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COLLEGIATE AVIATION REVIEW

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David C. Ison, Editor

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

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STATEMENT OF OBJECTIVES

The *Collegiate Aviation Review* is published semi-annually by the University Aviation Association. Papers published in this volume were selected from submissions that were subjected to a blind peer review process, for presentation at the 2013 Fall Education Conference of the Association.

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

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

> To encourage and promote the attainment of the highest standards in aviation education at the college level.
>
> To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignments, and other professional contributions that stimulate and develop aviation education.
>
> To furnish a national vehicle for the dissemination of knowledge relative to aviation among institutions of higher education 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 in the aviation and aerospace fields.

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Call for Papers

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

Authors should e-mail their manuscript, in Microsoft Word format, to the editor at CARjournal@uaa.aero no later than July 1 (Fall 2014 issue) or December 31 (Spring 2014 issue).

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

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

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

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

Call for Reviewers

The *CAR* is currently soliciting requests to join our reviewer panel. If you are interested in being a reviewer, please send an email to david.ison@erau.edu. Include your resume and list of recent publications. Also describe why you wish to be a reviewer and what you would like to contribute to the journal.

Editor’s Commentary

“We are what we repeatedly do. Excellence then, is not an act, but a habit” – Aristotle

Yet again the *CAR* had an excellent number of quality submissions. I applaud the faculty that have taken the time and effort to submit to the *CAR*. And kudos goes to those that have had their work accepted. For those who did not have their work accepted, do not give up. If you have never had a submission turned away, you either are not submitting enough articles or this is your first time writing. The peer-reviewed world is tough. The key is to keep trying. Please resubmit your work again. We need your labors to improve aviation research.

“If you really want something, and really work hard, and take advantage of opportunities, and never give up, you will find a way” – Jane Goodall

The *CAR* has come a long way over the past few years. I believe that the research we are publishing today is providing quality scholarly work to the aviation community. We had another record number of submissions and articles are already being received for the Spring edition. The publication rate for this issue was 60%, which is higher than most academic journals, yet I believe that the editorial staff and the reviewers performed as necessary to insure that only the highest quality of articles were accepted. Thank you to all reviewers for their time and hard work.

There are some changes that are taking place with the *CAR*. First, you will notice that we are now publishing commentary/position papers as well as book reviews. I hope you enjoy these. I would encourage submissions in these categories as well as any feedback you may have on these works. Second, we will be migrating to a rolling review process. In the past, articles were not sent out for review until close to the publication date. In the near future, reviews will be requested as articles are submitted. This process will begin after October of 2013. I hope that this will improve the response time for authors so they can plan accordingly.

As a reminder, the *CAR* now also accepts methodological papers, reviews of statistical analysis, pilot studies, and more – basically, we are now more flexible about submissions. Do not hesitate to contact me about ideas you may have.

Lastly, thank you again to all authors, reviews, and participants. There would not be a *CAR* without you. Cheers – David Ison, PhD, Editor

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Position Paper

How Can Higher Education Best Support UAS Growth in America?

Dr. Brent A. Terwilliger
UAS Discipline Chair
Embry-Riddle Aeronautical University-Worldwide

When considering how academia can assist with the domestic growth of unmanned aerial systems (UAS), including integration of UAS in the National Airspace System (NAS); it is necessary to consider what primary users and developers have said already. The National Aeronautics and Space Administration (NASA) and Department of Defense (DoD) have been long standing proponents of unmanned aircraft technology and operations, recognizing the value for research, information gathering, communications, and warfare (DoD, 2011a; DoD, 2011b; NASA, 2013; NASA, 2011b). From use in environmental protection to improving the effectiveness of agriculture (e.g., precision agriculture), the impacts and implications of this technology have been and will continue to be far reaching (AUVSI, 2013; GAO, 2013; NASA, 2011b).

NASA has identified several key challenges with integration into the NAS, including ensuring safe separation in airspace; providing secure and scalable command and control; using robust and certified pilot control interfaces; and providing standardized safety certifications/regulations (Walker, 2012). The DoD recommends three MUSTs as part of the strategy for UAS integration: a) aircraft must be certified as airworthy, b) pilots must be qualified to operate in appropriate classes of airspace, and c) flight operations must be in compliance with applicable regulatory guidance (DoD, 2011a). Ensuring successful integration will require the development of new technologies, processes, and regulations (Walker, 2012).

The worldwide UAS market is expected to reach $89 billion in the next ten years, with 62% of the anticipated R&D being performed in the US with an approximate value of $28.5 billion for the same period (GAO, 2013). Academia represents a major stakeholder, a third leg in a stool, with the others being Government and industry. As the educators of tomorrow’s innovators, researchers, operators, and maintainers, it is imperative that we support and encourage clear communication among the three parties. Having a comprehensive and shared view of our needs will provide a path forward for defining an effective and rewarding UAS curriculum, while ensuring the growing capabilities and needs of the other stakeholders are fulfilled.

The first aspect of academic involvement is use of academic and educational institutions in the performance of research and development (R&D) to identify new and novel solutions to UAS challenges. Our students bring new thoughts, perspectives, and creative energy to problem solving. It may be possible to realize and affect significant change if we leverage our diverse networks of colleagues, faculty, students, alumni, and partners (i.e. industry and Government) to identify innovative solutions or advances for UAS technologies, processes, and regulations.

Secondly, all the stakeholders need to work together to educate the public and lawmakers on what UAS truly are, their intended uses, and typical system capabilities and limitations. Encouraging community outreach (e.g., science, technology, engineering, and mathematics [STEM]), publication and presentation of R&D results, and maintaining currency on the latest regulatory and certification activities may prevent unnecessarily restrictive legislation (e.g., privacy and usage). As the DoD has recommended, we need to "engage as one" (DoD, 2011, p. 3). By working collectively in the same direction we can reach a broader audience to convey the benefits of this technology, while continuing to serve as stewards of our respective domains (i.e., education, service, and economic endeavor).

The third aspect is identifying what "our" individual needs are. For example, "the FAA expects small UAS (sUAS) to experience the greatest near-term growth in civil and commercial operations because of their versatility and relatively low initial cost and operating expenses" (FAA, 2011, p. 3). The low-cost, expedient assembly, and simplicity of operation are just a few of the traits desirable to researchers and users (Chao, Jensen, Han, Chen, & McKee, 2009; NASA, 2011a; Spigelmire & Baxter, 2013). To realize the full potential of sUAS as tools for academia, we need to establish and fully understand an operational framework supporting R&D, training, and education opportunities. Such activities will ensure the US maintains a leadership role in UAS innovation, now and into the future.

Finally, there is an increasing disparity between the "growing UAS fleet" (Chesebro, n.d., p. 8) and the development of the requisite infrastructure to support their use. This discontinuity is present in the areas of "training; service, support and maintenance; and data management" (Chesebro, n.d., p.8) and must be addressed and overcome if the industry is to reach its full projected potential (GAO, 2013). Focus could be placed on Governmental policy changes, achieving stakeholder alignment, and educational curriculum development to start to address this continuously expanding gap. Ensuring clear paths for communication and collaboration, among all the stakeholders, will facilitate the efficient and meaningful exchange of ideas, experience, and knowledge to address or prevent such shortcomings in the future.

Through considered and collaborative responses, the challenges in the domestic UAS domain can be surmounted or overcome. Involving and engaging all stakeholders, providing a collaborative framework for R&D, ensuring access to airspace is routine and available, and educating the public and policymakers will result in in an environment that fosters the technological and monetary growth expected from this field. As educators, it is our responsibility to add to the body of knowledge for our domains, contribute to our communities, serve as stewards of trust, and work collaboratively to educate and share our experience and knowledge. Only by working together, collectively as stakeholders with our varying areas of expertise, can we address and rise up to meet the challenges set before us.

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Book Review

Review of *Safety and Quality in Medical Transport Systems,* John W. Overton, Jr. and Eileen Frazer (Eds.)

Victor Ujimoto
University of Western Ontario

The editors of this book have made an important contribution to the study of safety and quality in medical transportation systems. They provide an integrative framework that examines the safety culture of an organization. The key strength of this book becomes immediately obvious by the well-organized introduction and the articles selected for each section.

In Section I, the editors address the characteristics of organizations "that foster clarity about purpose, vision, and goals." In Chapter 1, "A Brief Overview of the Foundations of Organizational Culture," Ralph N. Rogers discusses the importance of a strong culture in the success of any safety performance and quality management system. Organizational values, beliefs, and objectives must be thoroughly understood by members of an organization to develop a strong organizational culture.

In order to address this, the editors skillfully introduce the concepts of a "Just Culture" in Chapter 2, "Achieving Optimal Outcomes Through Just Culture" by K. Scott Griffith. Griffith describes the spectrum of culture from "blame-free" to "highly punitive" that will be "a key in determining an organizational ability to identify and mitigate risk." He discusses various behaviors that are essential to risk management.

In Chapter 3, Terry L. von Thaden differentiates "Safety Climate and Safety Culture" from a sociotechnical perspective. He observes that definitions of a "safety climate" include a psychological phenomenon that is "closely concerned with intangible issues such as situational, environmental, and personal factors, and that it is a temporary phenomenon." In contrast, a safety culture refers to "shared values among all the group or organization members. It is situational and describes the perceived state of safety."

Von Thaden discusses the key elements of a safety culture such as: organizational commitment, operations interactions, formal safety indicators, informal safety indicators, and safety outcomes. An interesting contribution by von Thaden is his "Safety Culture Grid" or "Safety Culture Matrix" which is a method of assessment that demonstrates the interrelationships among the organizational safety factors such as alignment gaps, leadership perception, employee perception, and degree of collaboration. The culture matrix is most useful for characterizing an organization's safety culture in terms of "consistency, direction, and concurrence." He provides an example of his matrix that compares safety culture across several aeromedical transport operations.

