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Todd P. Hubbard
Editor-in-Chief

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All correspondence and inquiries

For Content:
University Aviation Association
c/o Todd P. Hubbard
1700 Lexington Ave.
Norman, OK 73069
Tel. (405) 474-5199
E-mail: thubbard@ou.edu

Editorial Board
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No juried publications can excel without the tireless efforts of experts from all aerospace disciplines who volunteer their time to serve as anonymous reviewers. Indeed, the ultimate guarantors of quality and appropriateness of scholarly materials for a professional journal are the knowledge, integrity, and thoroughness of those who serve in this capacity. The thoughtful, careful, and timely work of the Editorial Board and the issue reviewers add substantively to the quality of the journal. On behalf of our Editorial Board, we extend our thanks.

STATEMENT OF 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

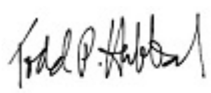
University Aviation Association

Editor's Commentary

In this issue, there are seven professional papers and one literature review. The subjects are varied, and there does not appear to be any themes coming through the articles that would unify them by area of interest. This is the beauty of this publication. As aviation professionals, we have a vast array of subjects and areas of interest or concern from which to pluck subjects that interest us. During the annual assessment time, at every institution in UAA, our administrators ask each of us if our departments and schools perform research with persons from other disciplines. Our response to them is that there are few disciplines on a university campus not part of aviation.

In a publication such as the *CaRi,* we might find articles written by an aerospace engineer, a medical doctor, a meteorologist, a psychologist, a mathematician, a physiologist, a teacher, a pilot, or an air traffic controller. The editorial staff welcomes all these persons to contribute to this publication that represents all those within the University Aviation Association.

I hope you enjoy the selection of articles in this issue.



Todd P. Hubbard, Ed.D

Table of Contents

Professional Papers

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Exploring ADS-B as an Alternative Data Source for Flight Data Monitoring of General Aviation

Chenyu Huang
Purdue University

Mary E. Johnson
Purdue University

Abstract

Flight data monitoring (FDM) is believed to be effective for mitigating risks of aviation accidents by the International Civil Aviation Organization (ICAO) and major airlines who implemented flight data monitoring programs. In the United States, flight data monitoring is recommended by the Federal Aviation Administration (FAA) as a voluntary safety program, namely the flight operational quality assurance (FOQA) program. However, implementing a FDM program not only requires an expensive investment on technological equipment, but also involves long-term labor costs to regularly collect and analyze flight data after flights are completed. Especially for general aviation (GA), implementation of a FDM program using on-board flight data recorder equipment may be too expensive for some owners or operators. Automatic Dependent Surveillance Broadcast Out (ADS-B Out) is a precise satellite-based surveillance system which can continually broadcast flight data. The broadcasted flight data can be received by other nearby ADS-B In capable aircraft or ground-based ADS-B receivers. This paper explores the ADS-B as an alternative data source of FDM for GA. First, the structure and content of flight data broadcast by ADS-B Out are analyzed. Then, based on the basic flight parameters, additional flight parameters are derived, and flight metrics are developed from the standpoint of flight operation analysts. Finally, the potential of ADS-B for supporting FDM is discussed.

Introduction

Comprising both commercial and general aviation, civil aviation is playing an important role in supporting global economic activities and development as a worldwide rapid transportation system. In 2015, commercial aviation transported approximately 3.6 million passengers, carried 51.2 million tons of freight and 35 percent of interregional exports of goods by value (International Air Transport Association, 2016).

Aviation safety is one of the major factors necessary for air transportation to generate stable and positive economic and social benefits. To improve aviation safety is one of the most fundamental objectives of the International Civil Aviation Organization (ICAO) and of the Federal Aviation Administration (FAA). Corresponding safety enhancement measures have been widely undertaken globally to address aviation risks (International Civil Aviation Organization, 2016). With continuous efforts and cooperation by aviation stakeholders, the total number of aviation accidents and the accident rates have decreased over the last years. According to the ICAO *Safety Report 2016*, the number of accidents worldwide, as defined in ICAO *Annex 13*, decreased by 5 percent to 92 in 2015 compared to 2014, and the global accident rates involving scheduled commercial operations decreased by 7 percent to 2.8 accidents per million departures in 2015 compared to 2014 (International Civil Aviation Organization, 2016). In *Destination 2025*, the FAA made reducing the general aviation accident rate one of its top priorities and set a goal of "no more than 1 fatal accident per 100,000 hours of flight by 2018" (FAA, n.d., p. 4). In the United States, general aviation (GA) had 1223 accidents, 257 fatal accidents and 444 fatalities in calendar year 2014 (NTSB, 2016). The GA fatal accident rate has fallen from 1.17 fatal accidents per 100,000 GA flight hours in fiscal year 2009 to 1.03 fatal accidents per 100,000 GA flight hours in fiscal year 2015 (GAJSC, 2016).

Flight data monitoring (FDM) is believed to be effective for mitigating risks of aviation accidents by the International Civil Aviation Organization (ICAO) and major airlines who implemented flight data monitoring programs. In the United States, flight data monitoring is recommended by the Federal Aviation Administration (FAA) as a voluntary safety program, namely the flight operational quality assurance (FOQA) program. However, implementing a FDM program not only requires an expensive investment in both aircraft flight data recorder (FDR) equipment and equipment on the ground, but also involves long-term labor costs to regularly collect and analyze flight data after flights are completed. Especially for GA, the implementation of a FDM program may be unaffordable considering the limited resources that GA operators have. Two examples of the many commercially available GA FDRs are Garmin's G1000 and Avidyne's Entegra. Automatic Dependent Surveillance Broadcast Out (ADS-B Out) is a precise satellite-based surveillance system which can continually broadcast flight data. The broadcasted flight data can be received by other nearby ADS-B In capable aircraft or ground-based ADS-B receivers. With the upcoming ADS-B mandated implementation date of January 1, 2020, there will be more GA aircraft equipped with ADS-B Out.

This paper explores the potential of ADS-B as an alternative data source for FDM for GA. After an introduction to FDM and ADS-B, then the structure and content of flight data broadcast by ADS-B Out are analyzed. Based on the basic flight parameters available in ADS-B messages, additional flight parameters are derived. By combining ADS-B data with aeronautical knowledge, additional flight metrics are developed from the standpoint of flight operation analysts. Finally, the potential of ADS-B for supporting FDM is discussed.

Flight Data Monitoring

Among different types of aviation safety enhancement strategies, ICAO and other relevant agencies believe that flight data monitoring (FDM) is an effective method to proactively improve aviation safety by routinely collecting and analyzing aircraft operational data and detecting operational anomalies (International Civil Aviation Organization, 2010). Before the ICAO *Annex 6* mandate that requires all airlines to implement a flight data monitoring program under regional legislation (International Civil Aviation Organization, 2010), the concept of FDM was presented by the Flight Safety Foundation named as the Flight Operational Quality Assurance (FOQA) in 1989 (Flight Safety Foundation, 1998). In 1990, the Federal Aviation Administration (FAA) officially initiated the development of FOQA program based on the basic concept presented by the Flight Safety Foundation earlier (Federal Aviation Administration, 2003). In 2004, the *Advisory Circular 120-82* was initiated by the Voluntary Safety Program Branch AFS-230 of the FAA and was published detailing the procedures and standards to be followed for the development and implementation of a FOQA program for commercial operators (Federal Aviation Administration, 2004). In the U.S., FOQA is encouraged as a voluntary safety program by allowing commercial airlines and pilots to share de-identified aggregated information with the FAA so that the FAA can monitor national trends and issues in aircraft operations and allocate resources to address operational issues (Federal Aviation

Administration, 2004). In addition to sharing de-identified flight data, routine flight data analysis is another key component of a FOQA program, and is more valuable and helpful from the standpoint of flight operators, because routine flight data analysis generates information to help improve flight safety proactively, shown as Figure 1.

Figure 1. Procedure of routine flight data monitoring

Routine flight data analysis consists of three primary components: onboard flight operational parameters recording systems, Ground Data Replay and Analysis System (GDRAS), and air/ground data transfers (Federal Aviation Administration, 2004). The Quick Access Recorder (QAR) is one of the most popular onboard flight information recorders. Unlike standard Flight Data Recorders (FDR), also known as the "Black Box", which only record the last 25 hours of flight information ahead of an accident, and the data is only accessible in the event of an accident, a QAR for FOQA purpose records flight parameters every one second with the availability for collection and analysis upon the request of users (Wiley, 2007). Still, a well performed FOQA program requires commercial operators to designate specific personnel to collect flight data from the QAR, typically during scheduled maintenance (Federal Aviation Administration, 2004; Wiley 2007). The GDRAS is typically a software program used to transform, process, visualize, and analyze flight data. Upon the analysis results, flight data analysts could report usable information to safety managers to proactively respond the anomalies during flight operations. Another value of FOQA programs is the mutual sharing of de-identified flight data among other users and state agencies under a voluntary data sharing agreement to capture external flight information other than self-generated data.

However, the advantages of FDM/FOQA programs reply on stable and regular input of flight data. Given the current approaches to acquiring flight data from flight data recorders, which are expensive and require the cooperation of pilots and ground crew, to explore a relatively inexpensive approach to acquire flight data is believed to be necessary to popularize flight data analysis.

Automatic Dependent Surveillance

Automatic Dependent Surveillance-Broadcast (ADS-B) is a precise satellite-based surveillance system, which retrieves aircraft's location, speed, altitude, and other data from the Global Positioning System (GPS) and broadcasts that information to ground stations and nearby aircraft, shown as Figure 2 (Federal Aviation Administration, 2016). ADS-B has two types of functions: ADS-B In and ADS-B Out. ADS-B Out periodically broadcasts encoded messages containing flight information; ADS-B In receives and decodes the messages broadcast by ADS-B Out. Theoretically, ADS-B In capable ground stations and aircraft are able to receive the aircraft information broadcast by all other ADS-B Out capable aircraft within the maximum range of the ADS-B Out signal, while communication satellites provide a solution to extend the coverage of the ADS-B Out signal.

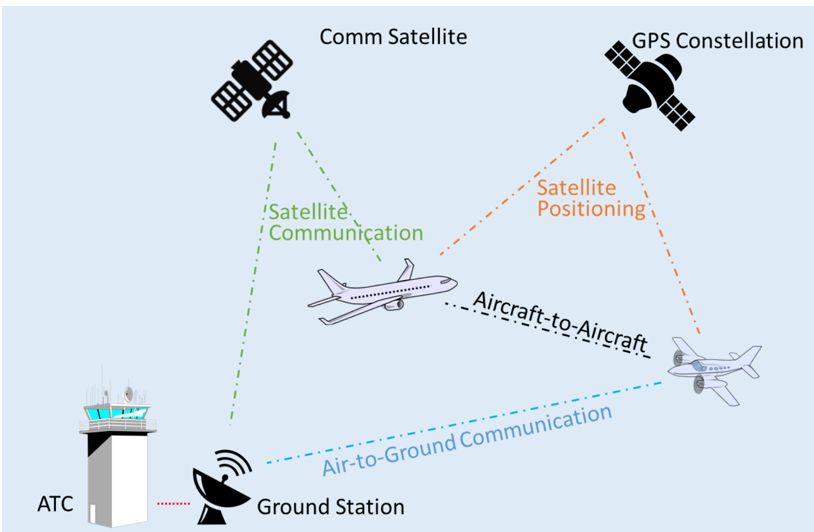

Figure 2. Overview of the ADS-B structure

To be effective January 1, 2020, the FAA requires all aircraft operating in designated airspace to be ADS-B Out equipped, which is believed to be an effective solution to improve air traffic safety and efficiency (14 Code of Federal Regulations, Part 91.225, 2011, Part 91.227, 2014). With the execution of the FAA's regulation on ADS-B Out, most aircraft operating in the U.S. will have to be ADS-B Out capable. Basically, there are two types of FAA compliant physical layers to support ADS-B Out – Mode S Extended Squitter (Mode S ES) working on 1090 MHz, and the Universal Access Transceiver (UAT) working on 978 MHz; the selection of solutions depends on the aircraft operation altitude in the U.S. (Federal Aviation Administration, 2016). In general, Mode S ES has the advantage of being wideband and an international standard but operates on a congested frequency, and the UAT has high data bandwidth and fewer interferers but is not an international standard (Chen, Lo, Enge, & Jan, 2014). In other words, the UAT can handle more data, so more aircraft in a concentrated area will work without overloading ground stations or other aircraft, but the Mode S transponders are already installed on most large commercial aircraft, which is believed to help minimize the expense of promoting ADS-B equipage (Federal Aviation Administration, 2014). To comply with the 2020 mandate, aircraft operating in Class A airspace – from 18000 feet mean sea level (MSL) altitude to and including 60000 feet MSL – must broadcast ADS-B Out position data using the Mode S ES; aircraft operating in designated airspace exclusively below 18000 feet MSL can use either Mode S ES or UAT (14 Code of Federal Regulations, Part 91.225, 2011). Currently, there are many aircraft already being equipped with a corresponding type of ADS-B Out system, but most of them are based on Mode S ES.

Literature Review

While commercial air transport services carry the most passengers and freight between major airports in the form of scheduled or non-scheduled flights, general aviation (GA) performs an important role in regional air transportation, recreation, agriculture, observation and patrol, flight training, and other tasks that supplement common aerial work.

With a goal of reducing the GA accident rates in the U.S. by 10 percent over the 10 years from 2009-2018 (Federal Aviation Administration, 2016), government and aviation industry have been working closely on a number of initiatives to improve GA safety, through organizations such as the General Aviation Joint Steering Committee (GAJSC), the National Transportation Safety Board (NTSB), the National Aeronautics and Space Administration (NASA), and the Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS). Other international agencies, such as the European Aviation Safety Agency (EASA), the European General Aviation Safety Team (EGAST), and the General Aviation Safety Council (GASCo) are also working toward improved GA safety.

Similar to the approaches adopted by commercial aviation, aviation authorities and industry intend to develop and implement proactive data-driven, consensus-based approaches to identify and mitigate risks to GA operations. Launched in 1997, the GAJSC is a public – private partnership working to improve GA safety through data-driven risk reduction efforts based on education, training, and promoting new equipment in GA aircraft (General Aviation Joint Steering Committee, 2016). Loss of control accidents are identified as one of the most important challenges for GA safety since 40 percent of fixed wing GA fatal accidents are due to loss of control (National Transportation Safety Board, 2015). In an effort to address the challenge of loss of control, the GAJSC has concentrated on the study of loss of control with two specific work groups focusing on the phases of approach and landing, and other phases of flight respectively (General Aviation Joint Steering Committee, 2016). By 2016, the GAJSC has accomplished more than 29 safety enhancements, covering training, procedures, and technology, to mitigate the risks of loss of control (Federal Aviation Technology, 2016). The angle of attack (AoA) system, the aeronautical decision making (ADM), stabilized approach and landing, and airman certificate standards are examples of recent GAJSC accomplishments.

The Flight Data Monitoring (FDM) program is one of the most popular strategies to proactively improve flight safety by routinely collecting, analyzing and sharing de-identified flight data to provide more information, and deeper insight into flight operations environment (Federal Aviation Administration, 2004). However, the high cost of implementing a FDM program impedes GA to adopt this approach. Flight operational data collection and analysis is one of the primary factors determining the FDM programs to be expensive. Therefore, exploring an alternative data source for flight data monitoring is expected to be important to facilitate FDM programs in GA community.

Statement of Problem

FDM is valuable, but the problem is that the implementation of a Flight Data Monitoring/Flight Operational Quality Assurance program requires a significant investment in onboard flight data recording systems, flight data processing and analysis tooling, and long-term labor cost for data collection. Based on the FAA published data by 2013, only 38 out of 88 air carriers operating under Part 121 have a FOQA program, of which 22 are large carriers by fleet size, 11 are medium carriers, and 5 are small carriers, shown as Figure 3 and Table 1 (Federal Aviation Administration, 2013). The relative lack of progress at medium and smaller air carriers is also due to a lack of funding to carry out focused strategies to assist small carriers (Federal Aviation Administration, 2013). In that case, exploring an inexpensive approach to undertake flight data monitoring appears crucial to popularize the deployment of FDM/FOQA programs in small air carriers and non-commercial operators. Decreasing the cost of flight data collection is one of the most effective breakthrough points to reduce the overall cost of routine flight data monitoring.

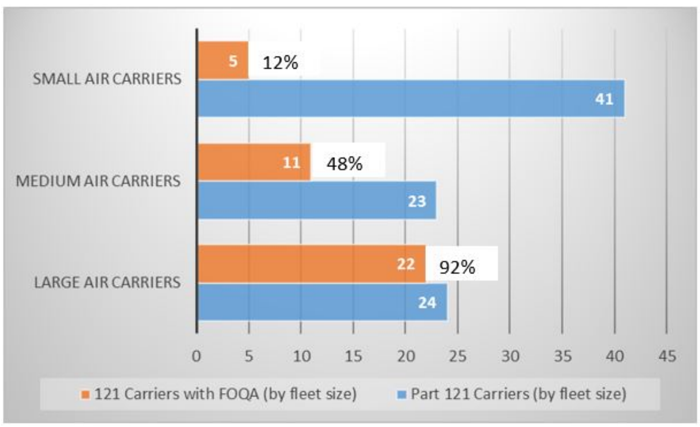

Figure 3. Deployment of FOQA programs in Part 121 carriers (Federal Aviation Administration, 2013).

Table 1
Carrier Classification by Fleet Size (Federal Aviation Administration, 2013).

	Small Air Carriers	**Medium Air Carriers**	**Large Air Carriers**
Size of Fleet	More than 50 aircraft	16-50 aircraft	15 or fewer aircraft

Methodology

The Automatic Dependent Surveillance Broadcast Out (ADS-B Out) as one of the major components of the next generation air transportation system is required to be installed in all aircraft operating in most controlled airspace beginning from January 1, 2020 in the U.S. (14 Code of Federal Regulations, Part 91.225, 2011, Part 91.227, 2014). ADS-B-Out is a function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B In capable receivers (International Civil Aviation Organization, 2008). Theoretically, flight data can be received by properly using an ADS-B receiver, which is relatively inexpensive compared to a Quick Access Recorder (QAR) or other flight data recording systems. Features of ADS-B Out support it being an inexpensive solution to facilitate Flight Data Monitoring.

In order to examine the possibility of using ADS-B Out in flight data monitoring, the following research work was conducted in this study:

1. The structure and content of ADS-B Out messages were analyzed.
2. Based on the content of ADS-B messages, an initial set of flight metrics was developed from the standpoint of flight data analysts.
3. Additional flight metrics were developed by incorporating other aeronautical information.
4. The potential of ADS-B data was discussed in terms of facilitating Flight Data Monitoring.

Results

ADS-B Message Structure and Content

ADS-B uses the global positioning system (GPS) to determine aircraft's location and airspeed, derives other flight data from onboard avionics, and broadcasts all information periodically over the 1090 MHz extended squitter (International Civil Aviation Organization, 2008). The extended squitter is an extended portion of the mode S transponders transmission bandwidth, which contains the ADS-B information in the form of data packets. According to ICAO's *Technical Provisions of Mode S Services and Extended Squitter* (International Civil Aviation Organization, 2008), ADS-B Out data is structured with a standard format. An ADS-B message is 112 bits long encoded either in BIN format or HEX format. The structure of ADS-B Out data in this research can be formatted as Table 2.

Table 2
Structure of an ADS-B message

Bit from	Bit to	Type of Data
1	5	Downlink Format
6	8	Message Subtype
9	32	ICAO Aircraft Address
33	88	Data Frame
89	112	Parity Check

The content of an ADS-B message is encoded in different sections in the 112 bits of the message. Each type of data functions to convey the necessary information to transmit relevant aircraft data. For example, the Downlink Format (DF), from bit 1 to bit 5, is used to identify the type of message, the DF for ADS-B message is fixed as 17, or 10001 in binary format. The most aircraft information is contained in the Data Frame, from bit 33 to bit 88. In the Data Frame, the value of bit 33 to 37 encodes the Type of Code, which is used to indicate the specific aircraft information, shown as Table 3.

Table 3
ADS-B message types

Type Code (TC)	Content
1 to 4	**Aircraft identity**
5 to 8	**Surface position**
9 to 18	**Airborne position (Barometric altitude)**
19	**Airborne velocities**
20 to 22	**Airborne position (GNSS height)**
23	**Test message**
24	**Surface system status**
25 to 27	**Reserved**
28	**Extended squitter AC status**
29	**Target state and status (V.2)**
30	**Reserved**
31	**Aircraft operation status**

Based on the ADS-B message types shown as above, a series of optional aircraft parameters can be encoded into ADS-B messages. In general, aircraft information that can be transmitted through ADS-B messages includes airborne position, airborne velocity, surface position, aircraft identification and emitter category, and event-driven protocols (ICAO, 2013). A comprehensive list of aircraft parameters that could be transmitted through ADS-B messages can be found in the ICAO Doc 9871 - *Technical Provisions for Mode S Services and Extended Squitter* (ICAO, 2008). In this paper, a set of flight parameters that most likely could be decoded from ADS-B messages is summarized as Table 4.

The prominent flight parameters that could be decoded from ADS-B messages include Aircraft Callsign, Latitude and Longitude of Aircraft Position, Barometric Altitude above the Mean Sea Level (MSL) or the Height of Aircraft above the Ellipsoid (HAE), Ground Speed, Ground Track, Airspeed, Heading, Vertical Speed, and other indicators of data integrity, accuracy, or uncertainties of the position measurement from GPS unit.

Flight Metrics Developed from ADS-B Data

With the purpose of supporting Flight Data Monitoring and flight operations analysis, a set of potential flight metrics related to exceedances, safety events, pilot performance, and fleet performance are developed using the flight data transmitted by ADS-B Out, shown as Table 4.

Given the limited number of basic flight data that is broadcast by ADS-B Out, the identified flight metrics can be directly retrieved from ADS-B messages or be derived with additional aeronautical and physics knowledge. For instance, the Glide Angle could be derived using Ground Speed, Vertical Speed, and Timestamp as shown in Figure 4.

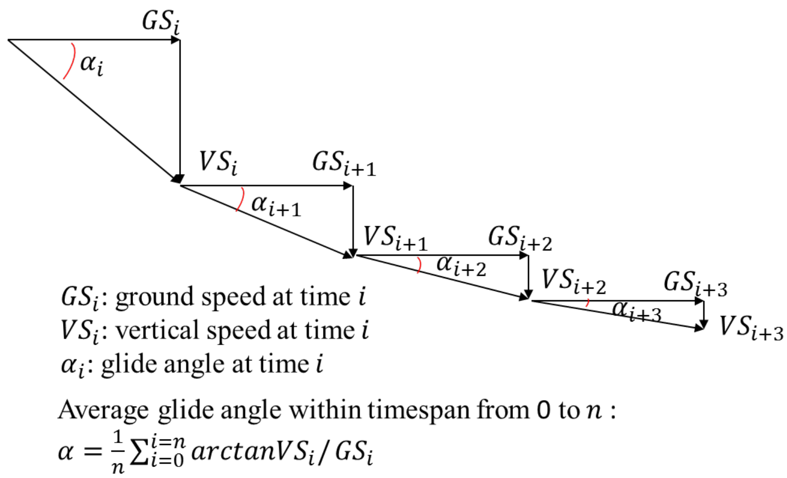

Figure 4. Derivation of the glide angle using basic ADS-B data

Table 4
Prominent flight information contained in ADS-B messages

Data Type	Primary	Alternative
Time	**Timestamp of received frame**	**Timestamp of received frame**
Aircraft Identification	**ICAO ID/Callsign**	**ICAO ID/Callsign**
Surface Position	**Latitude**	**Latitude**
	Longitude	**Longitude**
Airborne Position	**Altitude (Barometric Altitude)**	**Altitude (GNSS Height)**
	Ground Track	**Heading**
Velocities	**Ground Speed**	**Airspeed**
	Vertical Speed	**Vertical Speed**

Note: The primary flight information is transmitted as default by ADS-B Out; alternative parameters are transmitted as optional or when the primary information is not available.

Tables 4 and 5 show the initial and basic metrics; and all of these metrics can be retrieved or derived by directly using corresponding ADS-B data. More metrics are expected to be developed based on the purposes of specific flight data analyses. The list of flight metrics is expected to be extendable to meet particular requests of flight analysts. Flight Data Monitoring is used to detect flight operational exceedances, monitor pilot and fleet performance, and identify safety related occurrences. To demonstrate some of the flight metrics derivable from ADS-B messages, an additional set of flight metrics is developed by incorporating other common aeronautical information, shown as Table 6.

Table 5
Flight Metrics identified using basic ADS-B data

Flight Metric	ADS-B Data Needed	Flight Metric	ADS-B Data Needed
Flight altitude	Altitude	Maximum altitude	Altitude
Ground speed	Ground speed	Airspeed	Airspeed
Vertical speed	Vertical speed	Vertical g-force	Vertical speed
			Timestamp
Glide angle	Ground speed	Climb angle	Ground speed
	Vertical speed		Vertical speed
	Timestamp		Timestamp
Heading	Heading	Heading change rate	Heading
			Timestamp
Flight time	Aircraft ID	Longitudinal acceleration	Airspeed
	Timestamp		Timestamp
GPS track	Latitude	Night time operations	Aircraft ID
	Longitude		Timestamp
	Altitude		GPS track
	Timestamp		
Daytime operations	Aircraft ID		
	Timestamp		
	GPS track		

Discussion of ADS-B Data for Flight Data Monitoring

The purpose of this study is to explore the potential of ADS-B data to support Flight Data Monitoring (FDM). Because the motivation is to reduce the high cost of Flight Data Monitoring, compared to other flight data collection methods, ADS-B provides a low-cost approach to collect certain types of flight data without the cooperation of pilots or ground crew, as described in ***Automatic Dependent Surveillance***. Given that advantage of ADS-B, the potential of ADS-B data is examined by qualitatively analyzing the list of flight metrics from the different perspectives of Flight Data Monitoring.