In order to adequately address all the key elements noted to enhance safety and quality in medical transport systems, financial and human resources must be considered and provided. Senior management decision makers very seldom have the luxury to consider the long-term financial and human resources required to provide continuous safety education and skills training. Chapter 4, “The Financial Perspectives of Safety” by Clive Adams examines the role of senior management in the development of robust safety systems that is resilient and able to adjust to changing operational conditions. Thus, safety management effectively becomes a part of the risk management process. Because of a lack of a precise measure of safety effectiveness, it is often difficult for management to appreciate that allocation of resources to safety is a very wise investment. Adams argues that direct insured costs are quite miniscule when compared to the indirect costs of an injured worker, loss of life, and time lost by management and others in investigating an accident that may occur because of a lack of allocation of resources to safety education and skills training.

Section II of the book provides both air and ground perspectives on medical transport operations. First, a general overview of the background and evolution of the various sectors of the air medical transportation system is presented. Second, this is followed by an overview of the ground medical transport system. In Chapter 5, Terry L. von Thaden outlines “The Current Status of Air Medical Transport.” He examines the differences in the development of rotor wing and fixed wing services in the U.S. and in Europe. Differences in critical medical situations under various environmental and regulatory conditions are presented. Von Thaden concludes by noting some of the major challenges in air medical operations today: professionalism and ethics, properly trained personnel, aircraft design, and equipment maintenance/upgrade consideration.

In Chapter 6, ”The Current Status of Ground Medical Transport,” Nadine Levick addresses issues associated with changing the culture of general operational personnel. It is puzzling to learn that “ground ambulance vehicles are exempt from the Federal Motor Carrier Safety Administration (FMCSA) that governs other commercial vehicles.” Levick also notes that ground ambulance vehicles are also exempt from the Federal Motor Vehicle Safety Standards (FMVSS). Other areas that require immediate attention is the fact that health care providers “do not have training in automotive safety and automotive engineering design.” Furthermore, the ambulance manufacturing industry is “grounded outside mainstream automotive safety and occupational protection….. and also not part of the automotive crash worthiness infrastructure.” Thus, general ambulance transport lacks both safety standards and safety oversight. Levick provides key initiatives to optimize safety through safety education, risk management, fleet safety standards, Emergency Medical Services (EMS) practice, policy and fleet management. She discusses safety enhancements later in Chapter 13.

Section III consists of specific chapters that offer in greater detail the various topics noted earlier in improving safety and quality in Emergency Medical Services Transport Systems. In Chapter 7, “An Overview of the Risk-Management Process,” Kimberley Turner argues that a risk-management process provides the requisite framework for safety and quality enhancement in medical transport systems. She notes three different types of risks: uncertainty-based risk, opportunity-based risk, and hazard-based risk and discusses the importance of communication, the context, risk treatment, and monitoring and review of the risk management process.

In Chapter 8, “Safety Management Systems,” Kimberley Turner elaborates on improving safety and quality. She introduces the principle of continuous improvement or “kaizen” and describes the evolution of Safety Management Systems (SMS). The four pillars of SMS as defined by ICAO are safety policy and objectives, safety risk management, safety awareness, and safety promotion. The strength of this chapter is the emphasis on the development of an Integrated Risk and Safety Management Model (IRMSW).

Chapter 9, “Operations Safety: Developing, Executing and Upgrading the Operations Plan” by Bruce A. Tesmer focuses on how an operations safety plan is accomplished “in terms of the sequence of tasks and milestones, timeline, initial risk assessment and risk reduction.” Tesmer describes basic operations protocols, namely philosophies, policies, and procedures. By employing a typical airline flight plan timeline, the operations specifications are developed in an easy to follow manner. Threat and error management and human factors considerations are included to improve the initial operations plan. Based on his considerable experience at a major U.S. airline, Tesmer emphasizes important procedures to “verbalize, verify, and monitor (VVM) and when to use automation.

The importance of reliable communications in the integration of safety system elements is discussed in Chapter 10, “Improving Communications to Improve Safety” by Robin Graham. Graham describes how to manage sensory data such as stereotyping, the halo effect, and “expectancy and the selective use of information.” Other aspects of communications discussed by Graham are information overload and fixation, non-verbal communication, and various communication options that are available for EMS organizations to enhance effective communication in safety culture and safety management organization.

As noted earlier, education and skills training are important components in improving EMS transport safety and quality. Chapter 11, “Training to Improve Operational Safety” by Terry Palmer, discusses the use of scenario-based simulation training. The concept of Team Resource Management (TRM), an important and integral part of a safety culture, is advanced by Palmer. Concepts briefly noted earlier such as communication, assertiveness, teamwork, leadership, situational awareness, and decision making are all integrated into TRM. He argues that training in TRM is best achieved in an interactional scenario-based simulation environment.

An excellent follow-up to training is Chapter 12, “Operational Safety Training: Learning from the Mistakes of Others” by Roger Coleman. He demonstrates how to make better, safer decisions on aviation operations by learning from the mistakes made by others. Several examples are provided from FAA and NTSB reports. Coleman differentiates between static decision- making, which is based on large amounts of data and analysis, and dynamic decision-making, which is “based on operational risk analysis and real-time decision-making component as the mission is executed.” As Coleman has observed, decision making in time-critical situations is extremely difficult. Although it is essential for each new generation of pilots to learn from the mistakes of previous generations, good decision-making is based on good training and learning from the experience of others.

Key factors for optimizing ground transport safety are discussed by Nadine Levick in Chapter 13, “Adjuncts to Safety in Ground Medical Transport.” In this chapter, Levick notes several areas where improvements in ground medical transport can be made. Examples include the provision of a risk and safety awareness driver training program, development of ambulance design and safety performance standards and the use of Enhanced Vehicle Stabilization Electronic System. Such a system is effective in preventing vehicle rollover and provides greater vehicle control in sharp turns. Other intelligent transport system (ITS) technologies are also noted by Levick.

The rapid expansion in medical knowledge, transport systems, and associated technologies has also resulted in concomitant human errors. In Chapter 14, “Medical Error-Recognition, Reporting, Managing Response, and Limiting Harm” by Gregory H. Botz and John W. Crommett, the authors acknowledge that advances in patient safety have lagged behind medical knowledge and technological development. They address some of the challenges in the identification and reporting of medical errors.

Botz and Crommett note that reliable and accurate data for the frequency and types of medical errors do not exist for some domains of the medical system and that most health-care providers are prone to underestimating medical errors. They identify three types of errors: medical administration errors, failure to employ indicated tests, and avoidable treatment delays. The establishment of medical and transportation checklists is suggested. As in aviation safety reporting, a mandatory national medical error reporting system should be established as it does not exist at present in 2012.

Another important recommendation associated with the development of an error-reporting system is to incorporate educational strategies in the basic health care provider curriculum and training environment. The development of a patient safety education strategy will capture medical errors early and will facilitate reporting of medical errors more acceptable by all healthcare personnel.

Medical and transportation errors are prone to occur when healthcare providers are experiencing stress and fatigue. In Chapter 15, “Fatigue Challenges in Emergency Medical Services Operations,” Melissa M. Mallis explains sleep and circadian physiology. She describes how sleep loss can result in performance degradation and decreased alertness that contribute to fatigue. Mallis provides several fatigue countermeasures to manage the effects of sleepiness and fatigue to maintain performance and alertness levels.

There are two categories of countermeasures: either preventative or operational. Preventative strategies are those taken prior to a scheduled work activity, for example, ample rest and sleep. In contrast, operational strategies are those used during the duty period, for example, taking short naps. In this case, caution must be exercised to judge the duration of the nap to eliminate the effects of sleep inertia. Other strategies noted by Mallis are short activities or disengagement from operational task or taking a caffeine break to reduce sleepiness. Again, caution should be exercised to limit caffeine intake and to use it strategically. When sleep is not operationally possible, another approach is the use of a Fatigue Risk Management System (FRMS) which is currently gaining wide acceptance in aviation. FRMS allows for “continuous measurement, monitoring, mitigation, and management of safety risks associated with fatigue-related error.” In any event, fatigue mitigation education and training are the most effective as a fatigue countermeasure strategy.

In order to provide health care to others, healthcare providers themselves must be in good health. To combat sleep deprivation, fatigue, and stress is basically a personal responsibility. Chapter 16, “Individual Provider Wellness and Self-care” by John W. Overton, Jr., Laurie Shiparski and Philip D. Authier examines the challenges of self-care faced by medical transport personnel and they provide solutions for self-care. They argue that self-care is “not selfish attention but builds the resilience to weather stress and difficult times.” This requires time, energy, and consistent attention to one’s own health. The authors note the benefits of “solitude, silence and mindfulness” for enhancing one’s well-being and they suggest developing a self-care protocol (SCP) for renewing and restoring energy. A self-care protocol centers around four domains of individual needs: physical, intellectual, spiritual and emotional-social. Activities that bring joy and energy to the four domains are encouraged in order to renew and restore one’s energy level.

Regardless of the various fatigue and stress mitigating strategies, exposure to continued adverse situations will have a cumulative effect. Chapter 17, “Post Traumatic Stress Disorder in Emergency Medical Services” by Eileen Frazer provides an excellent overview of the history and recognition of post-traumatic stress disorder (PTSD). She describes the various symptoms of PTSD which range from sleepiness, nightmares, grief, and eventually depression. Physical signs that accompany the various symptoms are headaches and irregular heartbeats. Initial PTSD symptoms may become more severe "including chronic irritability, feelings of constantly being under threat, overeating, alcohol abuse, and perhaps dependency on tranquilizers or painkillers."