Table 6
Flight metrics *identified with additional aeronautical information*

Additional Metric	Basic Metrics	Aeronautical Information	Additional Metric	Basic Metrics	Aeronautical Information
Excessive longitudinal acceleration	**Longitudinal acceleration**	**Exceedance information**	**Excessive vertical acceleration**	**Vertical g-force**	**Exceedance information**
Loss of separation	**GPS track**	**Separation standards**	**Altitude above ground level**	**Altitude**	**Ground level above MSL**
Deviation from runway centerline	**GPS track**	**Airport information**	**Altitude en-route minimum**	**Altitude**	**Flight plan**
Undershoot/Overshoot	**GPS track**	**Airport information**	**Runway excursion**	**GPS track**	**Airport information**
Runway incursion	**GPS track**	**Airport information**	**Estimated distance from reported weather hazards**	**GPS track**	**Weather information**
Runway float time	**GPS track**	**Airport information**	**Altitude in relation to low-altitude en-route chart minimum obstruction clearance altitude**	**Altitude**	**Low-altitude chart information**
Altitude in relation to sectional chart maximum elevation	**Altitude**	**Sectional chart information**	**Altitude in relation to low-altitude en-route chart minimum en-route altitude**	**Altitude**	**Low-altitude chart information**

Exceedance detection. Exceedance detection is one of the most prominent approaches in flight operational data analysis (Federal Aviation Administration, 2004). Exceedance detection looks for deviation from flight manual limits and standard operational procedures (SOPs) (Australian Civil Aviation Safety Authority, 2011). In other words, the exceedance detection approach monitors interesting aircraft parameters and triggers a warning or draws the attention of safety specialists when parameters reach the preset limits or baselines under certain conditions. Usually, the focus list of aircraft parameters coincides with the flight operations manual or operator's SOPs. The pitch at takeoff, the approach speed, the glide path angle, and the climb speed are examples of typical flight parameters in the watch list (Federal Aviation Administration, 2004). Typically, exceedance levels are developed through an assessment of aircraft operations manuals, training programs, and risk assessment processes as part of the overall safety program (Federal Aviation Administration, 2004).

Therefore, the interesting exceedances are quite diverse and depend on specific analytical purposes. Roughly, exceedance detection can identify over 60 basic types of events, and more events and could be developed upon the carrier's operations manual (Federal Aviation Administration, 2004). Based on the flight parameters and flight metrics developed out of ADS-B messages, exceedances determined by Airspeed, Flight Altitude, Vertical Speed, Aircraft Location, or the combination of these parameters are most likely to be detected using ADS-B messages. However, Bank Angle, Pitch, and Yaw are not contained in typical ADS-B messages currently. These three parameters are typically used to describe the aircraft attitude and are expected to be important for flight data analysis, because many critical flight conditions and exceedances are detected by analyzing aircraft attitude. Threshold for stall speed and aircraft structural load factor are examples of interesting metrics for flight safety analysts. Therefore, exceedances related to Bank Angle, Pitch, or Yaw are unlikely to be detected using only the current version of ADS-B messages.

Safety events. Safety events refer to aviation occurrences that are accidents and incidents. Safety events are defined by the Commercial Aviation Safety Team of ICAO to permit analysis of flight data in support of safety initiatives (The Commercial Aviation Safety Team and ICAO Common Taxonomy, 2013). Currently, there are 36 categories of occurrences defined by ICAO, see *ICAO Aviation Occurrence Categories version 4.6* (The Commercial Aviation Safety Team and ICAO Common Taxonomy, 2013). Based on the set of flight metrics explored in this study, 11 categories of occurrences are identified to be supported by ADS-B messages are expected to support to identify 11 categories of occurrences, described in Table 7.

Table 7
Identified a potential role for ADS-B data for 11 of 36 ICAO defined safety occurrences

ICAO Defined Occurrence	Description	Data needed	ADS-B (Mode S ES)
Abnormal runway contact	Identify any landing or takeoff involving abnormal runway or landing surface contact	Latitude/Longitude	√
		Altitude	√
		Airport surface information	
Air proximity issues/loss of separation	Detect air proximity issue, loss of separation as well as near collision or collision between aircraft in flight	Latitude/Longitude	√
		Altitude	√
		Separation standards	
Collision with obstacle(s) during takeoff and landing	Detect collision with obstacle(s) during takeoff or landing while airborne	Latitude/Longitude	√
		Altitude	√
		Terrain information	
Controlled flight into or toward terrain	Detect in-flight collision or near collision with terrain, water, or obstacle without indication of loss of control	Latitude/Longitude	√
		Altitude	√
		Airspeed	√
		Vertical rate	√
		Ground speed	√
		Terrain information	

Table 7 (cont.)
Identified a potential role for ADS-B data for 11 of 36 ICAO defined safety occurrences

ICAO Defined Occurrence	Description	Data needed	ADS-B (Mode S ES)
Ground collision	Identify collision while taxiing to or from a runway in use	Latitude/Longitude	√
		Altitude	√
		Airport surface information	
Loss of Control-Ground	Identify loss of aircraft control while the aircraft is on the ground	Latitude/Longitude	√
		Altitude	√
		Terrain information	
		Ground speed	√
		Airport surface information	
Loss of Control-Inflight	Identify loss of aircraft control while, or deviation from intended flightpath, in flight	Latitude/Longitude	√
		Altitude	√
		Airspeed	√
		Roll angle	
		Pitch angle	
		Yaw angle	
		Ground speed	√
		Angle of attack	
Runway incursion/excursion	Identify occurrences at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff aircraft	Latitude/Longitude	√
		Altitude	√
		Ground speed	√
		Airport surface information	
Turbulence encounter	Identify and locate in-flight turbulence encounter	Latitude/Longitude	√
		Altitude	√
		Meteorological information	
		Pilot report	
Undershoot/Overshoot	Identify touchdown off the runway	Latitude/Longitude	√
		Altitude	√
		Airport surface information	
Unintended flight in IMC	Identify unintended flight in Instrument Meteorological Conditions	Latitude/Longitude	√
		Altitude	√
		Meteorological information	
		Vertical rate	√
		Pilot report	

Pilot and fleet performance. Pilot and fleet performance is another aspect that operators are usually interested in monitoring. Basic descriptive statistical analysis can assist in identifying trends, outliers, and signal changes in performance when employed properly, and is usually used to monitor pilot and fleet performance (Global Aviation Safety Network, 2003). Unlike exceedance and safety occurrence detection, statistical approaches to monitor the pilot and fleet performance can provide operators an overall view of performance. The findings of pilot and fleet performance monitoring, such as the distributions and trends of interesting indicators, can be important for developing and corrective actions to improve safety and operation efficiency. As per the initial analysis of ADS-B messages in this study, flight metrics could potentially be used to evaluate individual pilots. Many of those metrics could bring up information valuable to pilots in terms of personal performance during flight, such as flight time, night/day time operations, and deviation from runway centerline. In addition, airport and fleet operators can also take the advantages of ADS-B by adopting interesting metrics to monitor fleet operational performance. The number of operations at a specific airport or in a particular region is one of the example metrics that might interest operators. The number of aircraft parameters contained in ADS-B messages are limited compared to the number of parameters in Flight Data Recorders. ADS-B could still be treated as a low-cost approach to collect flight operational data for analyses.

Conclusion

This study investigated ADS-B as an alternative data source for GA flight data analysis as opposed to the high cost of traditional Flight Data Monitoring programs that require on-board flight data recording equipment and post-flight analyses. Since ADS-B Out messages are broadcasted, the data may be collected using equipment on the ground. The analysis of current version ADS-B messages revealed 11 types of primary flight parameters that can be decoded from ADS-B messages. In addition, a list of 15 initial flight metrics was developed using flight parameters transmitted by ADS-B Out. A list of 14 additional metrics was developed by incorporating common aeronautical information or other relevant information. Qualitative analysis of the developed flight metrics demonstrates a wide range of functions when ADS-B could be used in Flight Data Monitoring in terms of post-flight data analysis for exceedance detection, safety occurrence identification, and pilot and fleet performance monitoring.

Traditional Flight Data Monitoring programs can identify over 60 basic types of events related to flight safety, because current Flight Data Recorders can record over 1,000 aircraft parameters and are used as the data source for FDM programs (Federal Aviation Administration, 2004; Campbell, 2007). However, due to the limited number of flight parameters in ADS-B messages, ADS-B shows certain disadvantages to fully support some typical functions of flight data analysis; for example, to identify the attitude of aircraft through Roll, Pitch, and Yaw. In addition to the primary function of ADS-B as a traffic surveillance system, this study proposes to extend the use of ADS-B to the area of flight data monitoring for general aviation, and serve as a reference for relevant future study. Based on the findings of this paper, further study would focus on developing more useful flight metrics upon specific request of GA operators. In the meantime, the ADS-B technology is still under development, a corresponding study could be investigated to extend the capability of ADS-B in supporting Flight Data Monitoring.

Acknowledgement

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Private Pilot Incidents by Pilot Age and Recentness of Medical Certification

Donald R. Morris
Southern Illinois University

Abstract

The link between recentness of medical certification and increased likelihood of involvement in an NTSB incident has been previously reported (Morris, 2016). This study investigated this phenomena across pilot ages. Age groups were fit to an exponential-linear decay model using the least squares method of best fit. Standard errors were reported in order to verify quality of fit. Individual best fit lines were graphed and shown for demographic groups. Best fit lines from across groups were then compared.

This study verified the relationship between recent third class medical certification and increased likelihood of being involved in incidents for all age demographics. The study also showed that younger pilots have a marked initial increase in risk when compared to their older counterparts. It also showed that as pilots age, the relationship between recent medical certification and increased risk was significantly reduced in strength but still was very present.

Introduction

Statisticians have long cautioned that correlation does not imply causation. There are few better apparent examples of this fact than the correlation between how recently a private pilot has earned his or her third class medical and the likelihood of them being involved in an NTSB database incident. This relationship was recently reported in the Collegiate Aviation Review (Morris, 2016). The goal of this study is to analyze this data curve – shown in figure 1 – and to see how it varies depending on the age demographics of pilots.

Three possible reasons for this relationship were suggested in the original study. These included complacency due to recent medical certification, lack of recent flying experience for many of those with recent medical certification, and inconsistencies in the number of flight hours across time that are flown by private pilots (Morris, 2016).

It is important to note that the referenced study limited itself to private pilots with 3rd class medicals. As such, this data represents a group of pilots that tend to fly when they want to fly. Therefore, it is believed that the number of hours they fly is very inconsistent compared to commercial pilots whose flight hours are flown as part of their employment. In support of this belief, Hunter's 1995 survey of pilot hours flown indicates that the standard deviation of numbers of hours flown in the last year by private pilots exceeds the average number of hours flown by private pilots – indicating highly inconsistent flying habits. Airline transport pilots in the same study did not demonstrate this same tendency.

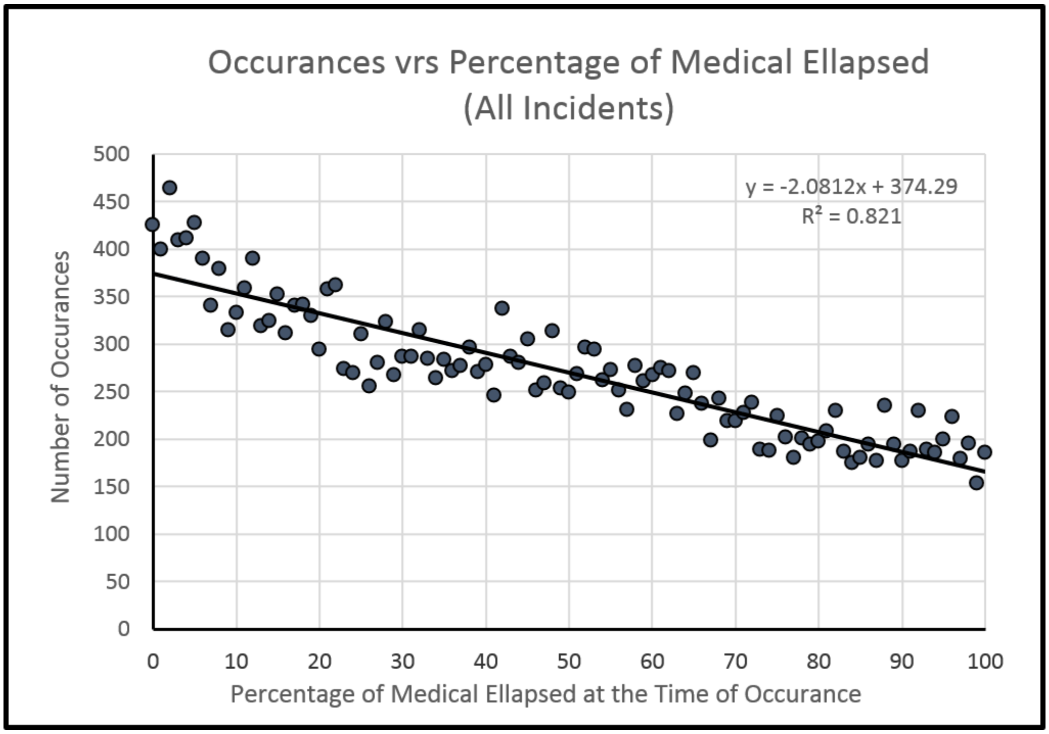


Figure 1: Likelihood of Being Involved in an Incident is Strongly Predicted by Recentness of Medical Certification (Image Source: Morris, 2016)

Rationale

Very little hard data is publicly available about the number of hours flown by the 'average' private pilot (Ohare & Chalmers, 1999). Unless a pilot earns additional ratings or certificates, they may never report how many hours they have flown. Even if they do progress through the system, the hourly totals collected on form 8710-1 under the *Record of Pilot Time* contain no time-based information. Except in rare cases, this provides only limited information regarding flight times for pilots.

In the US, there is no mechanism for collection of private pilot flight time data. However, part 830 of the NTSB regulations require a mandatory accident and incident reporting. These mandatory reports are the basis for the data analyzed in this study. Although the exact ratios and mechanisms of the link are a subject of intensive study (Knecht, 2015; Ison, 2015; Ohare & Chalmers, 1999), there is an indisputable correlation between the incidents recorded in the database and the number of hours flown by private pilots. A pilot that flies zero hours has a zero percent probability of being involved in an incident. It is the hope of the author that future studies will be able to combine the research validating this link with the research presented in this study to provide highly accurate average flight hour characteristic data for private pilots. As such, the emphasis of this study is on describing comparative trends across large amounts of data.

Data

Because this study is a follow up of the previously mentioned study, the data used in this study is the same as the data for the previous study. Specifically, the dataset consists of all incidents and accidents in the NTSB database between January 1st, 1982 and April 30th, 2015 in which the pilot held a valid third class medical at the time of the accident or incident. Some 26,987 distinct incidents or accidents are included in this dataset. Percentages of elapsed time on the most recent medical at the time of the incident were calculated based on the age of the pilot and the regulations at the time of the incident or accident. These regulations changed twice during the sample represented, increasing the duration of 3rd class medicals for those under the age of 40 from 24 to 36 calendar months in 1996 and then to 60 calendar months in 2008.

The original curve was created by constructing histograms of incidents vs time. In this study, the data was further filtered into eight distinct age-based demographic categories. These included those under 20 years of age, those in their 20's, 30's, 40's, 50's, 60's, or 70's, and those beyond 79 years of age at the time of the incident or accident.

Analysis

As in the previous study, the 0% and 100% histogram buckets of each sample were also doubled in size to compensate for their effective one-half percentage point width as compared to the other buckets full percentage point width. The resulting sample sizes are noted in figure 2, along with a graphical depiction of their relative size. This sample very closely approximates a theoretical bell curve distribution. Note that adding the size of each bucket gives a total of 27293 – some 306 higher than the overall sample size. This discrepancy is directly related to the doubling of bucket sizes just mentioned.

In order to adjust for different sample sizes and to be able to compare data metrics directly, the populations were next scaled to the same number of individuals. Each of these samples was then graphed, and best-fit lines were calculated. A visual examination of the graphs revealed a transient exponential decrease in the curve, fading into a linear fit. The general trend showed a much stronger exponential component for younger pilots, fading out as pilots increased in age. This model was seen as being consistent with the proposed reasons for the curve. The exponential portion of the curve fit very well with the theoretical effects of increased complacency and lack of experience – both of which would be expected to diminish exponentially with time. The linear portion, then, would seem to relate to the uneven number of hours that private pilots fly across time. This theoretical curve is not very different than the log-linear model presented by Bazargan & Guzhva in their 2007 study (as cited in Knecht, 2015).

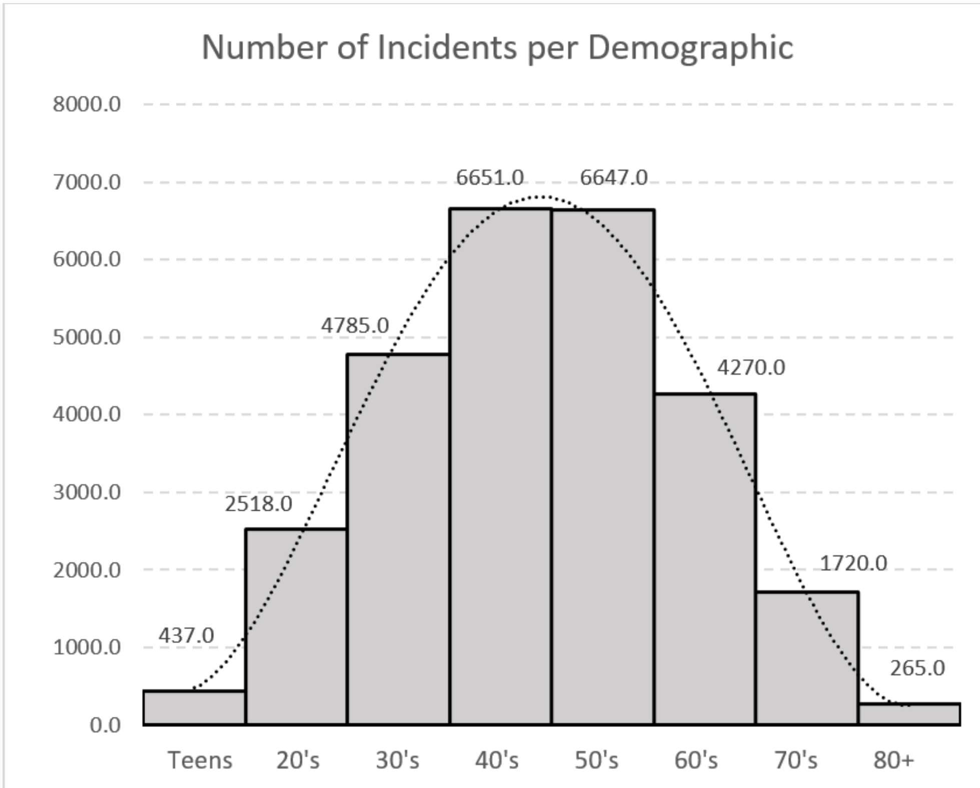
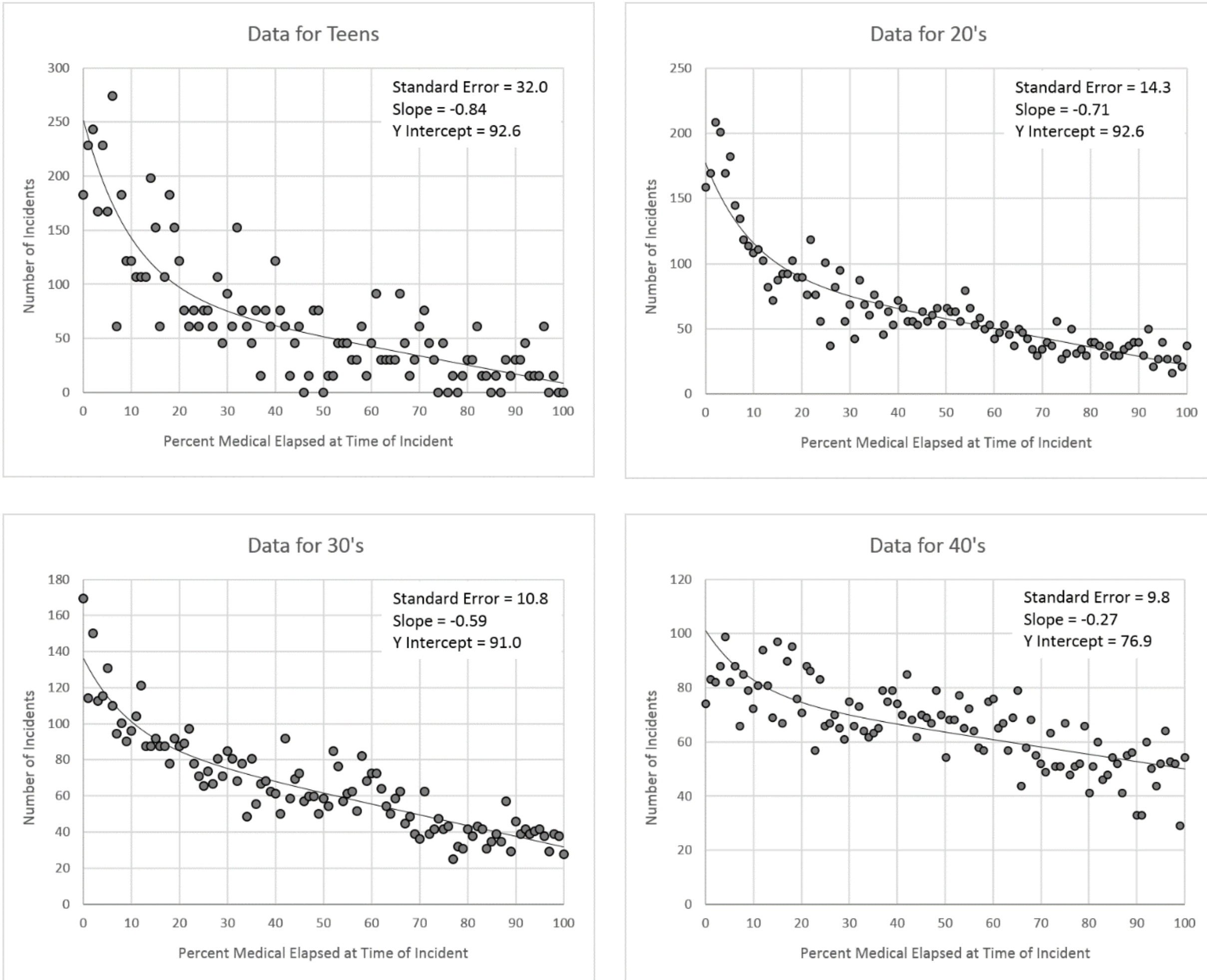


Figure 2: Graphical Depiction of Incidents Broken into Demographic Groups

Having decided on a theoretical curve based on the observed data, a custom best fit was calculated based upon the combined linear and exponential formula

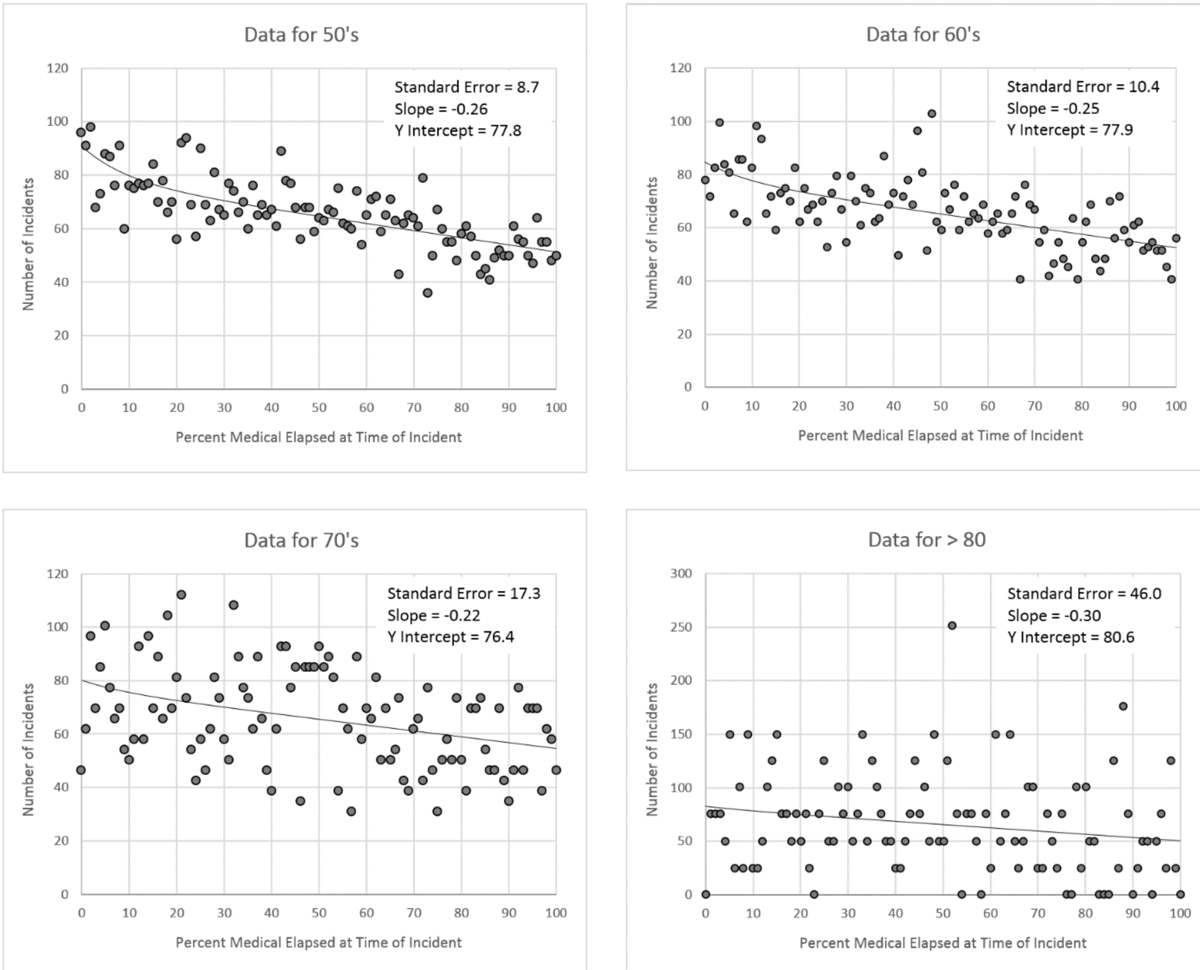
$$y = mx + b + Ae^{-Bx}$$

where *m* and *b* are the familiar slope and intercept of the line, *A* is the scale of the exponential component, and *B* is the rate of exponential decay. Microsoft's Solver add-in pack for Excel was used to calculate this custom best fit line for each age group using the least squares method. Since the rate of decay was fairly consistent across the data, the entire set of data was analyzed as a block to determine which value of B would return the lowest standard error when used consistently across demographic groups. This value was then incorporated into the graphs.



Figures 3 – 6: Data for Teens through 40's Showing Calculated Best Fits and Data

Finally, the scale of the exponential portion of the data fit – represented by A in the equation – was examined. As has been already noted, an observable trend existed where younger age groups had stronger exponential portions. Only one demographic group did not fit directly into this trend, and this was the 40-49 year olds. The strength of the apparent trend was judged to be sufficient to merit a best fit of best fits, and a variety of fits were tried. In the end, an exponential decay of A compared to sample age provided the minimum standard error. Figures 3-10 show all the data graphs with trend line statistics. Figure 11 shows all the best fit lines plotted on a single graph. Note that its appearance is substantially different from the initial graph reported in the previous study. This is due to the fact that each demographic has now been weighted equally, and this strongly increased the number of incidents corresponding to the younger groups. This has significantly increased the size of the exponential component seen in the upper left of the graph.



Figures 7 – 10: Data for 50's through 80+ Showing Calculated Best Fits and Data

In the previous article, R^2 was used to analyze the best fit. In linear fits, R^2 corresponds to the percentage of the data fit that can be directly described with the model. Unfortunately, R^2 is a relatively meaningless statistic on non-linear fits such as were used in this study. Therefore, the standard error (S) was calculated instead. This standard error corresponds to the average number of points that each data point is away from the curve, and can be visualized as the standard deviation of each data point from the best fit curve. Lower values, therefore, indicate a better fit.

Conclusions

The most obvious conclusion that can be drawn from the data is that younger pilots show a much higher initial probability of being involved in an incident than their older counterparts. This is most likely explained by the fact that the younger pilot demographic groups contain far higher numbers of new pilots. Consider, for example, the teenage pilots. Most of them have only had one medical. In this demographic group, recent medical certification is almost 100% associated with extremely low hours of flight time. As average age increases, so does the number of experienced pilots included in the sample (Ison, 2015). This means that recent medical certification in older demographic brackets is less strongly tied to very low flight hours of experience. This understanding correlates well to the data and provides a working explanation for its exponential decrease. Numerically, this decrease in initial incidents across demographics can be approximated by the expression $0.10e^{-0.063\times Age}$.

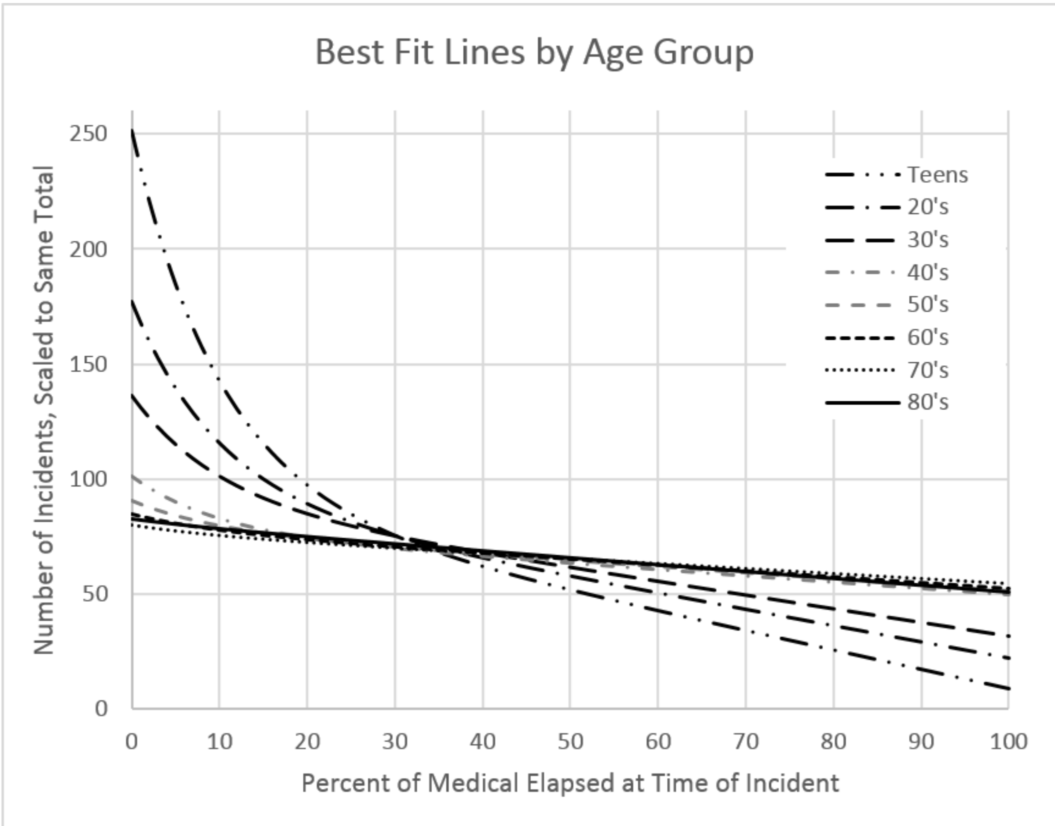


Figure 11: Data Across Demographics

In all age demographics, the exponential portion of the data faded into a relatively linear region with a much lower slope. Here, also, an interesting trend was observed. Increasing age corresponds to slopes that are closer to zero. In other words, the older a pilot is, the less strong the correlation between recent 3rd class medical certification is to likelihood of being involved in an incident. Table 1 summarizes the slopes of these lines. Note that until approximately 80 years of age, the value of this slope appears to converge to around the value of -0.22 seen in pilots in their 70's. This convergence is consistent with a pilot population that flies increasingly uniform numbers of hours across time. The increase in slope to -0.30 seen in octogenarian pilots is probably not significant, due to the much lower N and higher values of S seen in this population demographic. Another trend that is notable but easily explained is the relatively abrupt change seen in the slopes for those below 40 and those above 40. This jump is almost certainly tied to the regulatory change in the duration of 3rd class medicals that occurs at 40 years of age.

Table 1
Line slopes

Comparative Slope by Demographic	
teens	-0.84
20's	-0.71
30's	-0.59
40's	-0.27
50's	-0.26
60's	-0.25
70's	-0.22
80+	-0.30

This study verified the relationship between recent 3rd class medical certification and increased likelihood of being involved in incidents or accident reportable to the NTSB, and it did so for all age demographics. It also identified two separate trends that apply consistently across age brackets. The first trend is that younger pilots show a marked increase in initial risk represented by the exponential component of the data fit. This tendency diminishes rapidly with age. The second trend is that as pilots age, the relationship between recent medical certification and increased risk represented by the linear portion of the graph is also reduced in strength.

Future Work

This study is based on a series of reasonable assumptions related to the types of data fits that should be attempted. The resulting analysis provided no surprising results. Should the assumptions made in this study be demonstrable, much would be achieved in describing the average flight hour characteristics of private pilots across time. To this end, future study in this regard should probably be directed toward mass logbook based data collection of a random sampling of Private Pilots across time to determine if the observed number of hours actually flown agrees with the data and assumptions presented in this study.

About the Author

Donald R. Morris, Southern Illinois University, is an Assistant Professor of Aviation Technologies. While he teaches Aviation Maintenance, he is a CFI and avid flight enthusiast.

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Human Factors Regarding Age in Single Pilot Transitions to Technologically Advanced Aircraft

John A. Kolmos
CUNY Aviation Institute at York College

Abstract

The purpose of this research is investigating the relationship between computer simulated instruction and pilot performance in the transition to technologically advanced aircraft. With the advent of computerized glass cockpits in modern aircraft a problem has arisen of the ability of aging pilots and the human factors involved. These pilots for many years have received training on the round instrument gauges and the question is, can they now safely make the transfer to the new cockpit technologies? Studies show a cognitive deficit with pilot's age 40 years and older making transitions to these advanced cockpits. SPSS statistical software will be used to analyze data looking at specifically Spearman's Rank Order Correlation. This non-parametric statistic will be used to compare one group of under age 40 pilots and one group over age 40 pilots and their ability to transfer to more technologically advanced aircraft.

Introduction

With the movement from standard round instrument gauge setups in the cockpits to all glass in the general aviation (GA) community, problems have come up in regards to transitioning from one avionics setup to the other. The problem centers more on the older generation of pilots who may have difficulty with the transition (Rogers, & Fisk, 1990, p.177) who for years have flown the standard round gauge referred to as the "six-pack".

Purpose

The purpose of this research is to highlight a problem that is underlying the general aviation community. Up until the 1980s, the biggest change came in putting a nose wheel on small general aviation aircraft. Then came Loran ((LOng RAnge Navigation), and soon after in the 1990s GPS. Change came but at a slow pace, a pace that many pilots were able to adapt too.

No one could have predicted the rapidity of this change, least of all the hundreds of thousands of pilots around the world who will eventually use them. While the manufacturers were able to make a total shift to "glass" in two years, training pilots will take longer, since the more than 200,000 airplanes that exist today without glass cockpits will continue to constitute the majority of the fleet for years to come.

Glass cockpits give pilots the benefits of situational awareness, redundancy, decrease of pilot workload and large readable displays. The potential risk is the increased mental workload due to the inherently more complex software interface of glass cockpits. Programming the systems can distract a pilot from the primary task of flying the aircraft. There is also some risk of dependency upon the automation. To stay proficient, pilots will need to balance the time they spend hand flying an aircraft versus using the autopilot, so that their skills remain sharp in both areas. These risks are real and relevant, but under stress a pilot will revert to his old habits and this is where major safety concerns come into play with glass cockpits. Pilots, especially older pilots who for perhaps decades have been flying standard instrument gauges, may, in a crisis, perform a task that only deepens the problem or in a state of confusion the situation ends up becoming critical (Hamblin, Gilmore & Chaparro, 2006). Proper training coupled with a simulation program that would be available for the pilots to practice and become proficient in may be an answer.

Review of Relevant Literature

Aging

Aging has been shown to be a set of progressive changes in the physiological and psychological functioning of an individual. Age-related changes are largely continuous and subtle rather than discrete and dramatic (Czaja, 1990). These theories a generally considered a decline in the rate of central processing speed and a reduction in working memory (Salthouse, 1985, 1990) it affects the performance of complex tasks. Seeing that this is a problem with age and the complexities of operating a TAA aircraft, it can then perhaps present itself as a formable problem with aging pilots. Laboratory and simulator studies appear to support this general prediction in the decline of piloting tasks (Morrow & Leirer, 1997, p. 221). "Research on performance in other domains such as automobile safety suggests that there may be a "U"-shaped relationship between age and performance (Broach, Joseph & Schroeder, 2003)." For example, Massie, Campbell, and Williams (1995) found that automobile accident risk was greater for younger and older drivers than for drivers aged 25 to 65. However, changes in performance associated with aging are characterized as much by increased variability between individuals as by a decline in performance (Landy, 1992; Salthouse, 1985, 1990). "These findings in cognitive research and other transportation modes suggest that the longitudinal effects of aging on aviation safety outcomes such as accidents will be relatively subtle rather than dramatic. Changes in outcomes might be best described in terms of a trend across age groups (Broach, Joseph & Schroeder, 2003, p.9)."

Automation Training, Learning and Older Pilots

"The fact that statistics indicate that older pilots have more fatal accidents piloting TAA could be a reason for concern. Could the FITS one-size-fits-all training program be inadequate for older pilots (Homko, 2011, p. 15)?" Recent studies about age and learning have shown that even though some cognitive degradation occurs with age, the ability and desire to learn of older people are not significantly different than younger people when the learning is specifically changed to address their slower learning rate and need for positive reinforcement (Broady, Chan, & Caputi, 2010). Broady, Chan, & Caputi (2010) showed that the challenges of cognitive losses due to age can be effectively counteracted by recent training and positive experiences. Broady, Chan, & Caputi (2010) stated in their study that addressed age and attitude toward computers (Homko, 2011).

"What can be taken from this observation is an under-standing that older people could well be taught to use technology in much the same way as younger people are taught. However, the literature also suggests that at least two additional considerations are necessary in designing computer and technology education for older learners. First, consideration must be given to allow ample time for older people to master new skills. Second, care must be taken to treat any person learning to use technology in a positive manner that makes them feel like they are valued and that success is the expected outcome. While it is true that these two points ought to be considered for all learners, they nonetheless particularly pertain to older users (Homko, 2011, p. 15)." Homko, (2011) states that small electronic information displays that are installed in complex flight management systems need to change their displays to show additional information, and generally leave no visual indication of where the user has navigated to. "Without these positive visual cues, older adults lose partial episodic memory which in turn affects their ability to recall what they have done (Harada, Mori, & Taniue, 2010)." "The design of IT systems therefore may be hampering the ability of older users'abilities to use and understand the systems. This is supported by the work of Harada, Mori, & Taniue (2010) who stated: Older adults seemed to have particular difficulties in learning an abstract model or absorbing local rules during the operation of the system itself. That is, it is more difficult for older adults than younger adults to extract an abstract structure while operating and observing a system that is responding to their operations (Homko, 2011, p. 15)."

With the results shown above what are some of the solutions that may be found in the literature to provide guidance on the cognitive learning that pilot's, especially older pilots whose experience is in the conventional aircraft can be utilized effectively? The AOPA (Aircraft Owners and Pilots Association) through the Air Safety Foundation a division of AOPA states "More and better *simulation* is gradually becoming available to TAA pilots….Training to use nontraditional avionics using traditional methods is not optimal. Use of CD/DVD and online simulation is a step forward, as is the development of relatively inexpensive simulators for new TAA" (AOPA Air Safety Foundation, 2007). The TAA Safety Study Team in their report of August 22, 2003 states that "Overall TAA training should rely greatly on various levels of simulation, *beginning* with computer-based part task trainer for each major TAA system on the aircraft, and moving up to an integrated cockpit simulator for scenario-based training" (TAA Safety Study Team, 2003, p.19). "Research shows that computer-based training in conjunction with a desktop flight simulator can improve significantly the speed at which transition pilots acquire knowledge and skill, particularly for glass-cockpit navigation…" (Mitchell, Chappell, Gray, Thurman, & Quinn, 2001). Looking how the CBI (Computer Based Instruction) is designed and implemented, taking into consideration the age and experience of the pilot will have an important effect on the transfer of learning from conventional to TAA. Suzanne K. Kearns in her book "E-Learning in Aviation" states "Clearly, the effectiveness of any e-learning [CBI] course will be directly linked to how the course is designed" (Kearns, 2010, p.28). The point that Kearns makes is important in the fact that how the course is designed and how effective it is in producing the desired results is the starting point for designing a course of study for the older pilot. The results to be looked at would be pilots, especially those 40 years of age and over, which have had many years using conventional avionics, through a properly designed and executed course, making a successful transition to TAA aircraft in a safe manner. The ideal would be to locate and put into use such a design for those pilots looking into transitioning into TAA.

Has the research been looked into for such a course design and what would it consist of? Looking at the Kennedy et al. (2010) article in their concluding remarks it states "Our findings suggest that providing older pilots with *focused training in the flight simulator* [*emphasis added*] for situations that can carry a high degree of risk in real life, coupled with speed of processing training may be an ideal way to improve older aviators' flight safety" (Kennedy, Taylor, Reade, & Yesavage, 2010, pp. 496).

Research Methodology

The research methodology will consist of TAA aircraft in comparisons to traditional cockpit aircraft; it will be a content analysis of NTSB reports on accidents and incidents involving TAA and conventional display aircraft covering a period from March 2002 to November 2008. These are investigations that have been completed by the NTSB and reported closed. These results will then be a complete and accurate data that can then be collected and analyzed. The aircraft NTSB reports involved in this study are listed in the appendix.

NTSB Content Analysis

All accident data were extracted from the NTSB Aviation Accident Database. Study analyses were limited to accidents involving U.S.-registered aircraft.
Aircraft Fleet Involved In Study

Once the list of aircraft was compiled, that information was used to summarize the data and compare accident involvement by cockpit display type. Aircraft selected for the study included the following makes and models of airplanes manufactured between 2002 and 2006.

• Cessna Aircraft Corporation • 172
• 182 series
• 206 series
Cirrus Design Corporation • SR20
• SR22
• Diamond Aircraft • DA40
• Lancair/Columbia Aircraft/Cessna Aircraft Company • 300/35039and 400
• Mooney • M20 series
• Piper Aircraft Inc. • PA-28-161
• PA-28-181
• PA-28-201
• PA-32-301 series
• PA-46-350P
• Hawker Beechcraft Corporation • 36 series

A total of 266 aircraft were studied and listed in the Appendix. Of those 100 were of conventional cockpit display and 166 were included in the glass cockpit display. The study sample was further defined to include single-engine, piston-powered airplanes to allow direct comparisons between aircraft of relatively similar operational and performance capability. Data from the NTSB Aviation Accident Database were used, along with the registration information provided by the report, to identify aircraft in each cockpit configuration that were involved in accidents between 2002 and 2008 and to capture the details of those accidents. NTSB accident data include details of the accident event, such as type of occurrence, phase of flight, and environmental conditions; pilot demographics and experience; and accident investigation findings. This data was used to compare the accident experience of the two avionics type and to make statistical comparisons of the accidents each cockpit experienced.

Analyses

Summary statistics were calculated to compare the aircraft cockpits on variables such as the number of aircraft, hours flown, usage details, and accidents. For the aircraft in the study sample that had been involved in accidents, comparisons were made between the conventional and glass cockpit groups on the basis of data collected during the accident investigation, including accident occurrences and findings, weather and operational details, and accident pilot demographics and experience. Because the study was targeted at a relatively small set of aircraft, the number of comparisons that could be made between glass cockpit and conventional aircraft as a function of operational and pilot characteristics was limited by the sample sizes (number of accident cases) for each comparison. Statistical tests appropriate to the various accident-related variables were used to determine the extent to which the conventional and glass cockpits differed.

Using SPSS, chi-square statistics were used to compare the two types of cockpits on categorical accident variables such as weather, time of day, and purpose of flight. Mann-Whitney U tests were used to compare differences in continuous variables, including planned flight distance, pilot age, and flight experience. Spearman's Rank Order Correlation was used in comparing pilot age in conventional to glass displays. The following variables were selected for analysis:

Accident flight information
• Accident severity
• Planned length of flight
• Purpose of flight
• Day/night and visual meteorological conditions
• Visual/instrument meteorological conditions
• Instrument/visual flight rules flight plan
• Accident phase of flight and event details
Pilot information
• Number of pilots aboard accident aircraft
• Age at the time of the accident
• Highest certificate level
• Instrument rating
• Flight hours

Accident rates were calculated for comparison with the applicable exposure data, such as number of aircraft or flight hours. Standard error values were included with the following rate comparisons calculated:

• Accidents and fatal accidents per active aircraft
• Accidents and fatal accidents per flight hour
• Accidents and fatal accidents by time of day
• Accidents and fatal accidents by weather condition
• Accidents and fatal accidents by purpose of flight

Accident records for the 2002–2008 period covered by this study provided enough data to make statistically reliable comparisons between the two study groups. A comparison of the list of study aircraft with NTSB records identified 266 total accidents involving the study aircraft between 2002 and 2008, 62 of which resulted in one or more fatal injuries. Of the 266 study accidents, 141 accidents—23 of them fatal—involved conventionally equipped aircraft. The remaining 125 total accidents and 39 fatal accidents involved glass cockpit aircraft.

Data Analysis

Statistical comparisons of the 2002 through 2008 accident data, show similar differences in accident severity by cockpit display type. The percentage of accidents resulting in fatality was about twice as high for the glass cockpits as for the conventional displays. Of the 266 accidents involving study aircraft between 2002 and 2008, accidents involving aircraft in the glass cockpit displays were significantly more likely to be fatal: $\chi 2$ (1, N = 266) = 8.216, p = 0.004.50

Flight Conditions

Time of day. The 2002 through 2008 accident data indicate that a higher percentage of accidents involving aircraft in the glass cockpit group occurred at night, but the difference was not statistically significant: $\chi 2$ (1, N = 266) = 3.058, p = 0.080.

Weather conditions. The 2002 through 2008 accident data indicate that a higher percentage of glass cockpit accidents occurred in IMC. The difference in accident weather conditions was marginally significant: $\chi 2$ (1, N = 264) = 3.639, p = 0.056.

Filed flight plans. Consistent with the previous results showing that glass cockpit aircraft spent a higher percentage of flight hours in IMC, the aircraft cockpit displays also differed with regard to flight plan filed for the accident flight. Among those accidents during 2002 through 2008 with flight plan information available, pilots in glass cockpits were significantly more likely to have filed an instrument flight (IFR) flight plan for the accident flight: $\chi 2$ (1, N = 250) = 11.718, p = 0.001.

Purpose of flight. The study aircraft differed noticeably with regard to aircraft usage. The accident flights involving aircraft in the conventional cohort were almost equally split between instructional flights and personal/business flights, while glass cockpit accidents were significantly more likely to involve personal/business flights: $\chi 2$ (1, N = 258) = 31.616, $p < 0.001$.

Planned length of flight. Among those accidents for which both point of departure and intended destination were known, the median planned length of accident flights associated with the glass cockpit display was 96 nautical miles (nm), compared to a median of 25 nm for conventional aircraft flights. Differences in the planned length of study flights for both cockpit displays were evaluated using the Mann-Whitney U test statistic. Results indicated that accident flights involving the glass cockpit display were significantly longer than those for aircraft in the conventional cockpit display (U = 5649.5, N (conventional) = 140, N (glass cockpit) = 122, $p < 0.001$). Much of the difference in planned flight distance between the two displays can be attributed to the large percentage of conventional aircraft operating on local or very short flights, versus the percentage of glass cockpit aircraft, which were more likely to be operating on longer flights. Of the 140 conventional aircraft accidents with flight length information, 71 (51 percent) were conducting local flights that were planned to return to the departure airport or very short flights of less than 25 nm. Only 26 percent of glass cockpit accident flights were local or less than 25 nm, but 42 percent of accident flights involving glass cockpit aircraft were planned for more than 150 nm versus only 16 percent of flights associated with conventional aircraft.

Phase of flight. In general, aircraft in the glass cockpit displays were involved in a higher percentage of accidents during the in-flight phases from initial climb to approach, while conventional aircraft were involved in higher percentages of accidents during takeoff, landing, and "other," which include taxiing.

Accident Event Type. Glass cockpit aircraft were involved in higher percentages of loss-of-control in flight and collision-with-terrain events, and conventional aircraft were involved in more loss-of-control on ground and hard-landing events. This is consistent with the results of the previous comparison showing more glass cockpit accidents during in-flight phases and more takeoff and landing accidents for the conventional displays.

The higher percentage of collisions with terrain versus all other events for the glass cockpit displays was the only statistically significant difference between the two cohorts in accident events: $\chi 2$ (1, N = 255) = 3.980, p = 0.046.

Number of Pilots. Aircraft with conventional cockpits were more likely to have two flight crewmembers aboard than those with glass cockpits, which were more likely to be operated by a single pilot. The difference in the number of flight crew was statistically significant: $\chi 2$ (1, N = 266) = 7.063, p = 0.008. In approximately half of the conventional aircraft cases with two pilots, the second pilot was identified as a flight instructor, which is consistent with the previously presented results indicating that conventional aircraft were more likely to be used for instructional flights.

Pilot Age. Age data were available for 257 of the 266 accident pilots considered in the study. Accident pilots in the glass cockpit cohort ranged in age from 18 to 77, with a median age of 47. Accident pilots in the conventional cohort ranged in age from 17 to 73, with a median age of 43. Accident pilots flying glass cockpit aircraft were significantly older than those flying conventional aircraft (U = 6736.5, N (conventional) = 139, N (glass cockpit) = 118, p = 0.014). Much of the difference between the conventional and glass cockpit study displays with regard to age can be attributed to differences in the percentage of young pilots. Of the 139 accident pilots in the conventional aircraft cohort whose age was known, 38 (27 percent) were under 30 years old. In contrast, for the glass cockpit cohort, only 14 of the 118 accident pilots (12 percent) for whom age information was available were under 30 years old.