Frazer describes a true situation experienced by a flight nurse who was involved in an EMS helicopter crash and who went through the PTSD experience. Various phases of a prevention and treatment protocol called "Eye Movement Desensitization and Reprocessing (EMDR) developed by Dr. Francine Shapiro and the "Critical Incident Stress Debriefing (CISD) developed by Mitchell and Everly are briefly discussed by Frazer.

Section IV introduces the methods and tools used to evaluate and assess organizations. This section consists of relatively brief chapters on a step-by-step guide to implementation of individual programs. Chapter 18, "Measurement and Data" by Donna York Clark, Kate Moore and Donald F.E. Stuhlmiller informs several components of program actions when measuring quality. The chapter focuses on data gathering and the quantification of data to measure quality-critical aspects of medical transport. For this assessment, the Deming Cycle quality-improvement model is employed and objective scientific principles are included to evaluate quality.

The pursuit of improvements in quality measurement requires continuous education, training, and learning. Chapter 19, Essentials of Learning and Improvement" by Donna York Clark, Jacqueline Stocking and David F.E. Stuhlmiller focuses on developing education as an initial step to address the learning needs of diverse individuals. The authors concentrate on three domains most effective for meeting behavioral objectives: cognitive, psychomotor, and affective domains. They discuss instructional methods critical to the learning process. Learners today are from many disciplines, age groups, and diverse ethnicity. Thus, both intrinsic and extrinsic motivators and barriers to learning will vary. These factors must be recognized in the educational learning process in order to improve overall knowledge of safety and quality improvements in medical transport systems.

There are several methodologies to measure quality in healthcare organizations. In Chapter 20, "Practical Applications of Methodologies," Jennifer Hardcastle discusses the LEAN Management System and Sandra Kinkade Hutton provides an overview of Six Sigma. The authors then integrate their expert knowledge of Total Quality Management (TQM), LEAN-Six Sigma approaches to maximize organizational safety and productivity in medical transport systems. Key employee motivational factors are considered in the LEAN management process. Reduced variations in the production process, defect reduction, and a strong and engaged leadership are essential components of the quality improvement process. The authors caution us that implementing LEAN involves a cultural shift within the organization. Thus, resistance to cultural change may be a formidable barrier if the process is not introduced with a well-planned design.

For any social and organizational cultural change, it is necessary to secure unqualified support at the outset. In Chapter 21,"Teamwork and Integration," Patricia Corbett outlines the elements for effective teamwork: adequate resources, leadership support, and good communication. All of these topics have been discussed in earlier chapters and thus facilitates the author in advancing her argument for effective teamwork. She focuses on the ability to integrate skills, attitudes, and behavioral knowledge to promote a teamwork culture. Corbett describes those attributes that result in a highly functioning team. The various stages in team development and training are based on her integrative knowledge skills from multiple disciplines.

Section V, the final section of the book, focuses on real world challenges in maintaining a culture of safety in medical transport systems and related services. In Chapter 22, "Organizational Challenges within Medical Transport Services," Eileen Frazer examines "the challenges to provide quality care at a reasonable cost." She discusses the most compelling challenges faced by medical transport personnel. Many of the topics noted in earlier chapters such as medical errors, a non-judgmental culture, fatigue, financial and human resources needs are effectively integrated in this chapter and serves to illustrate the complexities of the medical transport business.

Chapter 23, "The Role of Associations in Safety and Quality" by David M. Mancuso looks at an organization- an association- that does not operate a single aircraft, nor provide any medical care. He presents a historical overview of the role of safety associations that evolved based on mutual concerns during the industrial revolution to establish product quality and safety standards. In addition, such associations were instrumental in research, consensus building systems and processes, education, and the certification and accreditation of various programs. Eventually, the Association of Air Medical Services (AAMS) was established in 1980 to advance safety and quality in air medical and critical care transportation. An important resource that an association provides its members is a network of individuals who have similar interests and challenges to share.

An example of operational safety and culture outside of the medical transport system is instructive and is provided in Chapter 24. "Safety and War-fighting: Taking Action to Shape the Safety Culture of Naval Aviation" by Kenneth P. Neubauer. Issues associated with the changing of naval aviation culture apply to air medical transport as well. Change begins with formal mandatory safety education given by certified Operational Risk Management Instructors. Naval aviation is a high-risk activity, and thus, continuous improvements to shape safety culture are made to reduce the frequency of accidents. Examples of highly effective programs are "the Culture Workshops, Operational Risk Management (ORM), and the Command Safety Climate Assessment Surveys," and the establishment of the Navy’s “superior performance” criteria based on “process auditing, rewards systems, quality assurance, risk management, and command and control.” These components are integrated into the educational structure to effectively shape naval safety culture.

The final chapter of this section, “Ethical Challenges” by David P. Thomson, focuses on the ethical challenges of medical transport and illustrates how ethics intersect with quality, safety, and culture. As argued by Thomson, “without an ethical framework the culture cannot produce a quality product. Ethics is also a necessary ingredient in deciding whether a given situation is safe. If there is no ethical structure it is impossible to determine the risks and benefits that define safety.” He discusses six principles that frame an ethical structure: autonomy, beneficence, non-maleficence, justice, dignity, and truthfulness. Thomson’s elaboration on ethics and quality, ethics and just culture, and ethics and the management of errors provides a forceful analysis and a powerful reminder of the overall integrative framework that this text/reference book succeeds in presenting. The authors of this book and the expert insights of each chapter make a very significant contribution to our understanding of safety and culture in medical transport systems. It is highly recommended as a required text in transportation and related courses.

Peer-Reviewed Research Articles

Characteristics of Pilots Involved in U.S. Air Carrier Accidents Between 1991 and 2010

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Abstract

This study used a case control methodology to analyze and describe the pilot characteristics of major U.S. air carrier accidents between 1991 and 2010. This study applied descriptive statistics and Chi-square for statistical analysis. The major findings of this study indicate that of the 50 accidents analyzed between 1991 and 2010, 96% of the first officers involved in a major U.S. air carrier accident possessed at least 2,000 hours of total flight time. Regarding first officer flight certificates (commercial pilot and ATP), the researchers separated the 1991 - 2010 time period into two time period groups (1991-2000 and 2001-2010).Of the two first officers (4%) with less than 1,500 hours of total flight time, neither was involved in an accident that cited pilot performance as a causal or contributing factor. This finding did not support the notion that a 1,500 hour total flight time requirement will contribute to the safety of air carrier operations conducted under 14 CFR 121. While an ATP certification requirement for first officers will not eliminate the possibility of any future accidents involving commercially certificated first officers, it was not possible to predict whether such a change will contribute to the enhancement of safety for 14 CFR 121 air carrier operations. It is possible there will simply be a redistribution of the number of accidents involving ATP certificated first officers. Results of this study also indicate that crew familiarity (captains and first officers) may have a negative effect on accident rates. The evaluation of captain and first officer cockpit interaction indicated that accident rates were higher in instances of lower crew familiarity in each of the three areas measured; first day of crew pairing, first leg of the day, and during the first pairing together.

Introduction

The demand for air travel in the U.S. grew from 172 million passengers in 1970 to more than 630 million passengers in 2010 (Bureau of Labor Statistics, 2011a; Bureau of Transportation Statistics, 2011a, 2011b, 2011c, 2011d). The Federal Aviation Administration (FAA) has projected the number of passengers to reach "…more-than one billion by 2015, and 1.2 billion by 2020" (Price, 2007).

As a result, the Bureau of Labor Statistics (2011b) has predicted the employment of pilots to grow by 12% between 2008 and 2018. The International Air Transport Association (IATA) has estimated the industry would need 17,000 new pilots annually to meet the industry's projected growth (Kirby, 2007). According to the IATA (2012), if nothing is done, this will translate into a world-wide shortage of approximately 42,000 pilots by 2020 (ATP Flight School, 2013). "Experts estimate that from now until 2025, airlines around the world will need to hire more than 300,000 new pilots to fly all the new jets – about 19,000 – expected to join the fleet by then; and replace retirees and others who leave" (Kaur, 2007).

While demand for air travel has steadily increased over the past several decades, the total number of pilots certified for commercial operations has remained relatively stable when both groups of Airline Transport Pilot (ATP) and commercial certificate holders are combined. While there has been an overall increase in the total number of ATP certificated pilots, the overall number of commercially certificated pilots has decreased (FAA, 2011a, 2011b).

New Pilot Certification Requirements for U.S. Air Carriers

In 2009, following the crash of a Colgan Air DHC-8, legislation was introduced to increase the minimum flight time and certification requirements for all flight crewmembers serving in 14 CFR 121 air carrier operations defined as regularly scheduled domestic, flag, and supplemental operation airlines (U.S. Government Printing Office, 2013). On October 14, 2009, the U.S. House of Representatives signed H.R. 3371, the "Airline Safety and Pilot Training Improvement Act of 2009", which sought in part, to require all flight crewmembers serving in 14 CFR 121 air carrier operations to hold an ATP certificate and possess at least 1,500 hours of total flight experience (Congressional Record, 2009).

On August 1, 2010, the President of the United States signed H.R. 5900, the "Airline Safety and Federal Aviation Administration Extension Act of 2010", which was adopted by the 111th Congress as Public Law 111-216 (The White House, 2010). Public Law 111-216, Title II, Sec. 216, mandated all flight crewmembers, to include first officers, serving in 14 CFR Part 121 air carrier operations to hold an ATP certificate. Title II, Sec. 217, mandated that in order to qualify for an ATP certificate, an individual shall possess at least 1,500 total hours of flight experience (U.S. Government Printing Office, 2010a). There is, however, a provision within the Act which authorizes the FAA to grant credit for specific academic training courses toward the 1,500 total flight hour requirement if a determination is made "…that allowing a pilot to take specific academic training courses will enhance safety more than requiring the pilot to fully comply with the flight hours requirement" (U.S. Government Printing Office, 2010b).