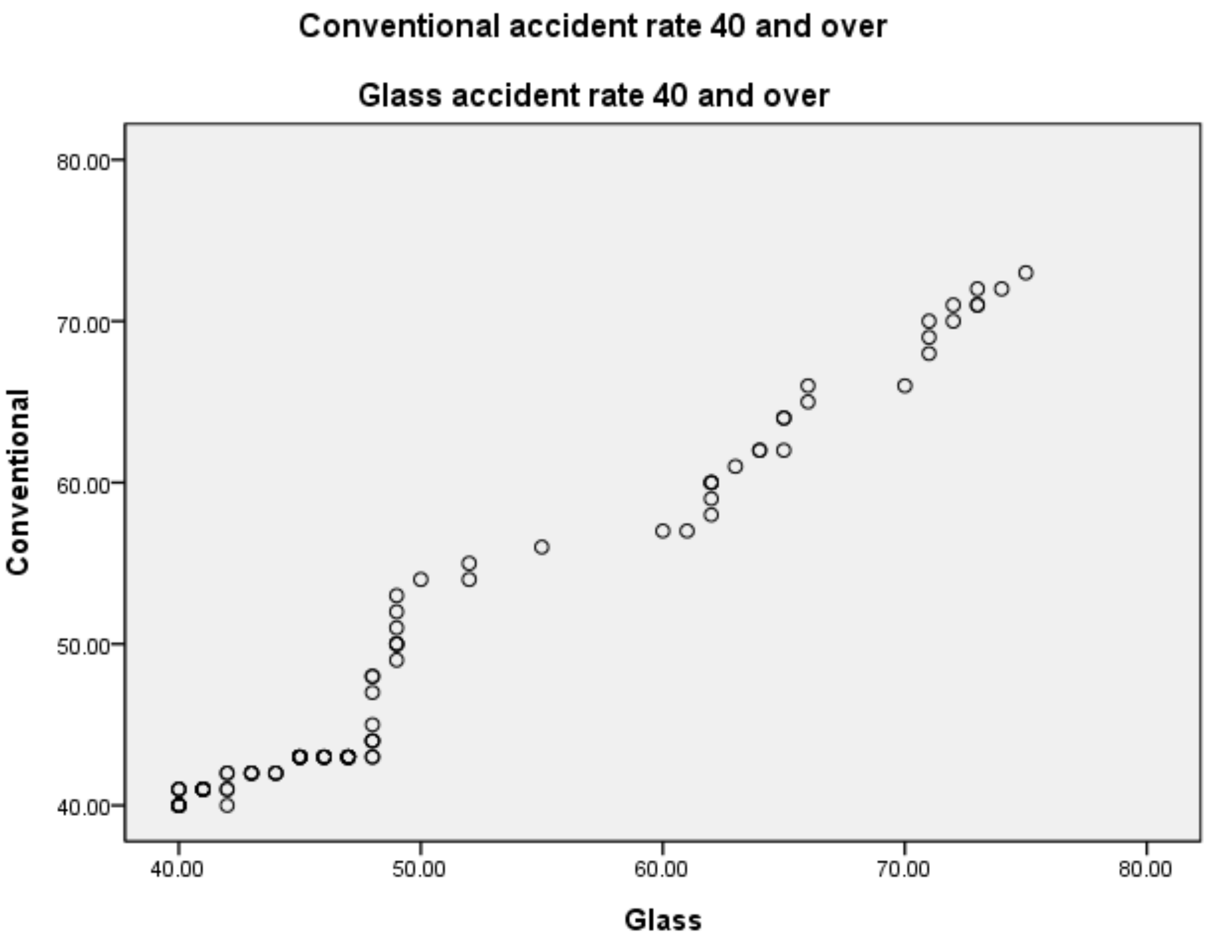

Figure 1. Scatter plot showing age and cockpit orientation between glass and conventional displays

Table 1. Spearman's Rank Order Correlation between Conventional and Glass Cockpits Pilot Certificate Level.

Correlations

			Conventional	Glass
Spearman's rho	Conventional	Correlation Coefficient	1.000	.986**
		Sig. (1-tailed)	.	.000
		N	101	101
	Glass	Correlation Coefficient	.986**	1.000
		Sig. (1-tailed)	.000	.
		N	101	104

**. Correlation is significant at the 0.01 level (1-tailed).

Of those accident pilots for whom certificate information was available, 26 percent held airline transport pilot (ATP) or commercial certificates, 50 percent held private pilot certificates, and 24 percent held student pilot certificates. Nearly equal proportions of the two display types held commercial or ATP certificates, but the two displays differed significantly with regard to student and private pilot certificates: $\chi 2$ (2, N = 261) = 21.931, $p < 0.001$. In comparison, the data concerning the FAA's U.S. civil airman certificate for 2002 through 2008 indicate that an average of approximately 14 percent of active pilots held a student pilot certificate, 38 percent a private pilot certificate, and 43 percent a commercial pilot certificate or ATP.

Pilot Instrument Rating. Approximately 65 percent of accident pilots in the glass cockpit displays were rated for instrument flight, compared to 37 percent of those in the conventional displays. The difference in instrument rating between aircraft displays was statistically significant: $\chi 2$ (1, N = 257) = 20.828, $p < 0.001$. In comparison, the FAA's U.S. civil airman statistics indicate that, on average, 51 percent of the active pilot population from 2002 to 2008 held an instrument rating.

Pilot flight hours. The most commonly available measures of accident pilot flight experience were total flight hours in all aircraft and total time in the accident aircraft make and model. The total flight time of accident pilots in glass cockpit aircraft ranged from 22 to approximately 25,000 hours, while the total flight time for accident pilots in conventional aircraft ranged from 1 to 23,000 hours. The median number of total flight hours for glass cockpit pilots was higher than the median total flight hours for pilots of conventional aircraft (466 hours and 167 hours, respectively), and accident pilots in the glass cockpit displays had significantly more total flight hours than those in the conventional displays: U = 5503.0, N (conventional) = 138, N (glass cockpit) = 118, $p <0.001$. Flight experience in the accident aircraft make and model for pilots in glass cockpit aircraft ranged from 11 to approximately 1,430 hours and for accident pilots in conventional aircraft, from 1 to approximately 6,200 hours. Median flight experience in make and model for glass cockpit pilots was higher than for those flying conventional aircraft (99 hours and 70 hours, respectively). However, the overall distributions of flight time in the accident make/model were not significantly different: U = 6087.5, N (conventional) = 129, N (glass cockpit) = 106, $p= 0.148$. It is important to note that data concerning flight experience in aircraft make and model made no distinction in cockpit design, so some pilots may have been experienced in the aircraft type while having little experience with the particular cockpit display in the aircraft.

Results

Accident and fatal accident rates were higher for the glass cockpits in IMC and at night despite the aircraft being flown by pilots with higher levels of certification and more flight experience, and the additional capabilities of glass cockpit displays, which were intended to improve the safety of those flight operations. This study showed similar patterns of accident rates for the study aircraft. Glass cockpit aircraft showed a lower accident rate but a higher fatality rate than conventional cockpit aircraft. Age also showed no real significance between the two, both groups average about the same over age 40 in accident rates. Age did play a role in that glass cockpit aircraft tend to be flown by older and more experienced pilots than conventional cockpit designs. Statistical comparisons of accident characteristics though did identify several variables with distributions significantly different between the conventional and glass cockpit groups, including accident severity, the purpose of the accident flight, and the planned length of flight, the number of pilots, pilot age, certification level, total flight experience and pilot instrument rating. Conventional cockpit aircraft tend to be flown by younger more inexperienced pilots and on instructional flights. These flights would have a tendency not be involved in a fatal accident, which historically, instructional flights have had lower fatal accident rates than personal flying.

Although the accident statistics identify a weakness in pilot decision-making, it is unclear why GA pilot training programs fail to teach this skill. The FAA requires pilot instruction in aeronautical decision making but offers minimal guidance to flight instructors of how this should be done. To date, most safety-related initiatives addressing weather-related accidents have consisted of motivational and experiential based approaches (Wiggins & O'Hare, 2003). However, training programs that identify dangerous behaviors (i.e., *scud running*) and advise individuals of the dangers of such behavior have little effect (Halpern, 1998, 2000). The absence of transferability of knowledge to real world settings may result from: 1) content (i.e., emphasis on wrong knowledge and/or skills) and 2) pedagogical style (i.e., part-task training versus SBT) as opposed to a more androgynous style approach. If pilot decision-making failures were related to one or both of these factors then the primary focus of future research would be to identify the fundamental skills and knowledge a pilot should master and the form that instruction should then be designed and replace what is offered in most flight schools at this time. At present, the literature does not identify which is the primary culprit in failures of GA decision making.

Conclusion

In the literature review, it was shown that age and pilot effectiveness in cognitive abilities do deteriorate and that in more advanced designs such as TAA aircraft, the effect is even more pronounced. It was also shown in the data analysis of the NTSB reports that pilots overall above the age of 40 in both glass and conventional cockpits are having more problems in aircraft accidents and incidents in comparison to their younger peers. The data also shown that particularly older pilots were having more difficulties in IMC and in what normally is considered a safe segment of a flight, cruise. The literature review and the data has also shown that through a properly designed program and instruction any pilot regardless of age can improve his/her performance to acceptable levels to perform safe and successful flights in transitioning to TAA aircraft. The aviation industry together with the Federal Aviation Administration have come together to develop a systematic program of training for today's technologically advanced aircraft. It is known as the FITS program of study. FITS is the acronym for FAA Industry Training Standards (Summers, Ayers, Connolly & Robertson, 2007, p.4). Summers et al. (2007) shows the design of the FITS program is to go beyond the traditional training in flight schools to scenario-based training (SBT) "where the instructor introduces real life situations for the development of the pilot. This training is a scenario-based approach to training pilots. It emphasizes the development of critical thinking and flight management skills, rather than solely on traditional maneuver-based skills.

For pilots 40 years and older who have not been exposed to these advanced avionics platforms, a training edge is given through these programs to develop the cognitive skills and processing speed necessary to perform safely in the National Airspace System that can be realized, giving them both a safe and successful flight experience.

Recommendation

SBT or scenario based training should be utilized by flight instructors and become part of a regular training syllabus. The FITS program and modules as outlined and presented by the FAA have proven to be effective in the training and transition of pilots to TAA aircraft utilizing scenario based training, similar to what FAR parts 121, and 135 use in their training programs known as LOFT or Line Oriented Flight Training. This exposes pilots to real world scenarios under the guidance of a flight instructor in a controlled environment experience situations where a pilot alone may not be able to handle. In other words the old idea of training to pass a test was perhaps useful in its time, but with advanced aircraft avionics and the complications of the National Airspace System and the coming implementation of Next Gen this is proving not to be enough. Ground based training must also pull away from just the generic to aircraft specific in the realm of the glass cockpit classrooms. Pilots must be able to demonstrate a minimum knowledge of primary aircraft flight instruments and displays in order to be prepared to safely operate aircraft equipped with advanced avionics platforms. There should also be a revision of the airman knowledge tests to include questions regarding electronic flight and navigation displays, including normal operations, limitations, and the interpretation of malfunctions and aircraft attitudes especially for instrument and commercial testing.

About the Author

The Author holds a PH. D from Capella University in Educational Psychology with over 1600 hours of flight time in various aircraft with an ATP, CFI, CFII, IGI, AGI and ADX. Also, an Embry-Riddle Aeronautical University graduate with a Master of Science in Aeronautics with concentrations in human factors and educational technology in aviation and aerospace.

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"We Can and Will Do It!" Female perceptions of pilot as a career"

Gabriella Lancia
University of Toronto

Abstract

The purpose of this study was to better understand the low female enrollment rate in flight training programs across Canada. An examination of the most significant barriers contributing to low female enrollment in pilot training programs will help provide valuable insight to partner flight training units on how they may attract more females in aviation training, in turn, increasing the number of woman working as airline pilots. This study was qualitative, with data being gathered from face-to-face interviews with current female students in aviation, including early leavers (n = 9) and commercial airline employers (n = 4). Interviews were coded thematically and the following themes emerged from our analysis: Awareness of Aviation, Suitability of Aviation Career and Gender Discrimination. Findings demonstrated that the aviation profession needed to emphasize the importance of providing early education and awareness about aviation to both female and male students.

Introduction

Traditionally, aviation is considered a male-dominated profession. Female pilots are working in one of the most gender incongruent fields of work, making it difficult to enter and be successful in the aviation profession. Of the 130,000 airline pilots worldwide, only 3% are female (Politano & Walton, 2014). Due to retirement and anticipated industry growth, airlines will need to hire about 42,090 pilots over the next decade (McCarthy, Budd, & Ison, 2015; Politano & Walton, 2014). The perception of aviation as a male-dominated career also extends to the education system, as aviation falls under the STEM (science, technology, engineering and mathematics) classification. Lack of awareness of career opportunities in STEM-related careers such as aviation, as well as confidence in academic preparation and achievement in math and science are strong contributors to female students failing to pursue STEM careers.

According to the 2011 Canadian Census, 6% of women were employed in the air transport industry, which is an increase from 1991 (4%). Concurrently, in 2015, 160 pilots employed by Air Canada were women, which were approximately 5.1% of its total pilots (Air Transport Association of Canada, 2016). Therefore, the purpose of this study was to better understand the low female enrollment rate in flight training programs across Canada. The study was framed by the following questions:

1) What obstacles do females face when entering the aviation profession?

2) How can the profession be improved to better accommodate the needs of females?

Perspectives were collected from current and former female students in aviation programs, as well as employers, across Canada. Understanding the perspectives of female students who were currently enrolled in aviation, as well as that of their current employers was essential in examining whether there was noted discrimination throughout their education and once they entered the aviation field. Therefore, an examination of the most significant barriers contributing to low female enrollment in pilot training programs will help provide valuable insight to partner flight training units on how they may attract more females in aviation training, in turn, increasing the number of woman working as airline pilots (Koch, Johnson & Marshall, 2013; Watt et al., 2012).

Literature Review

Reasoning for low female enrollment in aviation

Although there has been a great deal of progress in achieving gender parity across science and math-based occupations, female students continue to be less likely to pursue STEM-related careers. Traditionally, only about 19-21 percent of undergraduate STEM majors are women (Ma, 2011). Specific vocations associated with male employees include academia, technical roles, computing, craft working and aviation while administrative, secretarial and library positions are predominately classified as female occupations (Jacobs, Tytherleigh, Webb, & Cooper, 2010; Politano & Walton, 2014).

In aviation, women experience a rite of passage as they transition into the gendered culture of the airline pilot industry. In the United States, *The Federal Aviation Administration* (FAA) annual airman certificate demographics report revealed that women comprise roughly 23%—or a total of 162,284 of the non-pilot certificated airman in the United States. (FAA, 2014; Clark, Newcomer, & Jones, 2014). When looking at pilots specifically, only about 6% of pilots in the United States are women. In Canada, 5.2% of the commercial and airline pilot population was female (Canadian Aviation Maintenance Council, 2010). Part of the reason for the low population of female airline pilots is due to resistance from their male counterparts. 80% of female airline pilots in North America have cited that it was difficult to enter the profession because of male resistance who resented them entering their profession (Germain et al., 2012), as it is extremely difficult to secure training as a commercial pilot from an accredited institution (college or university).

Gendered nature of the aviation profession

Perceptions of piloting as a male-dominated career have been present since the emergence of commercial flying. Prior to the First World War, piloting was primarily a military-based occupation where both men and women participated and contributed to flying and building aircraft. In Canada, strong gender stereotypes resulted in a low ratio of females employed in the aviation industry during and after World War I (McDowell, 2015). In 1924 and 1925, the *International Commission for Air Navigation* (ICAN) banned the employment of women as flight crew, citing their menstrual cycle as being a barrier against the rigors of commercial flight. (Cadogen, 1993). However, by the war's end piloting was firmly and exclusively associated with danger, bravery and masculinity; thus shaping the perceptions of the commercial flight industry to reflect the image of a male pilot. Eventually, as commercial airlines began to expand, with Dan Air being the first airline to begin recruiting female pilots in 1965 (Mills, 1998). Currently, the numbers of female pilots have increased slightly, but are still quite stagnant. Information collected from the *International Society of Women Airline Pilots* (ISA) showed that 4,000 out of 130,000 worldwide pilots are females, which accounts for only three percent of the global pilot population (Morris, 2015). However, Boeing airlines forecasts that between 2015 and 2034 there will be a demand for 558,000 commercial pilots globally; thus increasing the need to push female enrollment to meet the growing demand for pilots (Boeing, 2015).

Some of the major barriers include: negative perceptions of female pilots, fewer advancement opportunities and a greater deal of professional scrutiny surrounding female pilots (Ashcraft, 2007; McCarthy et al., 2015). Despite the reduction in gender-based harassment towards females as reported in previous studies (Davey & Davidson, 2000), gender stereotypes and prejudice still exist within the flight deck. Politano and Walton (2014) conducted a study surrounding male and female perceptions of themselves and the opposite gender in the flight deck. While females generally perceive males as being on an equal playing field, males have a more negative view of female pilots across the board. Politano and Walton (2014, p. 6) explain "males see female pilots as not being very good at flying a plane and, in fact, as being pretty bad at flying a plane." This shows the undertones that are still dominant in the industry, which may not be as blatant, but still exist, therefore contributing to the difficulty in females not only entering the industry, but also being promoted to leadership positions.

Females in aviation leadership

Despite it being in the aviation field's best interest to train and promote females into leadership positions, male resistance ad lack of leadership development are cited as key factors in the lack of females in aviation leadership positions. Females that do obtain leadership positions (i.e.- captain, flight manager) often seem to suggest that women in aviation (as in other male-dominated professions) have had to adapt to the male culture in order to survive; putting them in a difficult position when it comes to promoting gender equality in their own organization. As a result, women in leadership positions did not always support equal opportunities policies, even though they may have faced similar difficulties throughout their career in aviation (Davey & Davidson, 2000; Neal-Smith, 2016). The increased degree of professional scrutiny surrounding female pilots is not only common when pursuing leadership positions, but is also present upon their entrance into the aviation field and even among passengers flying on their aircraft.

Assumptions that women have trouble managing and flying as they are too emotional or that women will not do whatever it takes to get the job done due to their lack of confidence in the flight deck. Additionally, female pilots report that male captains often expect less of female copilots and were more reluctant to give them necessary corrective feedback (Grant-Woffard et al., 2013; Wilson et al., 2015). However, little data has been found on the perceptions and co-operation between male and female students studying to become pilots. In turn, we hope that this study adds to the existing body of literature by providing a multi-faceted examination of the potential barriers behind low female enrollment in aviation programs and leadership positions in aviation from aviation students and individuals currently employed by commercial airlines in Canada.

Method

Data Sources

This study falls under the Aviation Research Program funded under the *National Sciences and Engineering Research Council of Canada* (NSERC) College and *Community Innovation Program-Innovation Enhancement Grant*. For this study, a semi-structured interview procedure was adopted; as the questions and prompts were prepared in advance, but only served as a guide to promote further inquiry among participants. To prepare the questions and prompts, interviews with industry professionals were also conducted to determine the major concerns and challenges for females pursuing aviation. Interview/focus group questions were formulated based on preliminary analyses of the literature surrounding females in aviation. Findings from the preliminary analysis that were incorporated into the interview questions included: 1) Internal and external perceptions of female's career choices (aviation and other STEM-related careers), 2) Lack of female role models in the aviation industry, 3) Gender discrimination (harassment, barriers, negativity) and 4) Confidence in pursuing/succeeding in the aviation industry.

Participants and Recruitment

Researchers interviewed three sample groups through one-on-ones semi structured interviews which were approximately 30-45 minutes in length. These sample groups included: 1) Current female students in the college's aviation program (n = 7), 2) Early leavers from aviation programs across Canada (n = 2), and 3) Various commercial airline employers across Canada (n = 4) for a total of 13 participants. Ethics approval was obtained from the college to recruit participants within the college's aviation and flight services programs to individually interview. Student participants were recruited through email and in-person discussions within the college; requesting participation from female students who were currently, had started to complete or had completed the aviation program at Seneca. Commercial airline employees were sought out through Seneca's professional network for placement in the aviation field and were asked to provide their perspectives of the lack of female employment in the aviation field.

Data Collection and Analysis

This study used a descriptive case study approach to gain a multi-faceted perspective on female enrollment in aviation from post-secondary to the workforce. In Canada, there are 32 programs across the country that students can attend to become certified as a pilot, with 11 of these programs situated in Ontario (Air Transport Association of Canada, 2016).

The interviews were transcribed and analyzed by the first author using inductive thematic analysis. Inductive reasoning is a process of coding the data without trying to fit it into a pre-existing coding framework or the researchers' analytic perspectives. Due to the varied roles of the study participants across the aviation profession, making the research data-driven was essential in ensuring that all individual perspectives were heard. Thus, the data were coded semantically, as the themes were identified based solely on what the participants said in their interviews (Braun & Clarke, 2006). To enhance further comprehension and understanding, the interviews were transcribed by both the primary investigators to further engage and understand the data in a detailed manner. Common themes were extracted from the interviews and contextualized both holistically (regardless of sample group) and individually (based on their sample group).

Results and Discussion

This study is unique, as it is one of the only studies that has provided a multi-faceted perspective of females selecting aviation as a career; following students from post-secondary (early leavers, current students) and into the aviation industry (employers). The main objectives of the study were to identify the obstacles the reasons for low female enrollment in aviation programs across Canada and ultimately, improve the aviation profession so it is more accommodating for females. Data from the interview and focus group transcripts were coded and common themes were extracted across and between each sample group. Major themes extracted from the analysis included: 1) Awareness of Aviation, 2) Suitability of Aviation Career and 3) Gender Discrimination. One sub-theme was also identified within Awareness of Aviation (Increasing Female Presence In Aviation). This section will provide an overview of these themes between and across sample groups to ensure parity among the data.

Awareness of Aviation

When asked how current students gained knowledge about pursuing a career as a pilot, none of them cited the high school as a source and stated that they had to find information about the programs they pursued, as well as opportunities to fly a plane through their own research. One of the current students stated, "I think why women would not go into aviation is because they don't know much about it."

In addition to students, employers emphasized the importance of bringing awareness to aviation at an early age. One employer had similar sentiments to the high school students in terms of aviation not being emphasized as a career path, "You go into the guidance counselor's office and its "Hey go be a lawyer, go be a doctor….I don't think too many guidance counselors say "Hey, think about being a pilot." One of the employers also stated, "I think it's horrible…You gotta take it deeper into the public school system…people think of being a pilot as like…being an astronaut or something, such as a lofty thing and "How did you get there?" Similar to the pursuit of aviation as a potential career for women, students also explained that a lack of awareness or investigation at the post-secondary level regarding female students in the pilot program is the prevailing issue in the lack of understanding regarding female retention, "I think there is a lack of awareness on the issue, like it's never been talked about at the school, but, yeah, no one has ever addressed it, no one has ever come to the women in the program and said "Have you ever felt like you've been treated differently? No one has ever really asked us how we feel about this situation? ... Not that it's a huge problem."

In almost every case, the aviation students in our study had an early association with flying, either through a relative or through self-financed pilot training. Students emphasized the need for more awareness surrounding aviation programs at the elementary and high school to increase female enrollment in aviation programs. One of the employers expanded on this by stating that, "Guidance counsellors [at the high school level], don't typically bring flight forward, or aviation forward, at least with those that I've spoken with, or other people in education, that have said "You know we really didn't know about that." Thus, increased exposure of both students and school staff to aviation as a potential career option may facilitate a growth in pilots entering the industry and a better understanding of the expectations required to be a pilot. Further, recruitment and enrolment of females for aviation among post-secondary institutions (Scott, 2012); and that aviation, specifically piloting, is primarily considered a male-dominated occupation (McCarthy et al., 2015; Watt et al., 2013). Although this played a small role in deterring females from entering the aviation industry, the primary reason cited by all sample groups was a lack of awareness of aviation as a career.

Increasing Female Presence in Aviation

In our study, there was a strong emphasis on raising awareness about aviation through placing female pilots in the forefront. One of the early leavers emphasized the importance of female role models, as increasing the visibility of female pilots could contribute to an influx of women choosing a career in aviation. A current student shared the sentiment that it was difficult to see females at the end of their careers stating, "While I do see an increase in females in the business… specifically there is an increase in females at the college… it is hard to see them actually at the end of the line establishing their career." One of the early leavers in our study stated that the problem was not due to the lack of female pilots but rather, the shortage of females in positions of authority, "The only thing that I would say… I think the biggest gap right now that would improve the industry is to get is to have those female pilots in management roles… but pilot management roles right? So whether if it's the VP or Chief pilot… I think it is important for those chief roles to be female and I don't think I've ever met a female pilot in a management role at an airline." Thus, the lack of female role models in the aviation industry awareness seems to contributes to the perceived suitability of aviation, specifically being a pilot, as an acceptable career for females.

Suitability of Career

The nature of the aviation profession demands that pilots spend time away from home and, in the past, overseas trips have involved (male) flight crew behaving in ways that they would not at home. Several employers, as well as current students in our study discussed this flexibility, stating that there were airlines in Canada working to accommodate women who were raising a family by offering shorter pairings, as well as the option to work longer pairings with a few days off. Family life was identified as the most prevalent challenge by current students in pursuing a career as a pilot and other aspects of aviation. Even though they acknowledged that the airlines were becoming more flexible and offering workable flight schedules, there was still a great deal of concern in how they would navigate family life and maternity leave. One of the current students stated, "Regarding family life, I know that this was a thing that I was contemplating and deciding how hard it would be and if it would really be the right choice for me… because what really pulled me back from flying was the family life. It would definitely be somewhat of a challenge." Concurrently, one of the current students in the focus group expressed concern about balancing their family life with their career as a pilot, "It's huge to choose between career and family because you work so hard to be here and then once you have kids, the schedule is hard. It's not conducive to having a family at all."