In the case of the Colgan Air DHC-8 accident, the captain held an ATP certificate and "…had accumulated 3,379 hours of total flying time, including 3,051 hours in turbine airplanes, 1,030 hours as pilot-in-command (PIC), and 111 hours on the [DHC-8] Q400" (NTSB, 2010). The first officer held a commercial pilot certificate and "…had accumulated 2,244 hours of total flying time, including 774 hours in turbine airplanes and on the [DHC-8] Q400" (NTSB, 2010). While the first officer held only a commercial certificate, both pilots involved in the Colgan Air DHC-8 accident possessed more than 1,500 hours of total flight experience.

The Colgan Air DHC-8 accident raised many concerns among legislators and regulators with regard to existing flight time and certification requirements for pilots engaged in 14 CFR 121 air carrier operations. The decision to increase those requirements appeared to support the notion that commercially certificated pilots and/or pilots with less than 1,500 hours of total flight experience pose a greater level of risk than pilots who hold an ATP certificate and have more than 1,500 hours of flight time. Unfortunately, it was not known whether the flight time, level of certification, or other characteristics of the pilots involved in the Colgan Air DHC-8 accident were characteristic of pilots who were involved in other major U.S. air carrier accidents. Therein lay the problem. What were the pilot characteristics of major U.S. air carrier accidents? With regard to a future increase in flight time and certification requirements for 14 CFR 121 air carrier operations, there was a need to better understand the characteristics of previous air carrier accidents.

The purpose of this study was to describe the pilot characteristics of major U.S. air carrier accidents between 1991 and 2010 operated under 14 CFR 121. For the purpose of this study, an accident was included if the following criteria were met: the accident involved a U.S. air carrier operating under 14 CFR 121 between 1991 and 2010 and the NTSB conducted a major investigation. For this study, major investigations are defined as investigations in which the NTSB adopted an aircraft accident report (AAR) or aircraft accident brief (AAB).

A select number of pilot related variables were used to describe the characteristics of major U.S. air carrier accidents in terms of pilot characteristics. According to the NTSB (1994), "previous accident investigations have identified a large set of operational and human performance factors as being related to the occurrence or seriousness of errors". Variables related to the characteristics of pilots included: flight experience; level of certification; duration of employment with the accident air carrier; crew assignment; age, gender, and crew familiarity. Using these pilot related variables, this study compared the characteristics of pilots involved in major accidents citing pilot performance as a causal or contributing factor with the characteristics of pilots involved in major accidents in which pilot performance was not a causal or contributing factor in order to determine whether any significant differences existed.

Studies conducted by the NTSB (1994) and Dismukes et al (2007) pertaining to major U.S. air carrier accidents laid the groundwork for this study. However, both studies were limited to only those accidents citing pilot performance as a causal or contributing factor. This study provides a more recent look at the pilot characteristics of major U.S. air carrier accidents between 1991 and 2010 operated under 14 CFR 121. In addition, this study expands upon the population studied to also include air carrier accidents in which pilot performance was not cited as a casual or contributing factor.

Between 1991 and 2010, there were more than 139 million aircraft departures within the U.S. air carrier industry (BTS, 2011). During that same period, only 747 accidents occurred while operating under 14 CFR 121 (NTSB, 2011). Fifty-one of the 747 accidents were operated under 14 CFR 121 and resulted in an NTSB aircraft accident report (AAR) or aircraft accident brief (AAB). These accidents included scheduled and non-scheduled passenger and cargo flights. Flights originated from airports within the U.S. during various hours of the day and months of the year. There were a number of U.S. air carriers involved, as well as a variety of different types of aircraft.

The NTSB’s Aviation Accident Database and Embry-Riddle Aeronautical University’s Hunt Library were used to gather the archival data for this study. The NTSB Aviation Accident Database provided access to the factual reports and probable cause reports. The Hunt Library provided access to the NTSB’s full aircraft accident reports (AAR) and aircraft accident briefs (AAB), as several of the older reports were not readily available on the NTSB's website.

The researchers identified U.S. air carrier accidents between 1991 and 2010 operating under 14 CFR 121. The NTSB Aviation Accident Database was used to filter the system for: (1) accidents with an event start date of "01/01/1991"; (2) an event end date of "12/31/2010"; (3) investigation type - "Accident"; and (4) operation - "Part 121: Air Carrier". All other fields were left at the default value in order to include all accidents that fit within the limits of the search. This resulted in the identification of 747 "Part 121: Air Carrier" "Accidents" between "01/01/1991" and "12/31/2010".

The researchers identified which accidents resulted in a major investigation. The NTSB's web-based list of aircraft accident reports and aircraft accident briefs were cross-referenced with the Hunt Library's web-based list of reports and briefs. Each of the reports and briefs were assigned a designator by the NTSB which specifies the year in which the report was adopted and a sequential number in which they are ordered. For example, the seventh report to be adopted in 2009 was AAR-09-07. The fourth brief to be adopted in 2007 was AAB-07-04. This enabled the researchers to sequentially check all of the reports for each year between 1991 and 2010. The researchers then reviewed each report to determine which of the accidents involved a U.S. air carrier operating under 14 CFR 121.

This resulted in the identification of 51 accidents that met the criteria required for inclusion in this study (see Table 1). Further analysis revealed that one of the 51 accidents (AAR 09/04) was the result of a ground fire prior to engine start. The information contained within this report focused on the ignition of supplemental oxygen stored within a supernumerary compartment while the aircraft was still parked, prior to engine start. Thus, AAR 09/04 was excluded from this study. This resulted in the selection of 50 accidents. The 50 accidents selected for inclusion in this study are presented in Table 1.

Measurement of the Variables

"Minimizing measurement error is critical. This is best accomplished by developing a well-though-out operational definition of the measurement procedure and by diligently using the operational definition in the research" (Graziano & Raulin, 2007, p. 83). Each of the variables considered in this study were defined in order to provide a reliable means of measurement and were modeled after the definitions established by the NTSB in 1994. In addition to the demographic variables of age and gender, the following were used as variables:

1. Flight experience – flight hours were used as the measurement of flight experience in this study. Flight hours were measured the following way:

    a. Total hours of flying experience – cumulative number of flight hours accumulated in all aircraft at the time of the accident.

    b. Hours of experience in the accident aircraft type – cumulative number of flight hours accumulated in the accident aircraft make and model at the time of the accident, regardless of crew position.

    c. Hours of experience in aircraft type and crew position – cumulative number of flight hours accumulated in specific crew position in the accident aircraft make and model (e.g. B-737 first officer) at the time of accident.

2. Level of certification – this variable was categorized as ATP certificate or commercial certificate.

3. Duration of employment with accident air carrier – this variable categorized on a nominal scale as less than one year of employment with the accident air carrier or more than one year with the accident air carrier.

4. Crew assignment – this variable was categorized as captain flying/first officer monitoring or captain monitoring/first officer flying.

Table 1
Selected Major U.S. Air Carrier Accidents

NTSB Report	Event Date	City	Carrier
AAR-11/02	27-Jan-09	Lubbock, TX	Empire Airlines
AAR-10/04	20-Dec-08	Denver, CO	Continental Airlines
AAR-10/03	15-Jan-09	Weehawken, NJ	US Airways
AAR-10/01	12-Feb-09	Clarence Center, NY	Colgan Air, Inc
AAR-09/03	28-Sep-07	St Louis, MO	American Airlines
AAR-08/02	12-Apr-07	Traverse City, MI	Pinnacle Airlines
AAR-08/01	18-Feb-07	Cleveland, OH	Shuttle America
AAR-07/07	7-Feb-06	Philadelphia, PA	United Parcel Service
AAR-07/06	8-Dec-05	Chicago, IL	Southwest Airlines
AAR-07/05	27-Aug-06	Lexington, KY	Comair
AAR-07/04	19-Dec-05	Miami, FL	Flying Boat, Inc
AAR-06/03	13-Aug-04	Florence, KY	Air Tahoma, Inc
AAR-06/01	19-Oct-04	Kirksville, MO	Corporate Airlines
AAB-06/02	24-May-03	Amarillo, TX	Southwest Airlines
AAR-05/02	9-May-04	San Juan, PR	Executive Airlines
AAR-05/01	18-Dec-03	Memphis, TN	Federal Express
AAR-04/04	12-Nov-01	Belle Harbor, NY	American Airlines
AAR-04/02	26-Jul-02	Tallahassee, FL	Federal Express
AAR-04/01	8-Jan-03	Charlotte, NC	Air Midwest
AAR-03/02	16-Feb-00	Rancho Cordova, CA	Emory Worldwide Airlines
AAB-02/04	5-Mar-00	Burbank, CA	Southwest Airlines
AAR-02/01	31-Jan-00	Port Hueneme, CA	Alaska Airlines
AAR-01/02	1-Jun-99	Little Rock, AR	American Airlines
AAR-01/01	3-Mar-91	Colorado Springs, CO	United Airlines
AAB-01/01	9-Feb-98	Chicago, IL	American Airlines
AAR-00/03	17-Jul-96	East Moriches, NY	Trans World Airlines
AAR-00/02	31-Jul-97	Newark, NJ	Federal Express
AAR-99/01	8-Sep-94	Aliquippa, PA	USAir (US Airways)
AAR-98/03	5-Sep-96	Newburgh, NY	Federal Express
AAR-98/02	7-Aug-97	Miami, FL	Fine Airlines
AAR-98/01	6-Jul-96	Pensacola, FL	Delta Air Lines
AAR-97/06	11-May-96	Miami, FL	ValuJet Airlines
AAR-97/03	19-Oct-96	Flushing, NY	Delta Air Lines
AAR-97/01	19-Feb-96	Houston, TX	Continental Airlines
AAR-96/07	7-Jan-96	Nashville, TN	ValuJet Airlines
AAR-96/05	12-Nov-95	East Granby, CT	American Airlines
AAR-96/04	20-Dec-95	Jamaica, NY	Tower Air
AAR-96/03	8-Jun-95	Atlanta, GA	ValuJet Airlines
AAR-96/01	31-Oct-94	Roselawn, IN	Simmons Airlines
AAR-95/05	22-Nov-94	Bridgetown, MO	Trans World Airlines