When interviewing the employers in our study, they expressed the changing landscape of the aviation world; stating that companies were starting to offer more flexible schedules to accommodate individuals who did not want to fly long distances. In our study, one of the employers outlined the typical scheduling options that their employees could choose from, "Most other airlines have multiple day pairings, where you are out for two or three days, five days in some cases and then come back. And we have those pairings as well, two, three, and four day pairings, but the longer pairings, there's fewer and fewer of them." Another employer reflected on his experiences and the flexibility his company offered him when he was a pilot, "My working conditions are very good, I'm getting about half the month off, and then all the sudden I had a kid, and you make those lifestyle choices, right? And I have no regrets whatsoever, and you know, I get bored after flying for a couple of hours, so overseas work doesn't really appeal to me." When discussing the qualities that a pilot should embody, there was also very little reference to gender, specifically from the employers. Some of the most important qualities mentioned by the employers in our study included being a team player, organized, open-minded to new experiences and a good personality. Students in the focus group shared these sentiments stating, "Well back to the flying for women, I think it takes a certain personality to be a pilot anyway... you have this kind of type A, very competent, leadership personality, I think you can handle what you get, but it takes, it's more of a mental game."

Understanding the requirements of a potential career option for students is important in recruiting individuals to pursue their career of choice. Due to the assumptions surrounding piloting as a career, females may be deterred from considering or entering an aviation program. Some of the most common assumptions were identified as high academic expectations in math and science, lack of time off for maternity leave (females) and the gendered perception that females are not meant to fly airplanes (Davey & Davey, 2000; Neal-Smith, 2016). As a result, females did not consider aviation a suitable career option for their vocational and personal lives. In regards to the perceived academic expectations surrounding becoming a pilot, one of the flight trainers explains: "I know when I was in high school and I wanted to become a better pilot, I guess the prevailing logic was you need to be an absolute genius in math and science and of course that does play a role, but…you don't need to be Einstein to be a pilot." Another one of the employers also discussed the dominant perception of a pilot, stating that people mainly see pilots as "male, dashing, chauvinistic, travels a lot and cheats on his wife." This perception, although not accurate, may discourage females, as they cannot see themselves in that role, due to their gender.

Gender Discrimination

Despite the reduction in gender-based harassment towards females as reported in previous studies (Neal-Smith, 2016; Smart, 2016), gender stereotypes and prejudice still exist within the flight deck. One of the early leavers from a pilot program who currently works as a crew scheduler shared this observation: "So I sit with the dispatch and maintenance… and even in that room… there is not that many females….and when you hear them talk about the women pilots… it's all about gossip right? Like they know the love life of one and they call her a w***….I mean they would never say that about the men and they're worse right?

Fortunately, the current and former students in aviation did not experience any blatant harassment based on their gender in their pilot education. However, the female students in our study still identified situations where undertones of discrimination based on their gender are still present within their program. Specifically, female students identified instances of gender discrimination in referring to machinery, estimating their strength, uniform requirements and the underlying male dominant culture present in the aviation industry. One of the female students in the pilot program explains, ""But like the thing is, you are invited in, you are not barred, you're not overtly discriminated against, but you gotta know how to play with the frat boys." As a result, assumptions are often made by the other students and sometimes, instructors about how much female students can handle, ""Something else that happened to me once with pushing planes…we pushed a whole bunch of them in and came back inside, and [the instructor] said, "Ok, we're going to have to take a break now to let [the participant] rest."

Although the prevailing opinion in the pilot program was that females are just as capable as males, it is still assumed that they simply cannot be pilots because piloting is considered a male's profession. While females in the aviation program emphasized that there were few cases where their gender caused them to be treated differently by their male peers and instructors, there are still instances where it is assumed they are not pilots, "Whenever I mention to people that I am in a flight program, they assume it's a flight attendant program." Ironically, there were even cases where other women had a lack of awareness surrounding women becoming pilots, such as in this case described by students in the focus group, "[The taxi driver] was like "what program are you guys in?" and we were like "We're in aviation" and she was like "Pilots?" and we were like "Yeah" and she was like "Even the women?" "Yes." And she was like "Aren't you supposed to be flight attendants?" Students hypothesized that it was a limited amount of exposure through societal images to female pilots that caused these assumptions, "I think that that leads back to a lack of education on the subject. There are still even women out there that don't understand that a woman can be a pilot."

Perceptions regarding whether specific careers are better for women based on their gender have been shown to start as early as middle school. Even the crew scheduler stated she placed higher expectations on female pilots stating, "Even my own expectations of a woman pilot are higher than what I place on a man. Which isn't good… it's not fair… but as a woman pilot who is 1 of 100 here, I expect a higher level of professionalism. I expect her to be proving a point for the gender." One of the employers in our study echoed these sentiments, not stating that they had higher expectations for female pilots, but their treatment was still not equivalent to males in the industry, "I think at some airlines women are not as widely accepted in the flight deck as they should be. And we welcome them with open arms… I'm only saying this because I still believe that there is still some inherent biases at some airlines…it's unfortunate, because that is not the way it should be."

Although this study showed that there were few cases of blatant gender discrimination against females, the prevailing dominance of males in the aviation industry has influenced the general attitude that individuals have towards female pilots. Despite students in the aviation program stating that they did not feel much of a difference as females in the program, there was still some discrimination present in regards to the physical strength and stereotypical role of females. Despite this, the females in flight school did not let these perceptions stand in the way of pursuing a career as a pilot. They were determined to succeed, as evidenced by this statement by one of the students, "You're not looked down upon, but you have to be better, be smarter than the guys around you to be respected on the same level. Like you've got to go out there in your slim pants and big butt and fly better than them to be respected. Whereas they give each other, I find, a lot of allowances, in everything, but you, you don't get slack."

Therefore, it was clear that awareness surrounding aviation as a career for women and open communication regarding issues on the flight deck that both women and men may experience. All sample groups agreed that awareness needed to start in elementary and high school. One of the employers explained that it should go one step further and start changing the expectations that we lay out from when children are young: "We have to teach little girls that are going into grade one, that they can be a pilot. And not just put it into some comic strip, and then give them some pathways on how to get there…lots of our female pilot population, I'd say at least sixty to seventy percent of them, have full on normal families, with kids and everything."

Female students in our aviation program agreed that there needed to be more awareness made available to them by teachers and guidance counselors. One student even provided an informal targeted approach to parents regarding aviation, "I feel like if my parents or anybody else, family members were exposed to it to they would be more open to ideas of going into aviation, so it's not just like yourself being exposed to it… I think that if [parents] were exposed to [aviation] too…the amount of people going into aviation would increase."

Employers provided some initiatives they were providing to increase awareness of aviation as a career, including increased online presence on social networking sites (Twitter, Linked in, You Tube), career days in elementary and high schools, and specialized cadet programs. Specifically, the representative from the airline gave information about a five-year cadet program agreement in December 2015 that includes direct entry as an employee after completing the Bachelor of Aviation Technology program. However, despite the importance of increasing the awareness of aviation to all students, there is still a call for placing those who are employed in the aviation field and are female to be brought to the forefront.

Conclusions and Recommendations

This study provides a framework for instructors, students and employers in aviation to understand what might deter women from entering the industry and some potential strategies to increase female enrollment. The reasoning for undertaking this study was to provide a multi-faceted perspective from high school to post-secondary and finishing at the workforce regarding the prevalence of female pilots. Based on previous research, one would expect to find multiple instances of gender discrimination and lack of confidence in female pilots, with these factors acting as the primary means as to why females chose not to pursue a career as a pilot (Davey & Davey, 2000; German et al., 2012). Even though the dominant perception of pilots is male-dominant and some individuals still perceive the occupation of pilot as male, this study pointed to the lack of awareness surrounding the aviation industry and pilot as an occupation as the primary reason why females choose not to pursue piloting as a career.

One of the major findings was that the specific expectations of a career in aviation are often misinterpreted, due to lack of information. These expectations include the perception that one cannot start a family because they will not be home enough and the idea that pilots are required to work multiple days at a time with few breaks. This study has demonstrated that several airlines are willing to offer flexible hours to accommodate employees including multiple day pairings, shorter flights within province or country and extended maternity/paternity options for families. This misconception further highlights the importance of ensuring that accurate information is provided to students who choose to pursue aviation and understand that there are many options available for individuals who prefer not to travel internationally and be gone for many days at a time. Additionally, the perception of pilot as a male-dominated occupation was another major finding that participants thought should be addressed very early on. Facilitating partnerships between flight schools and educators is essential in maintaining understanding and changing perceptions of aviation as a male-dominated industry. Ensuring that both male and female representatives from the aviation industry is also important in ensuring that students understand that flying is not an occupation that is reserved for males.

Lastly, career education surrounding aviation needs to start when students enter high school. The Ontario Curriculum website currently has resources available to guide students into specific careers, providing a list of essential skills that student should excel or improve to succeed in their selected profession. Specific skills included estimating numerical values, oral communication and problem solving (Ontario Student Success, 2016). Since none of the students in our study stated hearing about aviation or gaining the resources they needed to pursue to take a trial flight before applying, post-secondary institutions that offer flight training programs need to forge a relationship with high schools to recruit more students to enter the aviation industry.

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About the author

Gabriella Lancia is a PhD student at the University of Toronto: OISE, specializing in teacher mental health and emotional competence. She earned her MEd from Brock University.

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Expectations of Fundamental Knowledge in a Commercial Space Education Program by Space Industry Professionals and Aeronautical Engineering Technology Students

Dr. Sergey Dubikovsky, Tracy L. Yother, J. M. Thom, Jack C. Dozier, Alisha Garcia, Thomas Agler, Joseph Friedl, Nick Koehler, and Connor Hagan

Purdue University

Abstract

Career opportunities in the space industry are growing due to a combination of both the growth of the industry projected by the department of U.S. Labor Statistics and the age of existing employees. A new source of skilled workers is needed during this growth to ensure that companies can continue to develop quality designs, manufacturing, and production of the next generation spacecraft. One source to meet this need is the evolution of existing aerospace focused programs, such as Aeronautical Engineering Technology (AET). However, the transformation of any program must include an understanding of the new requisite and fundamental skills and unique requirements. This research includes a survey of space industry professionals to establish baseline commercial space industry knowledge. In addition, a survey of existing AET students is included to examine the difference between student and industry expectations. The results are combined to generate a ranked list of minimal knowledge expected by industry for recent graduates of a space focused AET program.

In addition, a comparison to what students expect versus professional realities is important to understand. This insight facilitates recruitment into the profession and enhances student retention and satisfaction. These concepts can and should be included in curriculum and course development to bring the meaningful relevance of information for the students as they learn. Inclusion also provides the student both context and a springboard for industry expectations.

Introduction

The commercial space industry is a new and growing industry in the aerospace sector. NASA's move toward outsourcing much of their routine rocket launches to the International Space Station (ISS) provides an opportunity for private companies to participate in the space industry in a manner previously unavailable to them. However, this opportunity is neither simple nor easy. Since commercial space companies are relatively new entities they must build their infrastructure, which includes personnel.

The challenge of developing personnel begins with understanding what skills should be cultivated. Having the right set of skills can make a significant difference to a candidate for the desired position.

Research Background

This research is an outgrowth of a senior design course of AET students at Purdue University led by Dr. Sergey Dubikovsky. The research, unique to this cohort of students, and a fellow professor and researcher on this project, Professor J. M. Thom, requested this particular topic. Anecdotal evidence leads him to believe an opportunity existed to both provide additional training to AET students to supply trained individuals to the commercial space industry for employment. This belief is supported by a confidential source from a commercial spacecraft company who indicated that new commercial space industry managers are not interested in hiring traditional space industry workers due to the potential inflow of negative legacy issues from 50 years of the first generation space industry (J.M. Thom, personal communication, October 28, 2010).

Review of Literature

Occupational Outlook

The size of the commercial space industry is large enough to become noteworthy, based on 2014 figures from the Federal Aviation Administration the launch events "amounted to approximately $2.36 billion. The opportunities for a recent graduate or upward mobility in this industry are present for those who are interested.

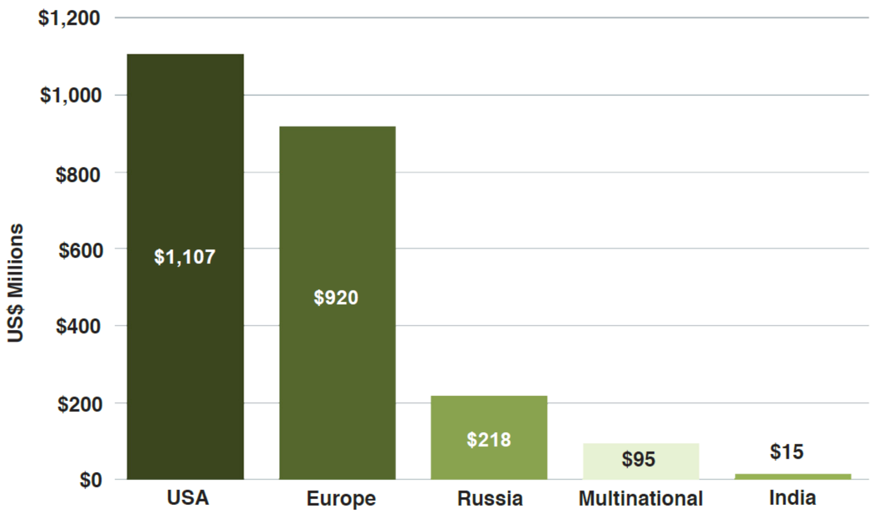

Figure 1. Estimates 2014 Commercial Launch Revenues

There are two main pathways for expansion in the commercial space industry. The first is focused on the expansion of the industry. According to the U.S. Bureau of Labor Statistics Occupational Outlook Handbook, "Employment of aerospace engineering and operations technicians is projected to grow 4 percent from 2014 to 2024" (U.S. Labor Statistics, 2017). Deloitte (2016, 2017) forecasted growth of the global aerospace and defense sector to be around 3 percent in 2016 and 2 percent in 2017. According to the same sources, defense subsector revenues will increase 3.2 percent in 2017 because of growing defense spending in the US. An analysis of a survey performed by Forbes Insights in 2016 showed that growth prospects are expected in the near future. In the course of the survey, almost 66 percent of 76 senior aerospace and defense executives expressed confidence that their companies will grow in next two years. Interviews with leading aerospace and defense experts (KPMG International, 2016) supported the results of the survey, which were included in the same study. While the expansion is not as high as some would like to see, it is still a growing market.

According to the Federal Aviation Administration's (2014) report, the number of launches is anticipated to hold steady for at least the next 10 years, see Table 1.

Table 1. Forecast Commercial GSO Satellite and Launch Demand

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total	Avg
Satellite Demand	18	25	24	23	22	23	23	22	23	23	226	22.6
Launch Demand	13	18	19	16	16	16	17	15	17	16	163	16.3
Dual Launch Demand	5	7	5	7	6	7	6	7	6	7	63	6.3

The second pathway focuses on the rapid retirements of existing space workers, the "so-called silver tsunami" (Zillman, 2013). Interestingly, the space industry is a contributing source of the labor problems facing the industry today. Over half of the aerospace workers of today have joined the industry as a result of the inspiration of the race to the moon (Zillman, 2013). The age of those workers is now reaching that which makes them eligible for retirement.

Aging workers are not a new phenomenon for the aerospace industry. The industry has been working through this challenge for almost a decade, and in fact, made progress in avoiding losing their experienced workforce all at once. Figure 2 below shows a reduction in the age of its workers since 2010. In fact, the average age is stable at 47 years old and has been since 2012 (Aviation Week Network, 2016, p. 11).

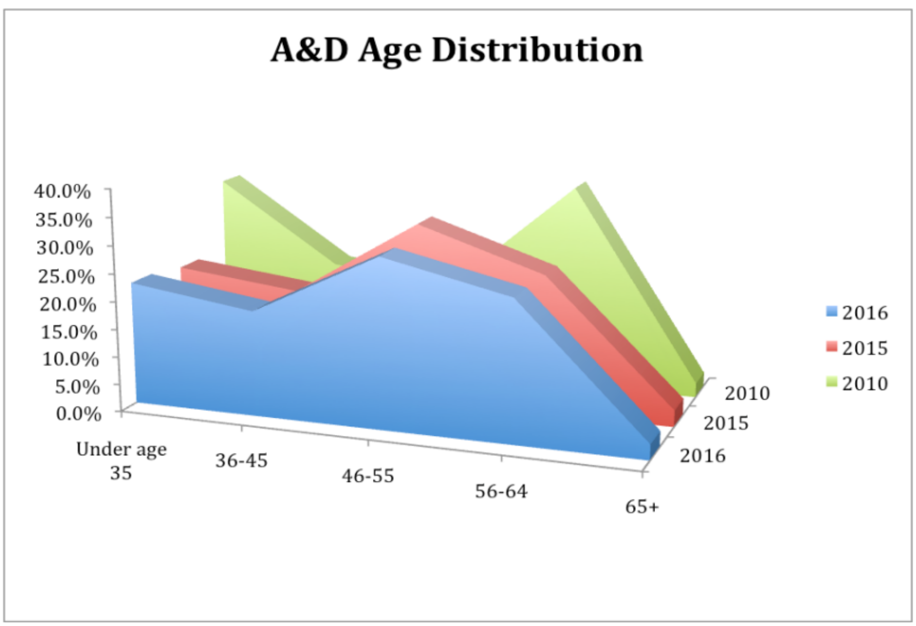

Figure 2 Aerospace and defense age distribution

Regardless of the work that has been done, the issue of age in the workforce is still problematic for the industry. According to the U.S. Government Accountability Office (2014), "Aviation stakeholders have expressed concern that an insufficient supply of certain types of aviation professionals–aerospace engineers, aircraft mechanics, and avionics technicians–could develop because of imminent retirements…" (p. 1). The workforce is aging, and replacement workers are needed to not only replace the aging workers, but more importantly, learn from them before they retire.

Purpose of Study

In order to understand the needs of the industry, this research is designed to answer two questions. The first question is what knowledge and skills do current commercial space industry professionals desire in candidates for employment? Second, what expectations do current students in AET have in a space focused curriculum?

Design of Study

To assess what key topics are applicable, current commercial space industry alumni were contacted and provided with two surveys. These same two surveys were then distributed to Purdue University AET undergraduate students. All responses were recorded and organized by average number participant responses.

Survey Instruments

The first survey (see Appendix A for a copy of survey #1) were given to both industry alumni and undergraduate students was designed to collect three pieces of information. The first allowed the participants to rate themselves on their personal level of experience and interest in the space industry. Participants ranked themselves on a scale 1-5, 1 having no experience and 5 having the most experience. The second piece was a list of personally important topics related to success in the space industry. The final question asked participants to choose a course administration model (i.e. lab and lecture vs. lecture and no lab).

Results from the first survey were used to develop the second survey tool. The second survey (see Appendix B for a copy of survey #2) provided participants a list of 25 topics found to be significant in the space industry. Using a scale of 0-5 (0 being not important and 5 being very important), participants rated each topic by what they felt was its own level of importance. Topics that participants thought were very important received 5's, while topics they felt had no importance to the space industry received 0.

Participants

The participants of this study consisted of 80 students from the AET undergraduate program and 4 space industry AET alumni. The survey results were anonymous and voluntary for all participants. Students participants ranged from the freshman to seniors, spread out through three different courses. The alumni participants were actively employed at four different companies that were involved in space/space technologies. For the purposes of our survey and the preferences of our alumni, their names and their company names were kept confidential.

Survey Results

Survey 1

The participants in survey 1 were 41 underclassmen, 39 upperclassmen, and four alumni from industry. All were asked to rate their personal experience in the space industry using the scale identified in Table 1. Although the research team expected all alumni participating in the survey rated themselves as a five, they were asked to rate their personal level of experience to prevent partiality. The results gathered from question one were measured using percentages as shown in Table 3.

Table 2. Individual ranking of personal experience in the space industry

1	I have no prior knowledge about space/space technology
2	I understand some concepts about space/space technology, but have not worked/studied with any space related classes
3	I have studied some aspects about space/space technology in a classroom environment or from personal interest
4	I regularly read space related publications, have participated on a space related class project, and/or study space related materials
5	I have had an internship/job with a company involved in space and/or have worked with space materials on a university level class project

Table 3. Percentage breakdown of the results of question 1 in survey 1

Ratings	Underclassmen	Upperclassmen	Industry
1	9.8%	7.7%	0%
2	48.8%	33.3%	0%
3	31.7%	46.2%	0%
4	7.3%	12.8%	0%
5	2.4%	0%	100%

Question 2 in survey #1 asked participants to list topics they felt were most important to succeed in the space industry; results are found in Table 4. The results from survey #1 were used to build survey #2.

Table 4. Top 5 topics seen most frequently from the participants

Top 5 Important Topics to Succeed in Industry		
Underclassmen	**Upperclassmen**	**Industry**
Physics	Physics	Rocket Propellants/Hazards
Technology	Astronomy	Propulsion Systems
Mathematics	Fuels	Management and Testing Facilities
Astronomy	Technology	Project Management
Aerodynamics	Propulsion	Orbital/Rocket Science

Survey 2

Rated by alumni and undergraduates, survey 2 was designed to show if there was a gap in knowledge of the students, compared to the industry.

Figure 3 shows the ratings of the 25 topics grouped by industry and students.

Survey Discussion

This research was intended to understand the needs of industry, the expectations of students, and, possibly, more importantly, understanding the differences between the two. In order to build a successful commercial space program, the expectations of both groups needed to be met. The industry needed graduates who met their needs. It was also believed that if students entered a program that did not cover anticipated topics the disconnect could result in retention problems.

Concernedly, survey #1 results showed a diverging opinion between industry and students. In general, students focused on topics related to the science of space such as physics, mathematics, astronomy, and aerodynamics. However, industry responses illustrated a split focus between the sciences such as; propulsion, orbital science, and propellants against more operation and support topics like management, testing facilities, and project management. This was a fundamental difference in expectations of a commercial space program and was noted that it would require considerable effort from the teaching staff to build bridges for the students between their expectations and industry needs.

Survey #2 results showed a closer relationship between students and industry, though there were still substantial differences. Of the 25 topics listed on survey #2, there were five topics where there was a three point, or higher difference, in ranking between students and industry. Those areas were: orbital and launch mechanics, rocket separation systems, ignition types, clean rooms and industry leaders. In all cases, except clean rooms, students felt these topics were more important than industry. Of the four, only clean rooms received a ranking greater than 4.0 by either students or industry.

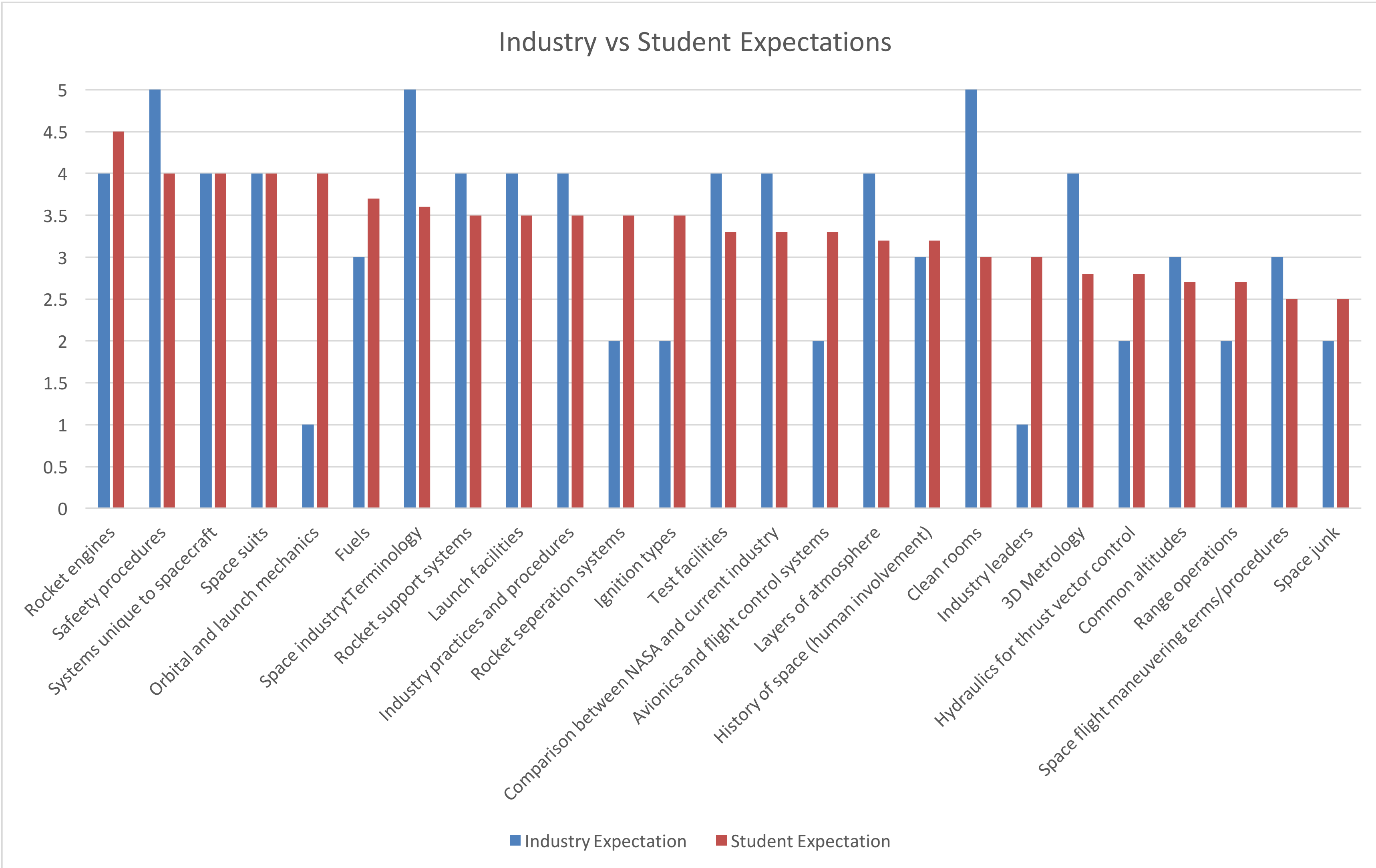

Figure 3. Comparison of topic ratings between industry and students

Areas of consensus

Though the surveys showed many areas of differences between students and industry, they also provided areas of consensus. These were seen as potential building blocks for a commercial program. Table 5 listed the topics that were ranked 4.0 or higher on a scale of 0.0 to 5.0. These were the most important topics to both industry and students and provided the greatest alignment. There were four topics that appeared on both lists. Those areas are rocket engines, systems unique to spacecraft, safety procedures, and space suits. Also, four topics total obtained a score of 4.5 or higher among either industry or students. Those topics included: safety procedures, clean rooms, space industry terminology, and rocket engines.