NTSB Report	Event Date	City	Carrier
AAR-95/03	2-Jul-94	Charlotte, NC	USAir (US Airways)
AAR-95/01	2-Mar-94	Flushing, NY	Continental Airlines
AAR-94/06	1-Feb-94	New Roads, LA	Simmons Airlines
AAR-94/04	18-Aug-93	Guantanamo Bay, Cuba	American International Airways
AAR-94/01	14-Apr-93	Dallas Ft Worth, TX	American Airlines
AAR-93/04	30-Jul-92	Jamaica, NY	Trans World Airlines
AAR-93/02	22-Mar-92	Flushing, NY	USAir (US Airways)
AAR-92/05	15-Feb-92	Swanton, OH	Air Transport International
AAR-91/09	17-Feb-91	Cleveland, OH	Ryan International Airlines
AAR-91/08	1-Feb-91	Los Angeles, CA	USAir (US Airways)

5. Crew familiarity – the NTSB (1994) identified two measures of crew familiarity in their study in which a high percentage of accidents seemed to occur. This study measured crew familiarity in the following manner:

    d. First sequence/pairing together – this variable was categorized as the first pairing together or not the first pairing together.

    e. First day flying together (current pairing/sequence) – this variable was categorized as the first day flying together or not the first day flying together on the trip sequence.

    f. First leg of the day – this variable was categorized as the first leg of the day or not the first leg of the day.

Analysis

Descriptive statistics were used to describe the pilot characteristics of major U.S. air carrier accidents in terms of measures of central tendency, variation, range, variance, and percentiles. Chi-square was used to determine statistical differences between variables with nominal data. According to Graziano and Raulin, a chi-square test is appropriate for determining statistical difference between nominal data (2007). Sampling procedures were not required in this study, as all major U.S. air carrier accidents between 1991 and 2010 operated under 14 CFR 121 for which the NTSB conducted a major investigation of the accident were selected.

Findings

Characteristics of the Accident Pilots

Pilot related variables evaluated for this study included: flight experience; level of certification; duration of employment with the accident air carrier; crew assignment; age; gender; and crew familiarity.

Crewmember Age

Crewmember age data was available for all of the captains. The age of captains ranged between 25 and 59 years old with a mean of 47 years of age.

Table 2
Age Distribution: First Officers

	Age
Mean	38.98
Median	38.00
Mode	34.00
Std. Deviation	8.31
Minimum	24
Maximum	57

Age data was available for 49 first officers. The age of first officers ranged between 24 and 57 years old with a mean of 39 years of age.

Table 3
Age Distribution: Captains

	Age
Mean	47.00
Median	48.00
Mode	59.00
Std. Deviation	8.98
Minimum	59.00
Maximum	25.00

Gender of Crewmembers

Gender data was available for all captains and first officers. Forty-seven captains (94%) were male and three (6%) were female. Forty-six first officers (92%) were male and four (8%) were female.

Certificates Held

Certificate data was available for all captains and first officers. All captains (100%) held an ATP certificate. This was expected as possession of an ATP certificate is required in order to perform pilot-in-command duties under 14 CFR 121. Twelve first officers (24%) held a commercial certificate and thirty-eight (76%) held an ATP certificate.

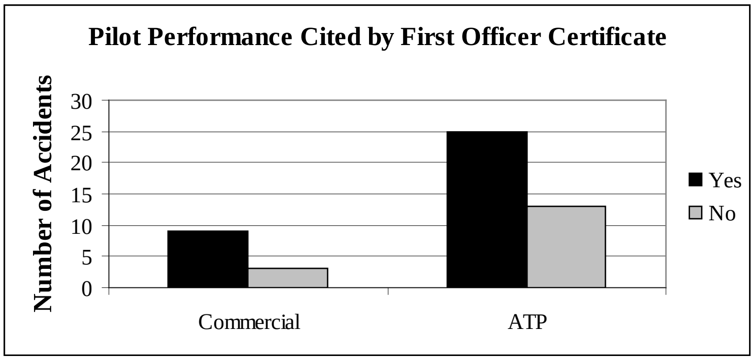

Figure 1. Pilot performance cited by first officer certificate.

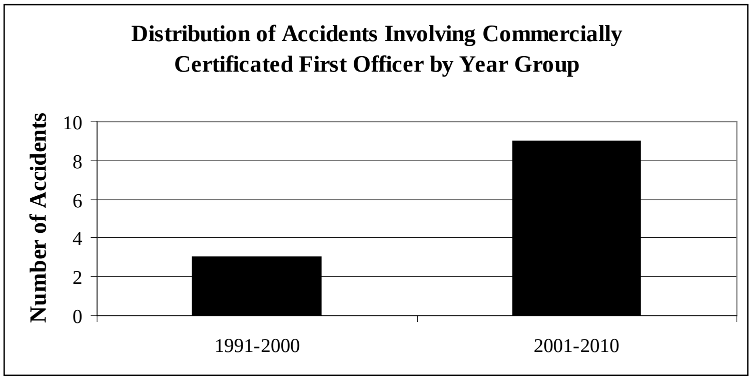

Figure 2. Distribution of accidents involving commercially certified first officer by year Group.

Further analysis revealed that of the twelve accidents involving a first officer whose highest certificate was a commercial certificate, three (25%) occurred between 1991 and 2000 and nine (75%) occurred between 2001 and 2010.

Irrespective of the citing/not citing of pilot performance, there was a significant difference between 1991-2000 and 2001-2010 with regard to the distribution of accidents based upon the highest certificate held by first officers between periods, χ^2 (df = 1, N = 50) = 9.175, p = 0.002.

Figure 3. Highest certificate of first officers by year group.

The reason two distinct year groups have been identified is because between 1991 and 2000, twenty-eight first officers (90%) held an ATP certificate while only three (10%) held a commercial certificate. Between 2001 and 2010, ten first officers (53%) held an ATP certificate and nine (47%) held a commercial certificate.

Duration of Employment

Employment data was available for all of the captains. The accident captains' duration of employment ranged from less than one month to over 30 years of employment with the accident air carrier, with a mean of 12.2 years. Only one captain (2%) had less than one year of employment with the accident air carrier. Forty-nine captains (98%) had more than one year of employment with the accident air carrier. There was not a significant difference between groups with regard to whether the captain had more or less than one year of employment with the accident air carrier, χ^2 (df = 1, N = 50) = 0.480, p = 0.488.

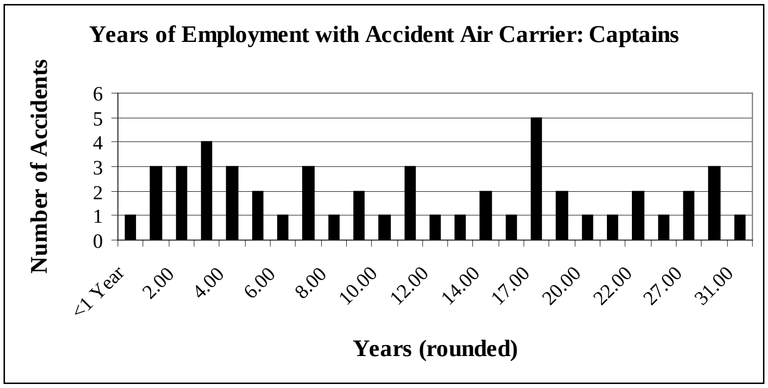

Figure 4. Years of employment with accident air carrier: captains.

Employment data was available for 49 first officers. The accident first officers' duration of employment ranged from less than one month to over 32 years of employment with the accident air carrier, with a mean of 5.4 years. Thirteen first officers (26.5%) had less than one year of employment with the accident air carrier. Thirty-six first officers (73.5%) had more than one year of employment with the accident air carrier. There was not a significant difference between groups of first officers with regard to whether the first officer had more or less than one year of employment with the accident air carrier, χ^2 ($df = 1$, $N = 49$) = 0.473, $p = 0.492$. Nor was there a significant difference between the periods of 1991-2000 and 2001-2010 with regard to first officers' duration of employment, χ^2 ($df = 1$, $N = 49$) = 0.406, $p = 0.524$.

Figure 5. Years of employment: first officers.

Total Flight Time

Total flight time data was available for all of the captains. The least experienced captain had 2,500 hours of total flight time and the most experienced captain had 25,000 hours of total flight time, with a mean of 11,994 hours.

Table 4

Total Time Captain

	Flight Hours
Mean	11993.62
Median	11500.00
Mode	11000.00
Std. Deviation	5741.17
Minimum	2500.00
Maximum	25000.00

There was not a significant difference between groups of pilots with regard to whether the captain had more or less than 1,500 hours of total flight time as 100% of captains had over 1,500 hours of total flight time.

Total flight time data was available for all of the first officers. The least experienced first officer had 1,096 hours of total flight time and the most experienced first officer had 17,734 hours of total flight time, with a mean of 6,838 hours. Only two first officers (4%) had less than 1,500 hours of total flight time. Forty-eight first officers (96%) had more than 1,500 hours of total flight time. Of the two first officers with less than 1,500 hours, one possessed 1,096 hours and the other possessed 1,420 hours of total flight time.