Table 5. Topics rated 4.0 or higher from industry representatives and students

Items ranked 4.0 or higher	
Industry	**Student Expectations**
Rocket engines	* Rocket engines
Systems unique to spacecraft	Systems unique to spacecraft
* Safety procedures	Safety procedures
Space suits	Space suits
* Clean rooms	Orbital and launch mechanics
*Space industry terminology	
Test facilities	
Comparison between NASA and current industry	
Industry practices and procedures	
Launch facilities	
Layers of atmosphere	
Rocket support systems	
3D Metrology	

* topics ranked 4.5 or higher

Other sources

Other research in this area was limited, but there are two other studies that provided additional insight into industry needs. A study by Brent Vlasman (2014), found seven subject areas important to the training of technicians of reusable launch vehicles.

- Rocket Propulsion
- Aviation Maintenance
- Electronics/Electrical Systems
- Mechanical Systems
- Engineering
- Project Management
- Aerodynamics

Yash Bipinchandra Mehta (2013), found yet another list of most important topics. His top ten list included:

- Spacecraft Systems
- Propulsion
- Orbits
- Space Policy and Law
- Satellite Applications
- Life Support Systems
- Commercial Space Programs
- Space Radiation
- Microgravity
- Space History

Both of these studies surveyed industry professionals to find their final list of most important topics. The consensus among the studies was not available at the time of this study, and there were multiple reasons for this. One example is the nascent nature of the industry, and as such, it does not yet truly understanding its needs. Additionally, each study surveyed "industry professionals", but it is not clear whether or not the professionals of each study have equivalent functions and thus, may see different needs.

Regardless, of the addition of additional results, each study does provide some insight into the needs of the industry at this time and should be considered before building a new curriculum. Further research may find these results are strengthened or weakened, or more likely, split up into requirements for different focused areas such as management, production, or support.

Further research

This research is just the first step in defining expectations for a new program and is not expected to be complete in and of itself. The needs of industry are complex and need more in-depth examination. Understanding requirements and their focus areas in greater detail could reconcile the different results from multiple studies.

Curriculum needs should be separated into groups to provide differentiation between the programs. The requirements for those in management, support, and production are different, and should have different curriculum outcomes.

Additionally, further probing on the meaning of the topics is needed to better understand the results. For instance, this survey combined a number of topics under "systems unique to spacecraft". Gaining greater granularity for understanding exactly what that means is vital to the graduation of successful students. Understanding the connection between student engagement and retention with reference to commercial space programs is fundamental to a successful program. What topics are critical to cover for students to remain and thrive in a commercial space program?

Additionally, a limitation of this research is the limited number of industry participants. Effort towards expanding the subject pool is needed to obtain higher industry-wide confidence in the results.

Conclusion

At first blush, it would appear that the topical areas of study in the Mehta (2013) study differ substantially from the expectation topics given in this paper. In reality, there are a number of overlap areas, and there is no disagreement by the current authors with the validity of the topical areas in the Mehta (2013) work. The difference lies in the intent of the work in the current study. The topic of expectations from students and current industry personnel have been chosen as the basis for this study, in order to define concepts regarding specific knowledge at a detail level. The focus on "expectations" in the current study is to gather information on topics related to daily hands-on operations.

This approach was taken for two reasons. Historically, when industrial representatives have been asked about relevant topics for commercial space education, the responses generated have been generic and high level. These responses have produced topics that have been more overall educational in nature and less practitioner. The purpose of a study that looked at expectations is to attempt to find more practitioner level topics. The concept is to build on a study such as the Mehta (2013) study and to find out what topics should be developed for hands-on study, and topics that would be of immediate use to a college graduate walking in the door of a commercial space company for that graduate's first job. The generic philosophical underpinnings of the expectations study is that of the question, what things do people in the space industry 'just know' as a function of being a professional? What vocabulary, what processes, what technological concepts are just assumed to be automatically a part of people "in the business"? The study of expectations has proved to be a good reflection of these low-level concepts.

When comparing the Mehta (2013) study to the current expectations study, it is easy to envision a commercial spacecraft program that delivers information on all of the Mehta (2013) topics, and then uses the topics in the expectations study as those used for hands-on learning or project learning in a laboratory environment. So, propulsion for example in Mehta (2013) is envisioned as being an education in the theory and application of various propulsion technologies, while in the current study "rockets" takes that same concept and focuses it down to specifics of propulsion components, materials, serviceable components, etc. Similarly spacecraft systems in Mehta (2013), again, provides an education in the theory and application of various spacecraft systems, the current study on spacecraft systems takes that same concept and focuses it down to specifics of system components, materials, serviceable components, etc. Other elements in the current study follow the same conceptual vein; look at these concepts at a high level, educations vantage point, but then drill down on specifics to a detailed, operational level. From this perspective, the Mehta (2013) study and the current study dovetail well together, and the current authors concur that Mehta (2013) provides an excellent selection of topical information. The non-overlapping concepts in this study, are areas where more detailed, practitioner level knowledge and skills are to be developed. Again, the desire of the current authors is to determine various areas for study of detailed, day-to-day knowledge concepts to prepare the graduate to be able to rapidly understand the activities on the manufacture, assembly, handling, and operations of spaceflight hardware. The perspective of an "expectations" survey has proved to be the most effective direction for getting this kind of information from the commercial operators to date by these authors.

The purpose of gathering expectations from students serves multiple purposes. When establishing a program it is important to know if there is congruence between what the students believe they are going to learn, and what is actually taught, and it provides perspective on how the information is to be presented. Additionally, where the topics overlap with industry expectations, it provides relevance to the students for the instruction being delivered, as well as an acceptance of the instructional personnel as having congruent values with the industry.

The commercial space industry has a need for technicians and technologists, and this provides an opportunity for technology and engineering technology schools to develop programs. The first step in any program is to develop an understanding the requirements and the niche the graduate must fill, after which a program can be built. The needs analysis must come first. Following that, a successful program can be developed that can serve and shape an industry, and provide excellent career opportunities for their students.

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Appendix A

Survey #1

This survey is voluntary and please do **NOT** list your name or any personal information. The purpose of this survey is to measure a level of interest and knowledge of students in a current undergraduate Aeronautical Engineering Technology class for the Space industry.

A) Please rate your personal experience about space/space technology.

1. I have no prior knowledge about space/space technology
2. I understand some concepts about space/space technology, but have not worked/studied with any space related classes
3. I have studied some aspects about space/space technology in a classroom environment or from personal interest
4. I regularly read space related publications, have participate on a space related class project, and/or study space related materials
5. I have had an internship/job with a company involved in space and/or have worked with space material on a university level class project

B) Below, list as many subjects as you can that you feel you should know in order to succeed in the space industry.

1.
2.
3.
4.
5.
6.
7.

C) If you were able to take a familiarization course about space and space technologies, would you be interested in (please circle one answer)

1. Attending two lectures and one 50 min. activity based lecture
2. Attending a lecture class three times a week
3. Attending two lectures and one lab a week

Appendix B

Survey #2

Please do **NOT** list your name or any personal information. The purpose of this survey is to measure a level of interest and knowledge of students in a current undergraduate Aeronautical Engineering Technology class for the Space industry.

Below are 25 topics related to space and the space industry. Using a scale of 0-5 (0 being not important and 5 being very important), rate what you feel is the importance of each topic for the space industry.

	Importance (0-5)
Launch Vehicles	
Space Industry Terminology	
Rocket Support Systems	
Clean Rooms	
Rocket Engines	
Launch Facilities	
Safety Procedures	
Space Suits	
Layers of Atmosphere and Meteorology	
Rocket Separation Systems	
Space Flight Maneuvering terms/procedures	
Test Facilities	
3D Metrology	
Fuels	
Industry Practices and Procedures	
NASA	
Orbital and Launch mechanics	
Common altitudes	
Ignition types	
History of Space (human involvement)	
Range Operations	
Hydraulics for Thrust Vector Control	
Space Junk	
Avionics and Flight Control Systems	
Industry Leaders	

The Status of Safety Management Systems at Collegiate Flight Training Institutions

Michael Robertson

Matt Romero

Steve Goetz

Southern Illinois University

Abstract

The purpose of this study was to determine the current status of SMS development and implementation at Collegiate Flight Training Organizations across the United States. Research questions address the following: What are the SMS demographics of collegiate flight schools? What level of organizational support is reported for SMS by collegiate flight schools? What progress is being made toward the development or implementation of the components of SMS at collegiate flight schools? The majority of the collegiate flight training provider's responses indicated some level of SMS implementation and overall indicate more engagement with SMS than other areas of the aviation industry.

Introduction

Safety Management Systems (SMS) is permeating the aviation industry. Airlines, air traffic, airports, flight training organizations, and other parts of the industry are all incorporating the SMS risk-based approach to safety management, and it is important to understand how the various parts of the aviation industry are incorporating elements of the new approach to safety management. The International Civil Aviation Organization (ICAO) defines SMS as "an organized approach to managing safety, including the necessary organizational structures, accountabilities, policies, and procedures" (ICAO, 2013, pp. 1-2). The Federal Aviation Administration (FAA) defines SMS as, "the formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk" (FAA, 2015a). An SMS requires the organization to examine its operations and the decisions made regarding those operations, which allows an organization to adapt to changes and promotes continuous improvement of safety at the organizational level (FAA, 2015a).

According to the Pilot Career Center (2016), there are over 100 colleges that offer some level of flight training in their curriculum. Many collegiate flight schools migrated to SMS in their organizations, but many schools have not yet transitioned to the new approach to safety management. It is important to understand how policies are adopted and implemented into the aviation industry, especially a policy as ubiquitous as SMS. This research begins to evaluate the status of SMS within collegiate flight training.

Research Questions

The purpose of this study is to determine the current status of SMS development and implementation at collegiate flight schools across the US. The following three research questions are used to assess the status of the development and implementation of SMS at collegiate flight schools:

1. What are the SMS demographics of collegiate flight schools?
2. What level of organizational support is reported for SMS by collegiate flight schools?
3. What progress is being made toward the development or implementation of the components of SMS at collegiate flight schools?

Background

Aviation safety management has progressed through many changes in the last 50 years. Historically, safety management improved through a "fly-crash-fix-fly" approach (Stolzer et al., 2011), but the industry recognized that the public's perception of safety is based on the number of accidents that have occurred. Evolving approaches to safety management create an aviation system in which its users feel safe, and SMS is the most recent approach to safety management that attempts to be more proactive and predictive to improve aviation safety. ICAO requires member-states to develop and implement SMS within the various sectors of their aviation industry. The FAA is now following ICAO's lead by encouraging the aviation industry to adopt SMS.

SMS Basics

To understand the basic structure of SMS, a brief overview of the four components of an SMS and their elements need to be discussed. The four components of SMS are policy, safety risk management, safety assurance, and safety promotion (FAA, 2015). These components work together and contribute to developing a positive safety culture within the organization.

The first component of an SMS is policy. The management of an organization supports SMS by establishing policies and safety objectives for the organization. The policy developed by management should establish the direction and set the safety principles in action for the organization (Transportation Research Board, 2009). The second component of an SMS is safety risk management (SRM). A key philosophy within an SMS is to manage risk proactively. SRM seeks to identify hazards and systematically assess the risk associated with those hazards. Controls are then put into place to lower the risk to an acceptable level (Transportation Research Board, 2009). The third component of an SMS is safety assurance. Safety assurance ensures that "performance and effectiveness of safety risk controls and that the organization meets or exceeds its safety objectives through the collection, analysis, and assessment of information" (AC 120-92B, FAA, 2015b, p. 8). The final and fourth component of an SMS is safety promotion. The purpose of safety promotion is intended to support the efforts in developing a strong safety culture. Training, education, and other means of communication are key elements of safety promotion (Transportation Research Board, 2009).

Origins of SMS

SMS principles are used in different high-risk industries like the petroleum, nuclear, railway, marine, and chemical industries. These industries adopted SMS principles after experiencing a catastrophic tragedies, such as the Chernobyl accident, with the intention of addressing safety concerns before additional tragic events occurred (Transportation Research Board, 2007). The aviation industry is another high-consequence industry concerned with its safety record, especially as traffic volumes around the world continue to increase. SMS changes aviation safety-related policy making from a reactionary activity to a data-driven, proactive, and preventive policy-making activity.

SMS throughout the Aviation Industry

Different parts of the aviation industry are using SMS principles to manage their safety programs, although the level of involvement varies across the aviation industry. In all, FAA applies SMS principles to six different sectors of the aviation industry: (1) 121 operators; (2) Non-part 121 operators; (3) Maintenance, repair, and overhaul organizations (MROs); (4) Training organizations; (5) Design and manufacturing organizations; and (6) Airports. This section provides a brief discussion of the status of SMS within the US aviation system.

SMS for 121 Operators

The only sector with in the aviation industry to have SMS incorporated into regulation are those businesses certified under Federal Aviation Regulation (FAR) Part 121 – Operating Requirements: Domestic, Flag, and Supplemental Operations. Implemented in January, 2015, the new FAR Part 5 – Safety Management Systems, outlined the regulatory requirements for 121 operators to implement SMS into their operations.

SMS for Airports

Substantial effort has been dedicated to the development of SMS at the airports across the US. Although not yet regulatory, rulemaking activities have been underway since 2010 (Safety Management Systems for Certificated Airports, 2010). Investigation of the viability began even earlier in 2008 when the FAA sponsored many pilot programs at airports of varying size and complexity. The rulemaking for SMS for certificated airports has been through several different rulemaking extensions and revisions, and despite substantial effort over nearly a ten-year period to incorporate SMS into the airport environment, SMS for certificated airports remains unregulated.

Robertson, Harrison, and Ruiz (2014) conducted a similar study to determine the status of SMS implementation at FAR Part 139 Airports. The study indicated that the airport industry holds safety in high regard but is not convinced that SMS is a significant improvement to existing safety programs. This mindset has led to many airports not engaging in SMS until it becomes a regulatory requirement.

Non-121 Operators, MROs, and Training Organizations

The FAA provides a structure for voluntary implementation of SMS into other parts of the industry including non-121 operators, MROs, and training organizations. Using the Part 121 documentation as a framework, the FAA provides some SMS guidance in the form of gap analysis tools and Advisory Circular AC120-92B – Safety Management Systems for Aviation Service Providers, which is the same guiding documentation used by 121 certificated operators. In short, the FAA has not invested as much into developing SMS for these types of operators as they did when developing SMS for airlines and airports.

Design and Manufacturing Organizations

According to the FAA (2016), SMS principles are being incorporated into recent rulemaking efforts related to a Part 21 SMS. The FAA claims that a notice of proposed rulemaking for FAR Part 21 – Certification Procedures for Products and Articles, will be available some time during fiscal year 2018 (US Department of Transportation, 2016).

Air Traffic

The air traffic section of the aviation industry has been incorporating SMS principles and elements since 2007 (US Department of Transportation, 2007). Air traffic uses a fairly comprehensive set of guiding documents to help implement and develop their SMS programs. The requirements for SMS are detailed in the following series of orders: Order JO 1000.37, Air Traffic Organization Safety Management System Order JO 1030.1, Air Traffic Organization Safety Guidance (US Department of Transportation, 2014).

Methodology

This research used a survey instrument approved by an institutional review board to answer the three research questions. The population for this survey include safety officers at collegiate flight schools that are also members of the University Aviation Association (UAA), a non-profit organization involved in the advancement of degree-granting aviation programs from all segments of aviation. The UAA represents 97 post-secondary education institutions involved in aviation education. The convenient sample for the survey is comprised of the 55 active safety associated with the 97 UAA member institutions. The list of 55 safety officers consists of flight schools that operate some type of a safety program, whether it is a traditional safety program or an SMS. Two rounds of email to the population initiated participation in the study.

Advisory Circular (AC) 120-92B – Safety Management Systems for Aviation Operators provides a framework to aid in the development of the survey. Although 120-92B was designed to help airlines meet their regulatory requirements of SMS within Part 121 operations, the AC provides a succinct and comprehensive overview of SMS, its components, and the individual elements that drive SMS which form the basic structure of the survey. Robertson (2016) helped to fine tune the instrument utilizing the expertise of safety professionals within the flight-training environment. In addition, colleagues that were considered safety specialists from Southern Illinois University, University of North Dakota, and Embry Riddle Aeronautical University reviewed the survey for validation.

Calculating SMS Implementation

Using AC 120-92B as a guide, this research developed a classification system to judge the degree to which a pilot training program has implemented SMS to manage their safety programs. Using the four components of SMS as a basic framework, the classification then adds the different elements that comprise each component of SMS. For example, a pilot training program that has implemented all four SMS components and all of their associated elements could be described as having a fully-implemented SMS. Further, this information can be used to calculate an overall degree of SMS implementation across the responding pilot training schools. For example, there are five different elements related to SRM. If all five elements of safety risk management are represented at all 28 institutions, the implementation score for SRM is calculated to be 100%.

It is important to note the limitations of calculating the implementation scores. There are two factors that limit the application of the implementation score. First, the elements that are listed in Table 1 derive from AC 120-92B, which is a guiding rather than a regulatory document intended to help Part 121 operators and other aviation service providers to implement and manage an SMS. We cannot claim that this method of gauging SMS implementation is validated, but further investigation may reveal this method to be an adequate way to infer overall SMS implementation in pilot training schools or in any other sector of the aviation industry.

Similar to the first limitation, the second limitation is caused by the lack of uniformity of SMS elements across different organizations. For example, the survey asks respondents to identify all of the elements they use that relate to safety promotion. Among the items listed is the use of safety stand down as promotional element. While we can agree that a safety stand downs may be a useful promotional element, it is not required for a fully implemented SMS. This certainly limits the utility of an implementation score of 100%, but the scoring system remains useful as a general guide to judge the overall implementation status of SMS and its components. Table 1 displays the four components of SMS and their associated elements that safety programs need to employ to implement SMS. It is important to note that there are elements and processes listed for safety promotion that are not necessary for SMS implementation.

Table 1

SMS Components and Related Elements

Safety Policy	Safety Risk Management
Completed gap analysis	**Hazard identification**
Implementation plan	**Hazard tracking and documentation**
Safety policy statement	**Risk analysis**
SMS objectives	**5-Step SRM process**
Identified accountable executive	**Conducted safety risk assessments**
Identified SMS manager/coordinator	
Identified safety committee	
Emergency planning and response	
Safety Assurance	**Safety Promotion**
Confidential hazard reporting system – Web	**Specialized SMS training**
Confidential hazard reporting system – Paper	**Regular SMS training – Employees**
Trend analysis	**Regular SMS training – Students**
Safety performance monitoring	**Safety bulletin boards**
Continuous monitoring of safety controls	**Safety newsletters**
Flight data monitoring analysis	**Employee safety meetings**
SMS audits or evaluations	**Student safety meetings**
Safety culture assessments	**Safety awards program**
	Safety stand-downs

Results

The survey is divided into three different sections that, collectively, answer the three research questions. The first portion of the survey relate to SMS demographics, the second section of the survey relates to the level of management commitment to SMS activities, and the third section of the survey relates to the progress collegiate flight schools have made toward implementing SMS.

The two rounds of email yielded participation from more than half of the population. Of the 55 safety officers emailed, 28 safety officers responded to the survey, generating a response rate of 51%.

Part 1 - SMS Demographics

One purpose of this research is to collect general SMS demographic information about collegiate flight programs. This type of information is useful as we monitor the propagation of SMS throughout the aviation industry. Just as Robertson et al., (2014) explored the spread of SMS throughout the airport sector, the current research aims to extend this line of research to monitor SMS in collegiate flight schools.

Basic Institutional Demographics.

The survey was used to discover the general demographic information related to SMS at collegiate flight schools. The respondents first provided information about basic school demographic information such as the name of the institution, whether their institution is certificated as a Part 141 pilot school, and whether their institution provides flight instruction or uses a third-party to provide their flight training. The names of the participating institutions were de-identified to keep the participants' responses confidential. Of the 28 survey respondents, 26 respondents indicated that their institutions classify as a Part 141 pilot school. Finally, the majority of the respondents (89.14%) indicated that they provide their own flight training to pilots and do not contract their flight training out to another entity.

General SMS Demographic Information.

To gather SMS demographic information about the participating institutions, the next part of the survey asked participants to indicate their level of SMS knowledge. They also provided information that described the degree to which SMS is currently being used at the participating pilot training programs. Last in this portion of the survey, the respondents indicated when they expect their organizations to implement SMS.

Table 2 displays the level of familiarity the respondents have with SMS. Of the 28 safety officers-respondents, 24 (85.71%) indicate that they are at least knowledgeable about SMS.

Table 2

Safety Officer Knowledge of SMS

Degree of SMS Familiarity	*n*
No Knowledge	0
Some Knowledge	4
Knowledgeable	11
Very Knowledgeable	13
SMS Expert	0

The participants describe their level of involvement to varying degrees. Table 3 displays the results the respondents provided for this survey question. At the time the surveys were submitted, only five respondents (17.86%) believe they have a fully implemented SMS. The majority of the population have not yet fully implemented SMS in their pilot training programs. Only six (21.43%) participants are not using SMS to manage their safety programs, which indicates that the majority of participants have adopted SMS to manage their safety programs.

Table 3

SMS Involvement

Degree of SMS Development/Implementation	*n*
SMS is Not Under Development	6
SMS is Under Development	9
Most SMS Components/Elements are in Place	8
SMS is Fully Implemented	5

The last SMS demographic question asked the survey respondents to project when their organization plans to adopt a fully implemented SMS. Table 4 displays the projections of when the organizations plan to implement an SMS and when they expect their organizations to have an SMS fully in place. It is important to note that this question did not apply to 9 (32.14%) of the respondents because they either have a fully implemented SMS or have no intention on further SMS development.

Table 4

Projected SMS Implementation

Number of Years Until Full SMS	*n*
Not Applicable	9
Within 1 year	8
Within 2 to 3 Years	9
More than 3 Years	1
Did Not Answer	1

Part 2 - Management Commitment

The second section of the survey aims to assess the commitment of the managers at the responding pilot training schools to SMS. In this case, management commitment is measured by assessing various management activities related to SMS and by asking survey participants to judge their managers' level of commitment to SMS.

SMS-related Activities.

The first question in this section asked respondents to identify all of the various SMS activities that indicate commitment to implementing and managing an SMS. Table 5 shows the distribution of the various SMS activities the respondents employ at their pilot training schools.

Table 5

SMS Activities at Pilot Training Schools

SMS Activity	*n*
Invests human and financial resources	19
Proactive in preventing accidents	25
Consistently enforces safety procedures	24
Views regulatory violations seriously	26
Involved in safety activities	24

Because there were 28 respondents to the survey, each activity has a maximum participation level (*n*) of 28. None of the activities were represented by all 28 respondents, but all of the SMS activities are used by the majority of the research participants.

Management's Commitment to Implement SMS.

The safety officers responding to the survey were asked to evaluate their managers' level of commitment to implement SMS at their institution using a rating scale ranging from 0 to 10, with 0 representing no commitment and 10 representing full commitment. There were 28 responses to this question with answers varying from 0 – 10 with a Mean of 7.5 and a Median of 8.00 (SD – 2.47).

Part 3 - SMS Implementation

The last portion of the survey aims to assess the level of implementation of SMS at the participating institutions. The four components of SMS and the associated elements provide the framework used to assess the level of SMS implementation. The level of implementation of SMS is measured by evaluating the different components and elements of SMS being used at the participating schools.

Safety Policy.

This section of the survey asked respondents to identify the elements related to safety policy that they use in their safety programs. Table 6 displays the results of this inquiry. Twenty-four of the 28 respondents (85.71%) had identified an SMS Manager or Coordinator and had emergency planning and response procedures in place. The least occurring element was the completion of a gap analysis with a total of eight replies (28.57%). One result from this inquiry indicates that most of the safety policy related elements are represented by a majority of the responding organizations. A percentage of overall implementation of the safety policy component across the pilot training schools is calculated to be 64.73%.

Table 6

Safety Policy Implementation

Safety Policy Activity/Process	*n*
Completed gap analysis	8
Developed an implementation plan	14
Developed a safety policy statement	22
Developed a set of SMS objectives	18
Identified an accountable executive	19
Identified an SMS manager/coordinator	24
Identified a safety committee	16
Developed an emergency response plan	24
Total Safety Policy Implementation Score	64.73%

Safety Risk Management.

This section askes respondents to examine their SMS to identify the elements and processes that they had that relate SMS. Table 7 displays the results of this question. Of the 28 participants, 24 (85.71%) have a method or methods in place for identifying hazards, and 50% of the respondents indicated that they have performed safety risk assessments. Only six respondents have a formalized 5-step SRM process established at their institution. The overall implementation score across all 28 pilot training programs is 57.86% implemented.