Table 5

Total Time First Officer

	Flight Hours
Mean	6837.92
Median	5407.00
Mode	6500.00
Std. Deviation	4478.40
Minimum	1096.00
Maximum	17734.00

There was a significant difference between groups with regard to whether the first officer had more or less than 1,500 hours of flight time, χ^2 (df = 1, N = 50) = 4.427, p = 0.035. Of the first officers with more than 1,500 hours of total flight time, thirty-four (71%) were involved in an accident citing pilot performance as a causal or contributing factor and fourteen (29%) were involved in an accident not citing pilot performance as a causal or contributing factor. Of the two first officers with less than 1,500 hours of total time, neither (0%) were involved in an accident citing pilot performance as a causal or contributing factor.

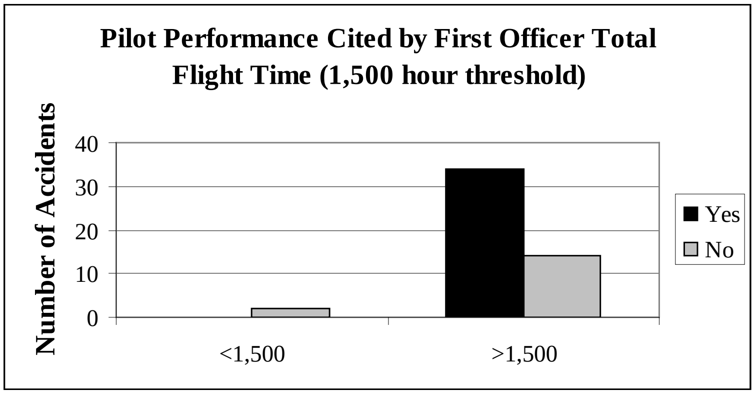

Figure 6. Pilot performance cited by first officer total time (1,500 hour threshold).

The findings suggest that first officers with less than 1,500 hours of total flight time did not contribute to any major U.S. air carrier accidents between 1991 and 2010. This finding may be of particular interest with regard to the total flight time requirements imposed by Public Law 111-216. It is, however, important to point out that it is highly likely there were proportionately very few first officers with less than 1,500 hours of total time who were employed by U.S. air carriers operating under 14 CFR 121 during this period.

Flight Experience in Make/Model

Flight experience in the make/model indicates how many total flight hours of experience the flight crew member had earned in the aircraft type which the accident occurred. Hours of flight time in the accident make and model was available for all of the captains. The least experienced captain had 111 hours in make/model and the most experienced captain had 16,000 hours in make/model, with a mean of 3,113 hours.

Flight experience in make/model and position indicates how many total flight hours of experience the flight crew member had earned as the role in which they were currently serving (captain or first officer). Hours of flight time in the accident make/model and position was available for 46 captains. The least experienced captain had 26 hours as a captain in the accident aircraft make/model and the most experienced captain had 16,000 hours as a captain in the accident aircraft make/model, with a mean of 2,048 hours.

Hours of flight time in the accident make and model was available for all first officers. The least experienced first officer had 20 hours in make/model and the most experienced first officer had 8,060 hours in make/model, with a mean of 1,683 hours.

Table 6

Make and Model: Captain

	Flight Hours
Mean	3112.54
Median	2507.00
Mode	111.00
Std. Deviation	15889.00
Minimum	111.00
Maximum	16000.00

Table 7

Make and Model: First Officer

	Flight Hours
Mean	1682.76
Median	1419.00
Mode	1200.00
Std. Deviation	8040.00
Minimum	20.00
Maximum	8060.00

Table 8

Type and Position: Captain

	Flight Hours
Mean	2048.43
Median	1537.50
Mode	1100.00
Std. Deviation	2536.20
Range	15974.00
Minimum	26.00
Maximum	16000.00

Flight Experience in Make/Model and Position

Hours of flight time in the accident make/model and position was available for 46 first officers. The least experienced first officer had 20 hours as a first officer in the accident aircraft make/model and the most experienced first officer had 8,060 hours as a first officer in the accident aircraft make/model, with a mean of 1,503 hours. Table 7 presents the distribution for first officers in make/model and position.

Flying Assignment

Flying assignment data was available for 49 accidents. Measurements were made in terms of “assigned” duties. In other words, if the first officer was assigned flying duties and the captain took control of the aircraft before, during, or after the accident occurred, the first officer was recorded as the flying pilot.

Table 9

Type and Position: First Officer

	Flight Hours
Mean	1502.87
Median	1110.00
Mode	1200.00
Std. Deviation	1584.64
Range	8040.00
Minimum	20.00
Maximum	8060.00

The captain was performing flying duties and the first officer was performing monitoring duties in twenty-two (45%) of the accidents. The first officer was performing flying duties and the captain was performing monitoring duties in twenty-seven (55%) of the accidents.

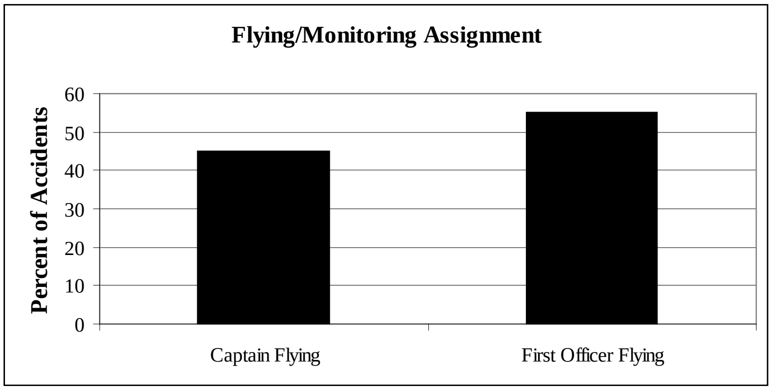

Figure 7. Flying/monitoring assignment.

There was not a significant difference between groups of pilots with regard to which pilot was performing the flying duties and which pilot was performing the monitoring duties, χ^2 ($df = 1$, $N = 49$) = 1.169, $p = 0.280$.

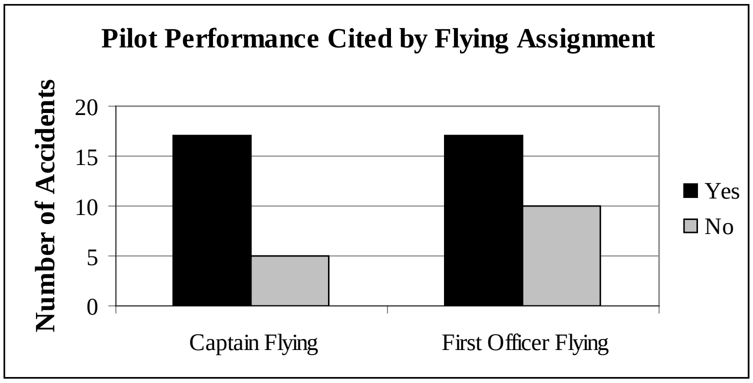

Figure 8. Pilot performance cited by flying assignment.

Crew Familiarity

Crew familiarity was measured in terms of (1) first day of pairing on the current sequence/pairing; (2) first leg of the day on the current pairing; and (3) whether the accident sequence pairing was the first pairing together.

First day of pairing on the current/accident sequence/pairing was available for 46 accidents. Twenty-five accidents (54%) occurred during the first day of crew pairing. Twenty-one accidents (46%) occurred on a day following the crew's first day flying together.

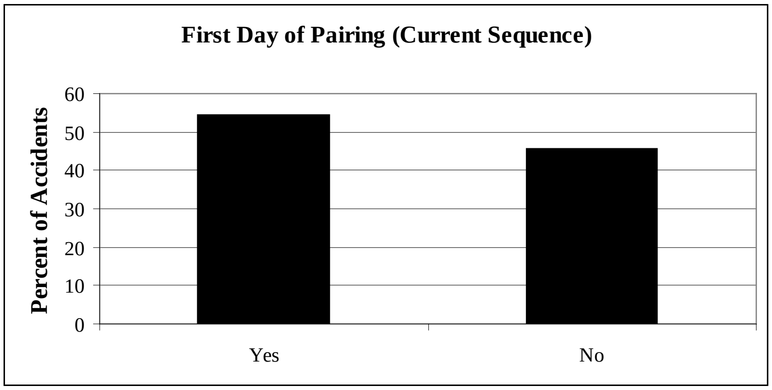

Figure 9. First day of pairing (current sequence).

There was not a significant difference between groups with regard to whether the accident occurred on the crew's first day of pairing on the current sequence/pairing, χ^2 (df = 1, N = 46) = 0.009, p = 0.923.

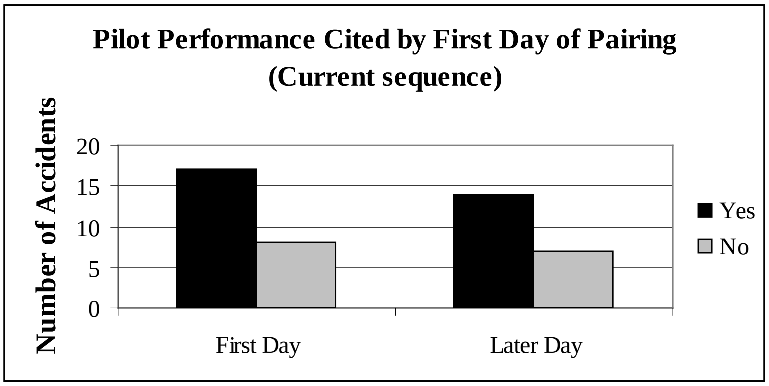

Figure 10. Pilot performance cited by first day of pairing (current sequence).

First leg of the day data was available for 49 accidents. Twenty-nine accidents (59%) occurred during the first leg of the day. Twenty accidents (41%) occurred after the crew had already completed at least one leg that day prior to the accident leg. It is important to note that not all trip sequences involve multiple legs per day. It is possible that a portion of the accidents that occurred during the first leg of the day involved a trip sequence with only one leg that particular day.

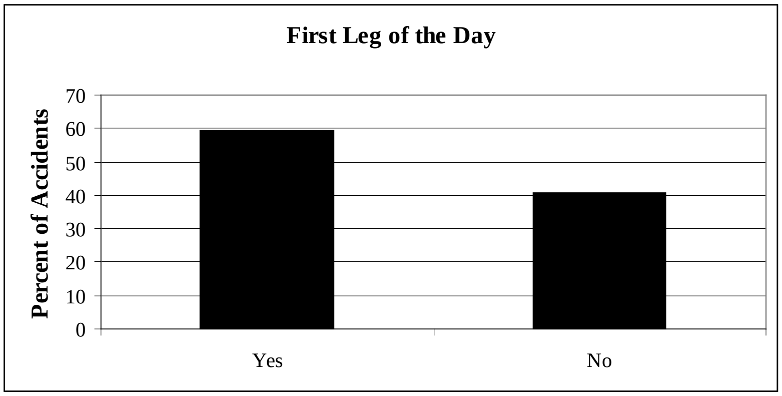

Figure 11. First leg of the day.

There was not a significant difference between groups of pilots with regard to whether the accident occurred on the first flight-leg of the day, χ^2 (df = 1, N = 49) = 0.108, p = 0.742.

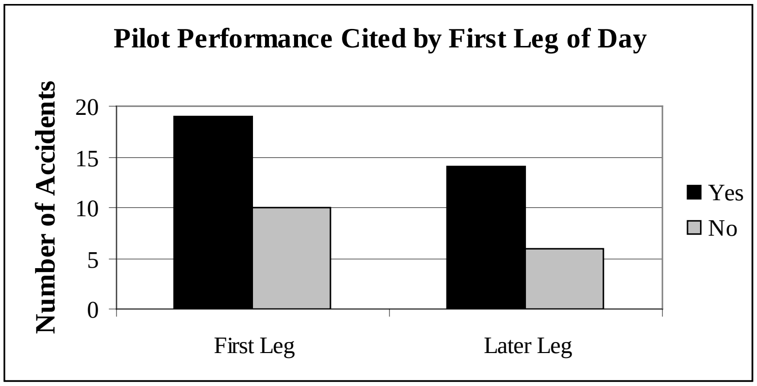

Figure 12. Pilot performance cited by the first leg of the day.

Data related to whether the accident crew had flown together in the past on another pairing sequence was available for 24 accidents. Thirteen flight crews (54%) had been paired together on at least one pairing, other than the accident pairing, in the past. For eleven flight crews (46%), the accident sequence pairing was the first time the crewmembers had been paired together.

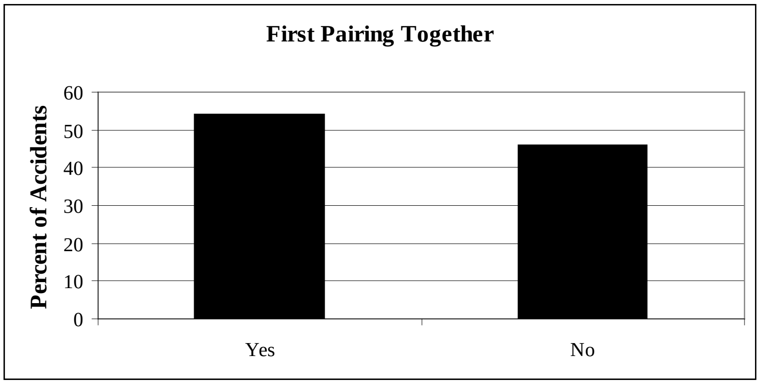

Figure 13. First pairing together.

There was not a significant difference between groups of pilots with regard to whether the accident occurred during the first pairing between pilots, χ^2 (*df* = 1, *N* = 24) = 0.511, *p* = 0.475.

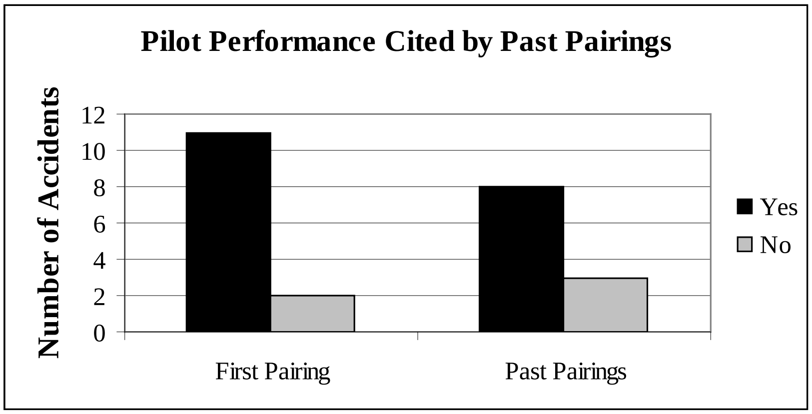

Figure 14. Pilot performance cited by past pairings

Discussion

The age of captains ranged between 25 and 59 years old with a mean of 47 years and the age of first officers ranged between 24 and 57 years old with a mean of 39 years. Forty-seven (94%) of the 50 captains were male and three (6%) were female. Forty-six (92%) of the 50 first officers were male and four (8%) were female. The disproportionate number of males was most likely the result of an underrepresentation of women in aviation. As a result, 43 (86%) of the 50 flight crews were comprised of an all-male crew of pilots. Seven (14%) of the fifty crews were comprised of both a male and female pilot and none of the accidents (0%) involved an all-female crew of pilots. There was not a significant difference between groups with regard to the composition of crews by gender.

All of the captains (100%) held an ATP certificate. This was expected as possession of an ATP certificate is required in order to perform pilot-in-command duties under 14 CFR 121. Twelve (24%) of the 50 first officers were commercially certificated and 38 (76%) were ATP certificated. While there was not a significant difference between those accidents citing pilot performance as a causal or contributing factor and those not citing pilot performance during the cumulative period between 1991 and 2010, there was a significant difference between the 1991-2000 and 2001-2010 year groups irrespective of the citing/not citing of pilot performance. Between 1991 and 2000, only three (10%) of the 31 accidents involved a commercially certificated first officer. However, nine (47%) of the 19 accidents which occurred between 2001 and 2010 involved a commercially certificated first officer. This finding suggests a significant shift in the distribution of major U.S. air carrier accidents involving commercially certificated first officers during the later period. It was unknown what the actual employment distribution was among ATP and commercially certificated first officers who were involved in 14 CFR 121 air carrier operations during either period. However, this finding may be of particular interest with regard to the certification requirements imposed by Public Law 111-216.

The accident captains’ duration of employment ranged from less than one month to over 30 years of employment with the accident air carrier, with a mean of 12.2 years and the accident first officers’ duration of employment ranged from less than one month to over 32 years of employment with the accident air carrier, with a mean of 5.4 years. Only one (2%) of the captains had less than one year of employment with the accident air carrier. However, 13 (26.5%) of the 50 first officers had less than one year of employment with the accident air carrier. There was not a significant difference between groups with regard to duration of employment and citing/not citing of pilot performance.

The least experienced captain had 2,500 hours of total flight time and the most experienced captain had 25,000 hours of total flight time, with a mean of 11,994 hours. The least experienced first officer had 1,096 hours of total flight time and the most experienced first officer had 17,734 hours of total flight time, with a mean of 6,838 hours. Only two first officers (4%) had less than 1,500 hours of total flight time and neither were involved in an accident citing pilot performance as a causal or contributing factor. The findings suggest that first officers with less than 1,500 hours of total flight time did not contribute to any major U.S. air carrier accidents between 1991 and 2010. This finding may also be of particular interest with regard to the total flight time requirements imposed by Public Law 111-216. It is, however, important to point out that it is highly likely there were proportionately very few first officers with less than 1,500 hours of total time who were employed by U.S. air carriers operating under 14 CFR 121 during this period.

The least experienced captain had 111 hours in make/model and the most experienced captain had 16,000 hours in make/model, with a mean of 3,113 hours. The least experienced first officer had 20 hours in make/model and the most experienced first officer had 8,060 hours in make/model, with a mean of 1,683 hours. In regard to pilot experience in the accident aircraft and crew position, the least experienced captain had 26 hours as a captain in the accident aircraft make/model and position and the most experienced first captain had 16,000 hours as a captain in the accident aircraft make/model and position, with a mean of 2,048 hours. The least experienced first officer had 20 hours as a first officer in the accident aircraft make/model and position and the most experienced first officer had 8,060 hours as a first officer in the accident aircraft make/model and position, with a mean of 1,503 hours.

With regard to flying assignment, the captain was performing flying duties and the first officer was performing monitoring duties in 22 (45%) of the accidents. Twenty-five (54%) of the 46 accidents for which data was available occurred during the first day of crew pairing on the current pairing/sequence and 29 (59%) of the 49 accidents for which data was available occurred during the first leg of the day. Of the 24 accidents for which data was available, 13 (54%) of the accident crews had been paired together in the past on at least one other pairing/sequence other than the accident pairing/sequence.

With regard to causal and contributing factors, 34 (68%) of the 50 accidents included in this study cited pilot performance as a causal or contributing factor. Furthermore, these 50 accidents indicated additional contributing factors to include; environment as a causal or contributing factor 15 (30%), mechanical factors 12 (24%), or other persons 23 (46%) as a causal or contributing factor. A comparison between the 1991-2000 and 2001-2010 year groups indicated there was not a significant difference between groups with regard to the involvement of pilot performance, environmental factors, mechanical factors, or other persons as a causal or contributing factor.