Table 7

SRM Implementation

SRM Activity/Process	*n*
Hazard Identification	24
Hazard Tracking and Documentation	18
Risk Analysis	19
5-step SRM Process	6
Safety Risk Assessment	14
Total SRM Implementation Score	57.86%

Safety Assurance.

The next question assessed the level of implementation of safety assurance activities at the responding institutions. To do this, the survey respondents identified which elements and processes that they had relating to the safety assurance component. Table 8 displays the results of this inquiry along with the implementation score for the safety assurance component.

Table 8

Safety Assurance Implementation

Safety Assurance Activity/Process	*n*
Confidential Hazard Reporting System - Paper	16
Confidential Hazard Reporting System - Web	15
Trend Analysis Capability	14
Safety Performance Monitoring	9
Continuous monitoring of Safety Controls	12
Flight Data Monitoring Analysis	8
SMS Audits/Evaluations	7
Safety Culture Assessments	18
Total Safety Assurance Implementation Score	44.20%

Twenty-six of the 28 respondents indicated that they had some type of confidential hazard reporting system. Four of the respondents indicated that they had both a paper based and web based system to report hazards. The elements of safety assurance are implemented at a rate of approximately 44% of the responding pilot training schools.

Safety Promotion.

The implementation of safety promotion activities is the last component assessed for this research. Table 9 displays the results of this survey question. Twenty-five (89.28%) respondents reported that they have employee safety meetings but only eight (28.57%) indicated that they have regularly scheduled training for their employees. Ten respondents indicated that they engage in safety stand downs. Typically, this involves closing down to discuss safety issues or have safety related training. Of these 10, only two indicated that they have regularly scheduled training and meetings for both students and employees. One particular school that does not organize regularly scheduled safety meetings or training did indicate that their safety stand down is one full safety day with a keynote speaker and 25-30 breakout sessions. Safety promotion activities are present 48.02% of the safety promotion activities are implemented across the sample of pilot training programs.

Table 9

Safety Promotion Implementation

Safety Promotion Activity/Process	*n*
Specialized SMS Training	10
Regular SMS training – Employees	8
Regular SMS training – Students	11
Safety bulletin boards	23
Safety newsletters	11
Employee safety meetings	25
Student safety meetings	19
Safety awards program	4
Safety stand-downs	10
Total Safety Promotion Implementation Score	48.02%

Discussion

Research Question 1: What are the SMS demographics of collegiate flight schools?

The first research question aims to find out about basic demographic information of the pilot training schools. It seems that knowledge of SMS is prevalent in the collegiate flight training industry as 24 of the 28 respondents indicated they were either knowledgeable or very knowledgeable about SMS. This knowledge appears to translate into implementation as 5 of the 28 respondents indicated they had a fully function SMS and 17 had one under development and most expect to be fully implemented within 3 years. These findings would seem to indicate that organizations choose to develop SMS once the processes and the intentions of SMS are understood. The collegiate flight training industry seems to be adopting SMS as their new safety standard as nearly all respondents either have or expect to have a fully implemented SMS within the next three years.

Two areas of interest arise when these data are analyzed. The first reveals a reluctance to change institutional safety programs. Six respondents indicated they were not currently developing SMS and five had fully implemented SMS, but nine indicated that their timeline to implementation was "N/A." For the five institutions that have fully implemented SMS, this response makes sense, but it also indicates that four of the six that have not begun SMS development seem to have no intention to start. There could many reasons why organizations choose not to begin SMS implementation, but one could be lack of knowledge. Fully half of those respondents indicating SMS was not under development indicated only "some knowledge" of SMS and only one was "very knowledgeable." SMS seems to be gaining traction in the collegiate flight training industry, but there appears to be a knowledge gap between those choosing to implement and not, and some organizations that will not change unless mandated to do so.

The second interesting area involves a comparison between airports certified under FAR part 139 and these collegiate flight training providers. Neither group is mandated to comply with FAR Part 5, but there have been rumors for some time that both groups will eventually need to comply. The findings of Robertson et al., (2014) reveal a similar circumstance to that found in collegiate flight training. Those with knowledge of SMS seem to be willing to implement it even before the mandate is given, but there are also some hold out organization that will wait until they are mandated to comply before beginning the development and implementation process. This tendency seems to be less pronounced in the flight training industry when compared to the Part 139 airports. While there are certainly parallels, it seems that the collegiate flight training providers are more willing to adopt SMS than their airport counterparts.

Research Question 2: What level of organizational support is reported for SMS by Collegiate Flight Schools?

While the other two questions examined the implementation and acceptance of SMS, this question is different because it concerns the propensity for management to engage new ideas and change their organizations. Based on the survey, respondents indicated that the management of their organizations were primarily concerned with areas that could have detriment on the financial standing of the organization, such as regulatory violation (n=26), accident prevention (n=25), enforcing safety procedures and being involved in organizational safety activities (n=24, n=24). In contrast, there were fewer that were willing to invest in human capital to improve their organization (n=19). This indicates that the management of these organizations are interested in the safety of their operations from a fiduciary standpoint rather than investing in them to promote growth. This should not be misconstrued as a bad thing as safety in any flight training organization is paramount. Management at the respondent organizations do seem willing to pursue SMS implementation, and seem willing to provide funding to do so. Nearly half of respondents reported using a software program of some sort to manage their safety program, and 69% of those use a commercial product or one developed in house. These two options require a capital investment by organizational management toward to management of a safety program and improving organizational safety. I would seem that flight training organizations are following similar paths to other industries by investing in technology and programmatic material over investing in their people and human capital.

Research Question 3: What progress is being made toward the development or implementation of the components of SMS at Collegiate Flight Schools?

The third question posed by this study involved the implementation of the components of SMS by collegiate flight schools. This is a broader question than simply SMS implementation as it concerns use of pieces of the SMS puzzle as well as the entire puzzle itself. To understand how SMS components are implemented by various collegiate flight schools, it is beneficial to examine each of the four major areas of SMS and see how components of those areas can be used.

Safety Policy

Safety policy in SMS determines the direction an organization will take with respect to safety programs. Safety policy activities are the first step in SMS implementation, and so it would be expected that most programs have elements of safety policy, which is what the data shows. Nearly all safety programs will have some form of policy statement, and we see that borne out in these data as 22 of the 28 respondents have safety policy statements and 24 have plans for emergency response. Most of the respondents have a safety coordinator of some sort (n=24), but far less have a full safety committee (n=16). Only eight respondents had completed a gap analysis, a precursor tool used to guide the implementation of SMS. While not required, use of a gap analysis can make the implementation of SMS easier for organizations. The safety policy areas that have been accepted into common use in the collegiate flight training industry are valuable, and it is the safety policy component that helps lay the foundation for SMS implementation.

Safety Risk Management

Safety risk management is the SMS component that deals with hazard identification and tracking as well as risk assessment and mitigation. Most respondents indicated they conducted hazard identification (n=24), but only ¾ of those (n=18) reported tracking and documenting those hazards to see hazard trends over time. It seems surprising that tracking hazard mitigation over time is not as common since it is important to track changes over time to understand if corrections were effective, but this could also be due to insufficient data to analyze. Trend analysis is one of the last stages in safety risk management because data must be collected over time. This could explain why fewer organizations have engaged in trend analysis.

Safety Assurance

Safety assurance deals with the ability to correct problems over time and continuously improve operational safety. This component also involves activities such as surveying organizational culture, instituting confidential hazard reporting, trend analysis, and tracking of performance indicators. These activities, and those like them within this component, are essential to the success of SMS over time, but safety assurance activities are typically conducted toward the end of SMS implementation. Much as we expect to see most organizations with safety policy initiatives, since it is the first step, we expect to see far less implementation of safety assurance, since it is the last step in SMS implementation. The most commonly implemented element was surveys of organizational culture (n=18), followed by confidential hazard reporting either by electronic (n=16) or paper (n=15). These would seem to indicate that many collegiate flight training providers are actively seeking to encourage a robust safety culture and help to do so by establishing a means for non-punitive hazard reporting. This also seems to indicate that all or nearly all the respondents have some sort of confidential hazard reporting, whether that is electronic, paper, or both. Only half of the respondents conduct trend analysis of hazards over time to see if their corrections are effective, and even fewer actively monitored their safety controls (n=12) or safety performance indicators (n=9). While many of the elements of SMS have been implemented in collegiate flight training, safety assurance seems to be missing critical buy in from organizations, which can lead to problems because the entire purpose of safety assurance elements is to assure that the safety program is functioning the way it should. It is possible that these data are too preliminary and that, with time, safety assurance will be a more robust portion of the SMS process in these organizations.

Safety Promotion

The safety promotion component of SMS ensures that all principle parties are aware of the safety program and its goals. There were few respondents that indicated they conduct SMS specific training with employees or students, but that is to be expected when only five respondents have a fully implemented SMS. It is encouraging that almost 90 percent of respondents have employee safety meetings (n=25) and safety bulletin boards (n=23) to make information publicly available. Additionally, 19 respondents hold safety meetings specifically with their students so that they are aware of the safety program and why it is important. It is encouraging to see the level of safety promotion that has been adopted throughout the collegiate flight training industry, as presented by the survey respondents. The greatest safety program in existence does no good if no one knows about it.

Conclusions and Recommendations

This research has shed light on the current state of SMS implementation within Collegiate flight training providers. While the sample is not large (N=28), the 51% response rate is within accepted margins for a survey of this nature (Baruch, 1999). SMS is being implemented in collegiate flight training much as it is by Part 139 compliant airports. SMS has not been mandated by either group, and so some are adopting early while others wait for a regulatory impetus to implement. About three-quarters of the collegiate flight training provider's responses indicated some level of SMS implementation, with nearly as many fully implemented as refusing to do so.

While this is interesting research, there are many areas of SMS at flight training providers which need to be explored, such as: What is the status of SMS implementation within the entire flight training industry? What role does general SMS knowledge play in organizational decision to implement SMS? How is SMS used to help understand and predict safety incidents or accidents? Is there a difference in how SMS is implemented at Part 61 flight training providers versus part 141 providers?

This study, if replicated, would benefit from some changes to the survey instrument to allow for more detailed information regarding the SMS elements and processes implemented at organizations. This instrument provided an overview, but lacked specifics as to how each item was being implemented. Additionally, more information collection on the quality and timing of safety promotion activities and the level of management commitment to SMS would further add to this important area of research.

SMS represents a shift in the understanding of safety. With SMS, safety awareness moves away from reacting to problems into a position of foreseeing and predicting where incidents will occur and actively trying to mitigate the hazards that lead to those incidents. It is heartening that the collegiate flight training industry has embraced SMS to this extent, but there is still more that can be done to improve aviation safety.

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When "SOP" Fails: Disseminating Risk Assessment in Aviation[1] Case Studies and Analysis

Ryan E. Quinn[2]

Saint Louis University

Abstract

In the early 1990s, a regional jet taking off from LaGuardia airport with ice and snow on the wings crashed into a nearby bay and killed 27 passengers and crew. The accident of USAir Flight 405 is studied critically in this review as a result of incomplete identification and dissemination of the risks involved in operations under icing conditions. The improper system risk dissemination and mitigation led the crew of USAir 405 to believe they were in a condition for a safe takeoff. In the larger context outside of this accident, unidentified hazards resulting from poor communication and company dissemination are still an everyday threat. I argue that this disconnect is a causal factor in Normalization of Deviance. Contemporary examples of safety incidents are used to support this argument and introduce possible new areas for monitoring and research. The author argues that companies should employ techniques to open new policies up for testing and feedback before being implemented as policy or standard operating procedure.

Accident Narrative

On the night of March 22nd, 1992, a fifty-passenger twin engine regional jet known as a Fokker F28-4000 lined up on runway 13 at LaGuardia Airport in New York City. With the Captain advancing the thrust levers, USAir 405 accelerated down the runway and reached one hundred thirteen knots. Upon "Vee R"[3] being called out by the First Officer, the nose was raised to thirteen degrees pitch up under the Captain's command and three seconds later the Cockpit Voice Recorder (CVR) registered the sound of a stick shaker[4] activation. Approximately three quarters down the runway the left wing began to scrape on the ground, and the aircraft rolled to the left, destroying the runway's approach slope lights and a water pumphouse. Four seconds from the initial rotation, the Fokker, now torn to shreds, laid inverted in the 34-degree Flushing Bay just a few feet off of airport property. A fire erupted and burned, mostly on top of the water, for 30 minutes before fire services were able to put it out. By the next morning, twenty seven of the fifty-one people onboard had lost their lives (Kleinfield, 1992; National Transportation Safety Board [NTSB], 1993). An investigation completed by the National Transportation Safety Board found that the sound of the stick shaker system was continuous

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[1] This work has not been previously published and is not currently under consideration for publication elsewhere.

[2] Email: quinnr@slu.edu.
421 Hanover St., Apt 31, Boston, MA, USA, 02113

[3] "Vee R", as it is transcribed from the voice recorder, refers to V_R, the velocity at which the pilot pulls back on the control yoke.

[4] Stick shakers alert the pilot of an impending aerodynamic stall.

after its initial activation. After liftoff, the plane had only reached an altitude of a few feet—instead of climbing the aircraft entered an aerodynamic stall a few seconds after rotation. In the course of a few seconds a normal flight appeared to have careened into the bay for no obviously apparent reason.

The factors leading up to this accident began long before the takeoff itself. The first leg of the flight was completed earlier that night by the same crew, with the First Officer completing an instrument approach to minimums without facing delays in the air. On the ground however the aircraft faced taxi congestion at LaGuardia, bringing them to the gate an hour behind schedule. After a pause to board passengers and prepare for the next leg of the flight, the aircraft was deiced with a fifty-fifty mixture of glycol and water known as Type I deicer. One of the ground service trucks caused a twenty-minute delay when, in the icy conditions, became stuck behind the aircraft blocking the path for a pushback. After it was moved the captain again requested that the airplane again be deiced a second time due to the commotion. Following their second deicing, however, the crew faced more delays as the snow was still congesting taxi operations. Altogether twenty-nine minutes had passed from the time of the last deicing procedure to the time the crew received takeoff clearance. The aircraft was now two hours behind schedule. During the taxi out, the First Officer (the only survivor from the flight crew) stated that he checked the wings, including a black "ice indicator strip", between three and ten times. Looking through the closed cockpit window from the right seat before takeoff, the wing seemingly appeared clear of ice. (NTSB, 1993)

Between the de-ice and the delayed taxi, the aircraft's previously clean wing had become substantially contaminated with snow and ice, reducing aerodynamic efficiency of the wing—and the flight crew had few ways to tell, since the ability to see contamination on the wing from the closed cockpit window was extremely compromised from the right seat. During the investigation, the National Transportation Safety Board (NTSB) conducted a viewing test from an F-28 and found;

> About 60 percent of the wing was visible when it was observed through both the sliding window and the window behind it…. It was difficult to see any details of any parts of the wing, such as rivets… When attempts were made to observe the black strip, it could only be seen through the scratched window behind the sliding window… the flat black strip was visible but distorted by the window glass. (NTSB, 1993, p. 40).

However, to the First Officer's knowledge there was no reason to doubt the veracity of the indicator in detecting contamination. Contrasting with the very negative outlook of the viewing test, the investigation report states that "throughout the investigation of this accident… [Fokker pilots] universally believed that they could detect any significant contamination from the cockpit". This suggests that flight crews of the Fokker never received company guidance stating anything to the contrary, when in fact tactile inspections of the wing were sometimes necessary to ensure a clean aircraft. (NTSB, 1993) This distinction between company accepted practice versus actual safe operation is an important topic that is touched on later in this paper.

Adding to the issue of the contaminated wing, one minor mistake was made by the crew by calling for V_R five knots earlier than was calculated. This may have been due to the fact that they were using a reduced V1 speed[5] —with most takeoffs in dry conditions, V1 and V_R would have been stated at the same time. Due to the early rotation, drag was even more significant and wing angle of attack was increased above normal takeoff angle. It was found that the early rotation condition in conjunction with the uneven, rough ice accumulation caused the initial left wing drop as the aircraft stalled.

Characteristics of the Fokker F28 led it to be a particularly poor performer in icing conditions. Upon rotation, standard angle of attack for the Fokker was nine degrees. However even with very light icing contaminations of the upper wing, it was found that a nine-degree angle of attack would cause an aerodynamic stall as well as reduce lift by 33% or more. Other aircraft have comparably larger margins for standard vs. stalling takeoff angles of attack. Yet another factor leading to the poor icing performance was related to the position of the fuel tanks in the Fokker. Aircraft that were cold soaked, typically those returning from another leg such as USAir 405, would have extremely cold fuel due to the temperatures encountered at altitude. The fuel had the capability of cooling the wing surface to even lower temperatures than ambient.

During the investigation of the accident, it was found that 757s which were deiced and held-over for a similar amount of time had no issues departing due to their leading edge slats[6] and significant excess thrust. In fact, the aircraft that departed directly in front of USAir 405 was a 757 (NTSB, 1993). The lack of problems these aircraft had during their takeoff could have led to a false sense of security in the ability of the F-28 that night. The NTSB (1993) noted that the Federal Aviation Administration (FAA) had concerns about placing focus on those aircraft without leading edge devices in regard to icing, since the administration was under the impression that this would lead to carelessness on the part of pilots who flew aircraft with leading edge devices in icing.

At that point in time the crew had done everything that was expected of them by standard operating procedure to fully inform themselves as the state of the aircraft contamination. (Dismukes, Berman, & Loukopoulos, 2007) The crew at the time of the accident was well qualified and had no record of incidents or deficiencies in training. The NTSB report of the accident states that "USAir flight crews received materials and training concerning winter operations consistent with, and in some cases, exceeding industry standards. The initial F-28 ground school emphasized the critical nature of the F-28 hard wing[7]…". While taxiing, the crew commented on poor nature of deicing being done at the gate rather than the runway, with conversation recorded on the CVR commenting on the new Denver airport's deicer pads:

> "[Captain:] That's the ideal way of doing it man. . . They ought to have something like that- this is New York you know… they ought to have that out here."

"[First Officer:] That's really the only sure fire safe way to do it" (NTSB, 1993, p. 91)

Overall, there is a bigger picture insinuating that the Captain and First Officer were a knowledgeable crew that knew only some of the risk of icing takeoffs, and to the best of their

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[5] V_1 is the point at which the aircraft must continue the takeoff since there is not enough runway left to stop).

[6] Leading edge slats are devices which allow the aircraft to more easily fly at slow airspeeds.

[7] Hard wing refers to wings that lack a leading edge device, which allows the aircraft to generate lift at slow airspeed.

knowledge, were free of ice contamination. Working contrary to them were the procedures and systems in place for the deicings themselves. The systems did not fully identify and account for all of the specific safety risks involved. According to the NTSB, USAir used the earlier Type I deicing fluid rather than the newer (at the time) Type II fluid. However, as stated earlier the board believed that the "procedures met or exceeded airline standards and were consistent with most of the industry". A problem revealed here is self-evident: even though all guidance from the FAA stated that the deicing was sufficient, the aircraft still took off with ice.

Primary Concerns

Procedures to identify, mitigate and continuously identify risk have undergone major changes in recent years through the mandatory development of Safety Management Systems (SMS). One especially important task of the SMS is the proper dissemination of risk information. Two instances in this accident stand out regarding poor dissemination of information. The first is the lack of reliability of the black ice indicator strip. The second is the ignorance of ground personnel that the Fokker may require a tactile inspection to confirm that the wing is clean of contamination.

Risk Dissemination is a critical component of a functional Safety Management System. Transport Canada, the Canadian equivalent of the FAA, has implemented a process flow which includes information dissemination as the final step of their SMS. Information dissemination according their policy includes trend analysis, safety bulletins, accidents, and report distribution (Stolzer, 2011). In 2013, *Annex 19 to the Convention on International Civil Aviation* was adopted into the Articles of the International Civil Aviation Organization (ICAO) and thus formally mandated the FAA and all member states to adopt SMS as the standard for airlines and the aviation industry (International Civil Aviation Organization, 2013). The system essentially allows for an organized process of risk assessment which in theory allows the user to predict risks as they emerge and compensate for them.

Accidents precursory to USAir 405 contained similarities that provided lessons to the FAA regarding icing. The NTSB (1993) accident report specifically makes mention of two important facts. "The investigation of past accidents has disclosed the difficulty involved with flight crews determining whether wings are clean. The industry acknowledges that it is nearly impossible to determine by observation whether a wing is wet or has a thin film ice". A disturbing aspect of the inference of this quote is that the necessity of up close inspection was well known to the industry as well as the FAA, while simultaneously remaining unknown to both ground personnel as well as flight crew at USAir. These critical portions of the company remained unaware of this risk due to the lack of dissemination of information. Ultimately, icing takeoffs were most likely very common in the era before this and other large scale icing accidents such as Air Florida Flight 90 in 1980 (Dismukes, et al, 2007).

Further supporting the idea that understanding of the risks associated with icing was inconsistent at USAir, some crews were found to be using their own improvised technique when they suspected contamination to be present. A captain for an airline which was later merged with USAir wrote a memo regarding icing takeoffs: "when wing contamination is suspected despite earlier preventative measures, rotation rates must not be excessive and takeoff speeds may be increased up to 10 knots. . . field length must be accounted for in the decision to rotate slower than 3° per second. . ." (NTSB 1993, p. 58). Fokker did not have a published procedure including this technique, nor was this technique published in the USAir Standard Operating Procedures. The disconnect between the informal procedure of USAir pilots and the standard operating procedure is one where the risk of icing takeoffs seems to be well understood by pilots yet not published under company approved procedures. The fact that this unwritten procedure was written but not used, or apparently known of, by the crew of USAir 405 suggests that this information was not disseminated successfully by the company. This is supported especially by the fact that the crew rotated five knots early, and rotated at an aggressive rate. This put them 15 knots slower than the guidance of the published memo.

The second procedural blunder came with respect to the use of the Captain's manually reduced V1 speed. Recent aviation incidents had been brought to the Captain's attention regarding the hazards of aborting a takeoff on a snowy runway. He decided that to reduce this risk they would establish a lower V1 speed. While this action was well intentioned with a conservative safety viewpoint in mind, it was improperly briefed and not part of standard operating procedure. The sense of timing in the crew's minds was thrown off and led to the early rotation (Dismukes et al., 2007).

These two examples of non-published procedures being used could be considered to fall under the category of normalization of deviance. Vaughan's (2009) book discusses normalization of deviance in the context of an extremely notable aviation disaster, the Challenger launch. She describes the endemic of normalization of deviance inside the National Aeronautics and Space Administration at the time as an effect of culture that resulted not from an attitude of rule breaking, but rather one of conformity. Likewise, as the crew of the Fokker prepared for takeoff that night they were not interested in breaking any rules. Rather, they were continuing with an unspoken tradition of taking off with questionable icing contamination. Had they used the unwritten procedure that the earlier memo stated, they would nonetheless still be following an unapproved procedure. Whereas the Challenger shuttle disaster is an example of normalization of deviance occurring as a side effect of external pressures and organizational culture, I argue that USAir 405 occurred in an organization where deviance was used to "fill in the gaps" of Standard Operating Procedure.

Contemporary Examples

Using the National Aeronautics and Space Administration's (NASA) Aviation Safety Reporting System (ASRS)[8] (NASA 2016), we can find a broader picture of contemporary safety incidents caused by poor information dissemination that are still going on today. The function of ASRS finds its value through identifying repetitive trends in incidents, like many found previous to US 405 (the NTSB [1993] had listed several safety recommendations regarding icing that were not found acceptably fixed by the FAA).

In many of these instances where safety information is not properly disseminated, good airmanship and flight crews become the last line of defense[9]. Thankfully, due to the lessons

[8] "The ASRS collects, analyzes, and responds to voluntarily submitted aviation safety incident reports in order to lessen the likelihood of aviation accidents." (NASA N.d.)

[9] Airmanship, according to Ebbage & Spencer (2004), is defined as "effective decision making to support a sequence of actions"

learned from USAir 405 and the near universal abundance of deicing pads and maximum holdover times, the prevalence of takeoff icing contamination incidents in scheduled air carrier operations is remote. This accident, however, can be looked at in a big picture sense. I have selected five specific incidents from the ASRS to highlight those that seem to share the same underlying organizational cause of the USAir 405 accident.

We can take for instance this NASA ASRS report regarding a Boeing 777 crew's communications with weight and balance dispatchers. The crew had made an unscheduled stop at an intermediate airport during an intercontinental flight due to a crew rest time issue. During the stop, no passengers were deplaned except for a few flight attendants and bags, and the plane was restocked with food. The company dispatch report, however, gave them takeoff numbers and speeds which corresponded to aircraft performance at a weight which was twenty thousand pounds lighter. The dispatcher was queried and responded that it was a mistake that they were working on. Nevertheless, the dispatch sent back new weights which were now nine thousand pounds in excess of their weight when the aircraft arrived. The captain noticed the mistake again before finally receiving corrected weights.

While this is an exemplary instance of a flight crew overcoming poor information that is being presented to them, there is a disconnect here regarding the dispatcher's versus the Captain and First Officer's assessments of risk. The Captain stated, "[h]ad we not queried the load planner with the original 19,670-pound decrease, which was not correct, and used that data for takeoff and experienced an abort at V-1, we would have gone off the end of the runway and killed everyone on board!". Later, the Captain says that the attitude of the dispatcher on Satellite phone was "indignant" (National Aeronautics and Space Administration [NASA], 2016, No. 1379224). Barring a willfully negligent employee, it seems that the dispatcher may have not fully understood the implications of an improper V1 speed. Judging by this incident, the crosscheck of the flight crew in calculating the performance numbers was vital. This incident supports the argument that safety information must be disseminated among all levels of the company, not just flight crews. In this case, the flight crew luckily caught the mistakes of the dispatchers but faced serious communication issues.

Another example where a communication breakdown was a contributing factor occurred somewhere over the airspace of Southern California Approach. A "super heavy" weight-class Airbus A380 took off with an approximate weight of 1.2 million pounds. In a clean configuration the aircraft had a minimum safe maneuvering speed of two hundred eighty knots. Upon advising the controller that they were required to exceed two hundred fifty knots, he scolded them, accusing the crew of "playing games". According to the pilot, "A less fortunate and less trained crew very well might have had a clean aircraft too slow (250 knots, as the controller mandated) and caused a serious safety concern" (NASA, 2016, No. 1376325). The speed regulation, what the controller seemed to think was a non-waiverable requirement of airspeed, led to pressure on the flight crew to do something unsafe. It is unlikely that there was company guidance on reacting to controller pressure to do something the aircraft isn't safely capable of doing.

A commonality between this situation and the situation at USAir in the years preceding the accident of 405 is the inconsistency of understanding within the scope of procedures. The "unwritten procedure" for icing takeoffs was one that many USAir pilots understood as necessary but was simultaneously unpublished by Fokker. In addition, the crew of 405 was under the impression that the black icing strip was an acceptable form of checking for wing contamination. Other pilots may have known that it was a vastly ineffective way of determining contamination. The commonality between the two situations is a disconnect in understanding between involved parties. The pilots knew that an A380 near maximum gross weight could not safely perform at the prescribed airspeed. The controller did not. The controller may not have even been aware that the requirement to fly faster than 250 knots is waivable for those aircraft that require it (Aircraft Speed, 1993). Modern Crew Resource Management relies on the collaboration between those not only in the company, but also air traffic controllers and any others involved in the flight (Kanki, Helmreich & Anca, 2010). Like the previous contemporary incident regarding the weight dispatchers, two of the agents involved were understanding present risk in two different ways. Thusly the risk in this situation sprouted from a lack of shared and disseminated risk information.

Notably, one study done of 28,000 ASRS reports found that 70% of all reports fell into the category of communication issues: "the most common findings showed that information was not transferred because (1) the person who had the information did not think it necessary to transfer it or (2) that the information was transferred, but inaccurately." (Billings & Cheney, 1981, p. 2) Reason (1) is extremely relevant to the scope of this paper. A lack of transfer due to the controller thinking the information is not important is, itself, an incorrect risk analysis that caused information not to be disseminated.

Techniques have been introduced by industry experts to increase the awareness of unidentified hazards in aviation operations. At the proceedings of The International Congress on Aeronautical Sciences (N.d.), a method was devised where a group of experts are brought together for brainstorming with a moderator present (who is themselves a safety expert), after which the group decides by individual vote which hazards should be looked into. The idea is that a company could cut down on any unimagined risk through brainstorming. Techniques such as these could prove valuable to an organization in proactively finding faults in any system devised. Similar programs have taken hold at air carriers through using a Safety Management System, which as discussed earlier, has become industry standard. These systems use a circular flow to mitigating risk. Step one is straightforward: find the risk. In the case of flight 405, while contamination risk was documented by previous Advisory circulars and FAA regulations, the crew was not sufficiently up-to-date on understanding of it. This was due to a failure of step two and beyond in the safety management flow: analysis and implementation.

An emerging realm of aviation presents new challenges regarding risk dissemination. Part 107 of 14 Code of Federal Regulations (CFR) provides for the commercial use of drones and takes the place of what was previously called the Section 333 exemption in the 14 CFR. Drone pilots, under the regulation, must at a minimum undergo online training but are not required to be manned aircraft pilots (Small Unmanned Aircraft Systems, 2016). This introduces the issue of drone pilots lacking aviation knowledge that can be passed on through a flight instructor as manned pilots have. One particular ASRS report mentions a near miss by a drone pilot. The drone pilot is thorough in his or her planning but nonetheless encounters another aircraft:

> I was operating a drone under Part 107 collecting aerial photographs. . . I had filed a UAS operating area report with Flight Services in an effort to warn air traffic . . .[including] the altitude I would be at, and the exact times of operation. We also had a hand held [radio] turned on and operating. . . A visual observer was also on site and fully briefed. . . The visual observer yelled out an aircraft

> sighting . . . and [I] saw a Cessna 172 flying at approximately the same altitude as the drone on what appeared to be a collision course approximately .4-.25 miles from the drones position. The Cessna pilot did not seem to see the drone, he was operating at or below 500 ft in my estimation, and was obscured from view . . . There needs to be a better way to freely communicate drone activities with pilots and more emphasis given to pilots to check UAS operating areas before they fly, especially when flying below or near 400 ft AGL. (NASA, 2016, No. 1410141)

In this case, a unique threat occurs in that see-and-avoid techniques become more difficult from both the drone pilot's as well as the manned pilot's perspective. For the manned pilot, consumer drones used for videography often weigh only a few pounds and measure approximately one foot across, making it significantly more difficult to spot. For the drone pilot, there is a comparably much lower line of sight that she or he is able to view traffic through. While the drone operator here did their due diligence on the ground, the manned pilot apparently did not know of the UAS operating area which was, in contrast, well known to flight service. Had the Cessna pilot known about the drone operations, the pilot would have been able to use other services such as contacting the drone operator on the aviation radio to maintain awareness of its position. Meanwhile the drone operator did not know of low level flying occurring in the area. This all suggests that there are new opportunities for researching information sharing regarding the interaction of drones and manned aircraft. More broadly it harkens to the original accident analyzed due to the confusion on parts of both operators. The near-miss highlights the disconnect between Flight Service, the operator on the ground, and the pilots in the air.

Operations manuals, both company and aircraft, played a critical point of investigation for the NTSB regarding USAir 405. In this next incident analysis, one airline pilot submitted an ASRS report alerting the company about a section in the aircraft operating manual regarding freezing rain:

> For the record, I have NEVER seen more conflicting confusion information on a topic of such importance. It needs to be clear and concise. Easy to follow along and easier to understand. The entire winter ops ...ice ...cold weather section is NOT any of this.
>
> Also, and probably more importantly, every time something is updated in any of our manuals on the iPad, you basically have NO idea what was changed/modified/deleted. It is now impossible to keep track of important safety of flight information. In the "old days" we could make and keep notes in the margin and review changes. (NASA, No. 1407973)

This report is eerily similar in many ways to what was found in the aftermath of 405. While the author of this report does not specifically mention what was missing in the manual regarding freezing rain, he or she implies that it was critical to the safety of flight. The pilot later mentions even asking a dispatcher friend of theirs if they have heard of the specific aircraft restriction in that type of weather, and he or she replied that they did not. The company's solution was to add a note onto dispatch releases in certain weather which clarified the information. As noted by the pilot, the iPad (or more generally, electronic flight bags [EFBs]) introduces benefits, but also new risks. The technology could have the ability to disseminate risk information and assessment more easily to entire companies, but in this pilot's judgement it was not doing so properly. This is acknowledged in the conclusions of Billings and Cheney (1981) regarding dissemination of information. As technological solutions are introduced, they state, it "may give rise to serious new problems unless they are implemented with an understanding of the capabilities and limitations of the humans who operate [them]" (p. 13).

Following this trend, a notable incident report occurred when a CRJ-200[10] pilot, after arriving at the destination, noticed ground handlers unloading ballast bricks from the cargo hold. The pilot however did not notice said ballast listed on the weight and balance dispatch form before the flight. Upon conversing with ground supervisors, it was confirmed that these were not accounted for before departure. The captain summarily noted, "anyone involved in ANY part of the loading process should have a box to sign or initial on the Cargo Load Report AFTER reviewing it and ensuring that ALL information is correct." (NASA, No. 1379603) A consistency in this report as it relates to both USAir 405 and the previous reports is that there is a breakdown in the line of communication between crew and others. Interestingly, a technology introduced to attempt to fix the solution may have caused another problem. "The scanners used by ramp personnel seem to be very useful for maintaining an accurate bag count. However, there is no way to scan a brick of ballast as it ascends the belt loader. Ramp crew must rely on their fingers and toes to keep an accurate count. Perhaps a generic bar code could be added to each ballast brick so that it may be scanned and counted electronically before being transferred to the Cargo Load Report." It might be that as the ramp crew were typically relying on the automated bag scanner, complacency was introduced for other, non-typical items such as ballast.

Conclusion

As shown, NASA ASRS reports have proven incredibly useful in studying risks in aviation since they are focused on the actual day to day operations of pilots. Systems such as these should continue to be utilized and refined, and combined with systems that can analyze them effectively to prevent future problems or incidents. A notable limitation of ASRS reports is that they are not able to be directly linked to audio recordings (or if they are, that aspect is not analyzed by NASA themselves). Analysis of actual audio files or transcripts could be valuable in studying this type of communications error due to the reports themselves being biased by reporter viewpoints (Kanki et al., 2010). However, dissemination of information through controller interactions is only one of the issues mentioned in this paper. In a wider scope, SMS utilized by companies should include analyses to ensure that "hypothetical" company operations (i.e. the recommendations and guidance published in manuals) is in line with how companies operate in reality (e.g. during line flights and the everyday work of employees). Typically, normalization of deviance is characterized as the habit of a maverick that is uninterested in safety. USAir and its safety-minded crew showed otherwise. Normalization of deviance rather seems to occur particularly when company policy is lacking in some manner.

Before implementation, I recommend that policies be scrutinized by companies and put into testing and feedback processes. Since the implementation of holdover times and deicing pads, the accident of USAir 405, which took twenty-seven lives, has not been in vain. This was

[10] The CRJ200 (Canadair Regional Jet) is a twin-engine regional jet capable of carrying 40-50 passengers.

unfortunately due mainly to a retroactive effort. Aviation accidents have the ability to highlight the lacking aspects of aviation safety, but they do not have to occur before issues are solved.

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Literature Review

Alternative Energy Sources for Aviation- Literature Review

Christina Hiers

Middle Tennessee State University, Unites States

In the current market, growth is inevitable. Fuel and aircraft sales are increasing and the Federal Aviation Administration is creating a new market called Business Aviation. Business Aviation is opening doors for organizations that previously used roads or airlines for travel. Since 9/11 the aviation industry partnered with the government to create and implement security measures to prevent future terrorist threats. This improved the social aspect of aviation, as people are not as afraid of flying as they once were.

Sustainability

Sustainability is the economic development that meets the needs of the present generation without compromising the future (Epstein, 2008). This includes corporate social responsibility, citizenship, and improved management of social and environment impacts (Epstein, 2008). By improving the sustainability of an organization, leaders are able to increase the benefits for stakeholders in the future by ensuring resources for continuance. The current state of sustainability shows signs of improvement in the future.

The aviation industry faces severe environmental opposition. Organizations criticize the aviation industry for CO emissions it emits. However, the aviation industry only contributes 2 percent to the global emissions. Below, Figure 1 shows the Contributors to Global Emissions. The largest contributors in order are the Energy Supply, Industry, Forestry, Agriculture, and then Transportation at 13 percent. Of the 13 percent the transportation sector, the aviation industry only makes of 2 percent of the global emissions, road travel makes up 10 percent (Owen, Lee, & Lim, 2010).

In the aviation industry, leaders are working to create drop-in fuels that are plant based in order to not become dependent on oil for fuel supplies. Drop-in fuel is a fuel alternative that is added to jet fuel, as much as 50 percent add-in, and is interchangeable in jet engines (Abeyratne, 2010). The problem with the current drop-in fuel is the alternative is two to five times more expensive than jet fuel (Abeyratne, 2010).

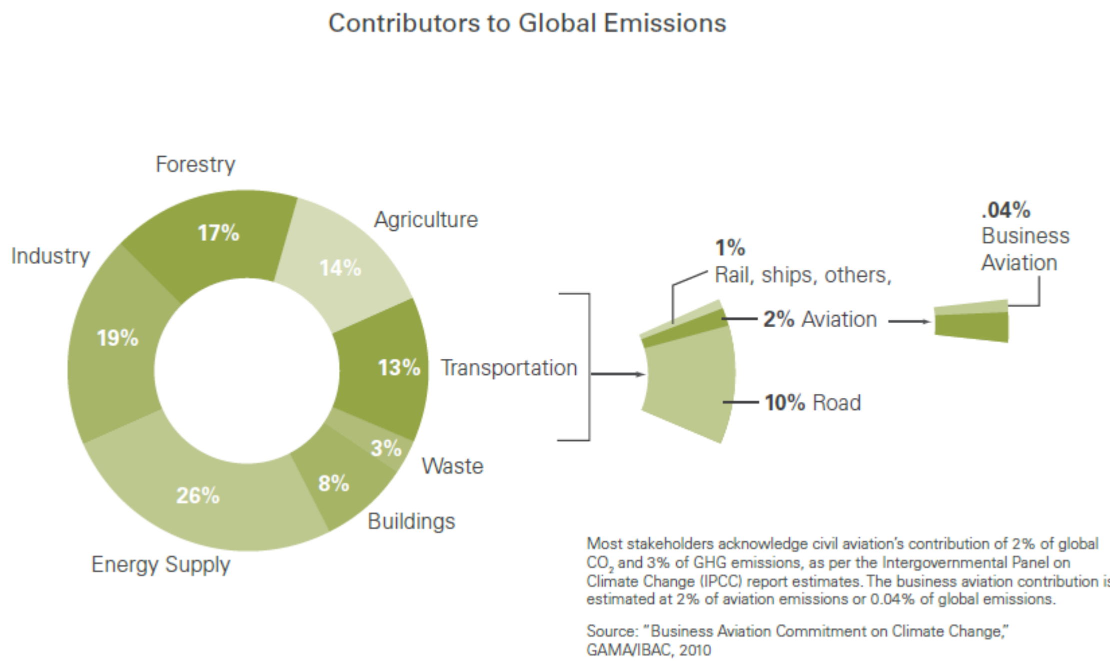

Figure 1. Contributors to Global Emissions "Business Aviation Commitment on Climate Change" GAMA/IBAC, 2010. (NBAA, 2010)

Fossil energy resources could meet this requirement through burning coal. This means CO_2 emissions in the atmosphere would need to accommodate twice their pre-anthropogenic values by 2050 using present technology (Brinker, & Ginger, 2011). This would suggest not only a negative impact on the climate, but also significant world competition for these limited resources. Energy price increases would make energy intensive commodities like fertilizer or manufacture of steel and metals expensive to produce and sell. This would be a geopolitical problem and maintain social consequences, making energy an issue of national security in the future (Brinker, & Ginger, 2011).

Scientists are working to develop energy production methods that produce fewer carbon emissions than previous methods. These methods involve more efficient production methods, recycling or reusing materials, biofuels, alternative sources of energy, and energy storage methods (Tonn, 2008; Tillman, 2009). These methods might give organizations a more sustainable future than current methods.

Scientists predicted global energy consumptions to increase 40 % of the present value in the next 20 years, and double by 2050 (Brinker, & Ginger, 2011). In 2006, President George Bush declared that biofuels were the answer to the worldwide dependence on oil (California Agriculture, 2009). Corn-made ethanol seemed to be the key to the biofuel question. Shortly there after, grain prices increased. Again, scientists must look for a sustainable biofuel. Scientists projected the human population to increase from 7 billion people in 2008 to 9 billion people by 2050; additionally it is difficult to see how the transportation industry could handle an increase in energy consumption and costs (California Agriculture, 2009).

Since the 1980s, organizations have been looking towards the future in terms of sustainability. Leaders recognized the need to provide stakeholders with useful options for the future. In 2005, Hurricane Katrina hit the New Orleans area causing an energy shortage in the United States through the effects of the oil production sites in the area (California Agriculture, 2009). In the United States, leaders are in a regular political debate over the dependence on other countries for oil production and consumption (U.S. Department of Energy, 2010). Government organizations and private sector organizations look for biomass possibilities for sustainable fuel alternatives.

Corporate sustainability is a business approach to establish long-term shareholder value by implementation of opportunities and managing risks from economic, environmental, and social issues (Makipere, & Yip, 2008). Leaders must force organizational wide sustainability efforts in order to achieve progress. The four challenges facing this pressure are the nature of the industry's product, the level of energy consumption, the human capital needed for success, and the size of the company within the industry (Makipere, & Yip, 2008). Makipere and Yip (2008) suggested leaders turn these challenges around into incentives. If products are not environmentally friendly, soon customers will discontinue purchasing those products, instead, companies need to search for environmentally friendly products (Makipere, & Yip, 2008). Many companies such as steel production have high-energy consumption, thus all the more reason to search for an alternative source of energy. Many organizations struggle to find and retain top-level knowledgeable employees, by making the organization more sustainable and environmentally friendly, employee moral will be higher, and employees will enjoy their jobs (Makipere, & Yip, 2008). In the study by Makipere and Yip (2008), the only two industries that showed a correlation between company size and its success in environmental and social sustainability were pharmaceuticals and automobile industries. This research suggested that corporate sustainability should be achievable in most industries in companies of all sizes (Makipere, & Yip, 2008).

Current Theories

In order for organizations to promote sustainability in the future, they must examine energy alternatives. Currently scientists are working in the fields of biofuels, recycling, technology for energy storage, and alternative sources of energy. Currently, all of these fields require more research and engineering before they will become worthy alternative forms of energy.

Biofuels

Biofuel production could reduce the United States' dependence on foreign oil. Biofuels are alternate energy sources derived from plant materials and of other types of biomass (Tillman, 2009). Biofuels came into prominent existence as a homegrown alternative to petroleum. Biofuels have seen criticisms and praises. Scientists are investigating the use of energy created from municipal and industrial wastes for biofuel production (Tillman, 2009).

Recycling

Recycling is a form of reusing products that are more efficient than producing more products. Recycling or reusing products, such as newspapers, aluminum cans, and plastic containers, can reduce products going into the waste streams, thus reducing emissions (Tonn, 2008). Scientists found ways of converting urban and industrial wastes to produce liquid fuels for other energy applications (Tillman, 2009).

Currently, organizations look towards more efficient production methods to use fewer resources, and produce fewer wastes (E.E., 2012). Many organizations are finding ways to recycle or reuse materials such as recycling cardboard shipping containers and wooden pallets. A group of researchers developed a method of using mixed recycled aggregate from nonselected construction and demolition waste (CDW) in rural road construction (Agrela, Ayuso, Galvin, Jimenez, & Lopez, 2012). They found that using the CDW versus limestone had similar structure. They subjected both roads to various tests, and the road made of CDW had the same results as the road with limestone aggregate (Agrela et al., 2012).

Energy Storage

A research team from Drexel University in the College of Engineering developed a new way of quickly and efficiently storing large amounts of electrical energy (E.E., 2012). Energy companies can produce energy during times of reduced usage such as during the night time when families and industries are not working. The electrical energy can be stored and put into use when offices, schools, and businesses open and increase the demand for electricity (E.E., 2012). The researchers created a plan to incorporate an electrochemical storage system that combines principles of the flow of batteries and super capacitors to store electrical power. These researchers could implement this strategy into the grid of mainstream communities (E.E., 2012).

Alternative Energy Sources

Scientists are working on creating new technology that would allow extensive production of biofuels with fewer negative impacts than previous technologies (Tillman, 2009). Evans, Strezov, and Evans (2009) examined the different alternative energy sources including coal, nuclear power, hydropower, geothermal, wind, and photovoltaics. Evans, Strezov, and Evans (2009) evaluated sources of energy using the factors: technology cost of generated electricity, greenhouse gas emission, availability of renewable sources, and efficiency of energy conversion, land requirements, water consumption, and social impacts. These authors concluded that solar power was the best present available source of sustainable energy (Evans, Strezov, & Evans, 2009).

Currently there are benefits and drawbacks to every method. Wind required the smallest land use, and little social impact but did not provide much energy compared to other methods (Evans, Strezov, & Evans, 2009). Solar Power was the first in terms of power created, land usage, and resources used for energy supplied (Evans, Strezov, & Evans, 2009). In addition, solar energy has little social impact (Evans, Strezov, & Evans, 2009). Corn-based biofuels required large amounts of resources and land use (Evans, Strezov, & Evans, 2009). Biofuels in their present situation are expensive and require massive amounts of land and resources for production (Evans, Strezov, & Evans, 2009). In 2012, drought conditions in the midwest of the United States (US) limited the creation of corn, one of the major biofuels (California Agriculture, 2009). For a fuel or oil alternative, biofuels still need further research and development (California Agriculture, 2009). Scientists found that organizations could easily obtain, store, and utilize solar energy or photovoltaics to a grid system. Organizations are testing solar cells in the housing and office building markets. Solar cells require optimized space to transform solar light into electrical energy (Tonn, 2008). Leaders are considering land buffers, such as near airports for possible sites for solar arrays.

Impacts

Industries that require large amounts of fuel such as the transportation industry would see the greatest reduction in emissions and efficiency. Automobiles are being made more energy efficient with the use of alternatives fuels such as electrical or hybrid power (Tonn, 2008). Vehicles are improving aerodynamics to decrease energy consumption on the highways.

Many organizations, homeowners, and businesses already use solar technology to reduce emissions and energy costs. Organizations could study and implement energy storage using methods such as solar power to increase sustainability. A storage system combined with solar technology could create self-sustaining energy (Tonn, 2008).

All of the energy sources have benefits and drawbacks. Biofuels have high land and resource utilization. Solar energy has high costs of implementation. Energy storage has high costs of implementation. The overall problem with sustainable energy alternatives is costs (Orecchini, Santiangeli, Valitutti, 2011). In seven to ten years, solar power could cost the same to customers in markets like California and Italy as electricity generated by fossil fuels (Lorenz, Pinner, & Seitz, 2008).

Burning of coal and fossil fuels is presently widely used because of reasonable costs and quantities of resources (Orecchini, Santiangeli, Valitutti, 2011). However, this common practice creates high amounts of emissions and greenhouse gasses. Global consumption is rising, while organizations and nations look for a more sustainable solution (Brinker, & Ginger, 2011). If organizations do not make the change to a cleaner form of energy, customers will purchase from more environmentally friendly organizations like those in the United Kingdom or other countries (Gibbs, 2009).

Future Directions

Two thirds of the U.S. oil supply comes from other countries; the transportation industry uses 60% of this supply (U.S. Department of Energy, 2010). With the rise in the energy demand, competition for the world's petroleum rises. The U.S. Department of Energy is developing advanced alga biofuels from use in the aviation and transportation industry. The benefits of algal biofuels include high field efficiency, minimized competition with traditional agriculture, uses a small amount of water from a wide range of water sources, and it recycles stationary emissions of carbon dioxide (U.S. Department of Energy, 2010).

Solar power is a growing industry. By 2020, global capacity of solar power could be 20 to 40 times its level today (Lorenz, Pinner, & Seitz, 2008). With the projected growth in solar energy, this would represent only 3 to 6% of installed electricity (Lorenz, Pinner, & Seitz, 2008). Solar power could help to reduce emissions, create sustainability, and satisfy the need for more electricity (Lorenz, Pinner, & Seitz, 2008). The technology still requires more research for further development and implementation.

Biofuel production typically requires large areas of land and large quantities of water. The United States government and the Department of Energy are working on creating biofuels from alga (U.S. Department of Energy, 2010). Converting alga to biofuels requires harvesting the alga or removing the water to make a higher concentration of the alga. Conversion, extraction, and processing the alga have different products. These different products have different applications. Extracting the lipids or fatty acids from the alga is the most difficult part of the production (U.S. Department of Energy, 2010). Scientists are working to develop a secure method for removal or an alternative method of harvesting the alga. Using alga versus other crops for biofuel performance is promising due to the high yields of gallons of oil produced by the mass (U.S. Department of Energy, 2010). Alga harvests also do not require as much land or water use as other crops. An alga-based biofuel could have an impact in the transportation industry and produce fewer emissions.

Potential Impacts

One industry that uses the largest amount of fuel is the aviation and travel industry (U.S. Department of Energy, 2010). The leaders of the Federal Aviation Administration (FAA) and the leaders of the Department of Energy (DOE) move towards technology development and standardization to reduce operation costs and increase the general aviation market (U.S. Department of Energy, 2010). In 2010, the government began an eight-year funding plan concentrating aviation fuel (U.S. Department of Energy, 2010). The aviation industry matched the eight-year funding for development (U.S. Department of Energy, 2010).

The U.S. Department of Energy currently has many applications for construction of biofuels and bioproducts from biomass (2010). The most promising alternative energy methods are advanced-biofuels including high energy density fuels for ground and aviation transportation. The alga biomass offers significant advantages for these fuel applications (U.S. Department of Energy, 2010). Developers need partnerships with experts in the aviation and transportation fields across the value chain to ensure the proper specifications of these biofuel productions, and address technical and nontechnical needs (U.S. Department of Energy, 2010).

Several organizations demonstrated that it is possible and worthwhile to pursue the goal of becoming a completely sustainable organization (Mirchandani, & Ikerd, 2008). In today's current environment, organizations look for sustainable alternatives. The best alternatives on the market today are recycling, or reusing materials, reducing costs through energy consumption, and researching new and future technologies for alternate energy sources (Meadows, 2009). Corn based biofuels in their current state are not effective for industries like the transportation industry; however, scientists are working to develop better methods of producing biofuels (Meadows, 2009).

Conclusion

The future of aviation is in sustainability. To reduce energy costs and emissions, organizations could invest in solar technology or photovoltaics. Alga biofuels offer a sustainable alternative in the future of transportation and aviation. Recycling is another way for aviation companies to reduce consumption and plan for a sustainable future.

About the Author

Dr. Christina Hiers teaches in the Aerospace Department at Middle Tennessee University. She has 8 years of experience in various Aviation Management positions. Her research interest include Alternative Energy Sources for Aviation, Leadership and Innovation in Aviation, and Small Aviation Business Management. Dr. Hiers received her Doctor of Business Administration with a focus in Leadership from Walden University in 2016.

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