Of the 50 accidents investigated in this study, all fifty captains (100%) had at least 2,500 hours of total flight time and forty-eight first officers (96%) had at least 2,000 hours of total flight time at the time of the accident. There were only two first officers (4%) with less than 1,500 hours of total time, having 1,096 and 1,420 hours respectively, and neither were involved in an accident citing pilot performance as a causal or contributing factor. These findings do not support the notion that a 1,500 hour total flight time requirement will contribute to the safety of 14 CFR 121 air carrier operations, as neither (0%) of the first officers with less than 1,500 hours of total flight time were involved in a major U.S. air carrier accident which cited pilot performance as a causal or contributing factor.

Conclusion and Recommendations for Further Research

Results of this study indicate that crew familiarity may have a negative effect on accident rates. Crew familiarity was measured in terms of (1) first day of pairing on the current sequence/pairing; (2) first leg of the day on the current pairing; and (3) whether the accident sequence pairing was the first pairing together. Evaluation of crew familiarity indicated that accident rates were higher in instances of lower crew familiarity in each of the three areas measured. The majority of accidents occurred on the first day of pairing (54%), the first leg of the day (59%), and during the first pairing together (54%).

Upward pressures on the demand for air travel will result in upward pressures on the demand for labor. As witnessed in 2006 and 2007, several air carriers were forced to reduce minimum flight time hiring requirements in order to hire a sufficient number of pilots. Under the Airline Safety and Federal Aviation Extension Act of 2010, air carriers operating under 14 CFR 121 will potentially lose access to the more than 100,000 commercially certificated pilots with an instrument rating, according to FAA data, or approximately 45% of the potential labor supply under existing regulations (FAA, 2011c). This is a significant number of personnel and could have potentially negative consequences given the cyclical nature of the aviation industry.

Furthermore, while an ATP certification requirement for first officers will not eliminate the possibility of any future air carrier accidents involving commercially certified first officers, it is not possible to predict whether such a change will contribute to the enhancement of safety for 14 CFR 121 air carrier operations. It is possible there will simply be a redistribution of the number of accidents involving ATP certificated first officers.

Study findings suggest a significant shift in the distribution of major U.S. air carrier accidents involving commercially certificated first officers during the later period. It was unknown what the actual employment distribution was among ATP and commercially certificated first officers who were involved in 14 CFR 121 air carrier operations during either period. Further research could assist in identifying employment distribution among ATP and commercially rated first officers between the period of 1991 and 2010 and in particular when comparing the two time period groups (1991-2000 and 2001-2010) analyzed by this study.

Future studies could also include further analysis into crew familiarity issues and their correlation to accident rates. While it is not surprising that limited crew familiarity may have a negative effect on accident rates, additional research may identify solutions that can improve accidents related to crew familiarity issues. Additionally, further research should explore the potential affects that new pilot certification requirements will have on the future commercial pilot workforce. The literature indicates a continual increase in demand for air travel and the need for pilots. Will new pilot certification affect this prediction of future increased in demand for air travel and additional pilots? The commercial pilot workforce may be ill-prepared to react to consequences of new pilot certification requirements.

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Building a Viable Flight Risk Assessment Process in Business Jet Operations: Selecting a Risk Assessment Tool, Setting Baselines, Trigger & Mitigation Points

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Abstract

In November 2006, The International Civil Aeronautics Organization (ICAO) issued a mandate for all member nations to set a state standard for all aviation service companies to have integrated safety management systems (SMS) in place by 2009. The FAA issued an advisory circular (AC120-92A) in 2010 addressing this issue. To date SMS has not been mandated in the United States. A major part of any SMS is creating a process for assessing risk. This paper is a case study of how one jet charter company selected a flight risk assessment tool (FRAT), trained their pilots and then analyzed close to 800 flights in order to set trigger points for assessment use, risk values that required management involvement, and risk values that required some sort of mitigation. The paper also discusses how the operation dealt with pilot push back, FRAT evolution and the dynamic personality of aviation in general.

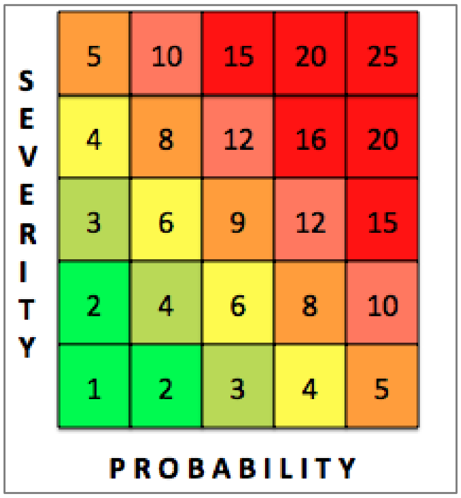
Introduction

In November 2006, The International Civil Aeronautics Organization (ICAO) issued a mandate for “all member nations to set a state standard for all aviation service companies to have integrated safety management systems (SMS) in place by 2009” (p. 1). The Federal Aviation Administration (FAA) issued an advisory circular (AC120-92A) in 2010 addressing this issue. The focus of the FAA shifted elsewhere after the fallout from the Colgan Air Disaster in Buffalo, New York, however; hence, to date there has not been an SMS mandate issued in the United States. According to most industry sources an FAA mandate is still inevitable (Allen, 2011). Further SMS integration is also occurring in fields as diverse as academia and heavy industry as entities such as the Occupational Safety and Health Administration (OSHA) and the Aviation Accrediting Board International (AABI) are both considering implementing an SMS requirement (AABI, 2013; OSHA, 2013).

ICAO Annex 6, Appendix 1 describes the “framework,” which is the standard for a “robust” SMS program (FAA, 2011). The “components, elements and processes” spelled out are mirrored by the FAA advisory circular as well as third party groups such as the International Business Aviation Council (IBAC) and the Air Charter Safety Foundation (ACSF) (ASCF, 2013; IBAC, 2013; FAA, 2010). The FAA is taking the stance that they will mandate “what” an organization does rather than “how” they do it. The framework consists of four components, or “pillars” as the ACSF likes to call them. These pillars are Safety Policy, Safety Risk Management, Safety Assurance and Safety Promotion. Each pillar is further delineated into elements, which contain processes. This article will deal primarily with the Safety Risk Management component, and more specifically the Risk Assessment process contained in the Safety Risk Management component.

Risk Assessment

Most safety professionals are familiar with the elements involved in a good risk assessment process. Basically, any valid risk assessment should take into account the severity of an occurrence balanced by the probability that the occurrence will actually happen (FAA, 2009, p. 4-2). Many risk assessments will appear in a matrix form similar to Figure 1.



5	10	15	20	25
4	8	12	16	20
3	6	9	12	15
2	4	6	8	10
1	2	3	4	5

Figure 1. Risk Assessment Matrix Depicts Probability vs. Severity adapted from FAA Matrix (FAA, 2008).

The matrix demonstrates that factors that need the most attention are the ones that have both a severe outcome (i.e. death or heavy monetary loss) and a high probability of occurrence. Risk values or scores will go down from there as the predicted severity and probability of occurrence go down.

The National Transportation Safety Board (NTSB) considers any occurrence in an aircraft, once people are aboard, which involves a death or substantial aircraft damage to be an aircraft accident (NTSB, 2011, p.1). Some agencies, for instance the state of Indiana, take it one step further and require an accident report for losses as low as 100 dollars (Office of Code Revision Indiana Legislative Services Agency 2013). With the current cost of jet aircraft, even the simplest of incidents can easily exceed this particular threshold. With this information in mind, it is understandable why most flight risk assessment tools (FRATs) only require assessors to place a value on the probability side of the matrix; the severity side is pretty much a given.

Mission

Early in 2008, the author of this article was tasked with developing a flight risk assessment process for a medium-sized jet operator in the intermountain west. Medium-sized refers to the fact that at the time they operated four Gulfstream jets, two Hawkers, two Citations, one Challenger and three Pilatus aircraft. The company did quite a bit of supplemental lift for the fractional carriers and brokers. These entities required annual safety audits, so this operator already had a fairly robust SMS in place. The issue was the level of the system. A good flight risk assessment process is important to any flight operation's safety management system and for that reason the operator also had a FRAT in place that had been provided by one of their ex-military pilots. He had used the FRAT in the US Air Force and the company was grateful for the help. It wasn't a bad FRAT; the problem was that it was cumbersome at best. It was three pages long and asked for quite a bit of subjective data, it had questions that meant different things to different people, along the lines of illness, stress and fatigue. These are great for determining personal airworthiness, but we were looking for consistency. The FRAT filled the checklist box. Whenever an auditor came by, management could show them the tool. If the auditor asked a pilot about it, he or she may have been able to find a copy, even fill it out, but had no idea what the numbers meant once completed. After all, it is one thing to have a FRAT that lives in a drawer so you can prove to an auditor that it exists, but it is quite another to be able to show an auditor that all of the pilots and dispatchers have been trained to use it (and show competence), to be able to demonstrate the average risk value for a summer or winter flight, and to understand at which particular risk value management involvement is required and at which value the pilots need to mitigate risk.

What follows in this article is a five-year case study of how this medium sized jet operator developed and implemented a flight risk assessment process into everyday operation. Included is a report on the findings of a study of over 700 flights and how the operator used this information to set baseline risk values for the department. Though this information was never meant to be a hard scientific study, it represents a logical way to figure out where to set thresholds. Therefore, the study is not perfect but it represents a much better system than simply setting arbitrary limits based on nothing but a guess. Following a description of the study will be a discussion of some of the pushback received from the pilot group, how buy-in from that group was achieved, how the entire process was allowed to evolve through continued additions to the database, how "use triggers" or "trigger points" were developed and at what point management required risk mitigation ("mitigation points"). Finally, a discussion of what went right, and what went wrong from an implementation point of view will be presented and how new options currently available may be applied for those presently developing a risk assessment process.

Method

In this section we will discuss how a team of managers worked together to select a suitable FRAT and then how data collected from its use was analyzed in order to set the aforementioned mitigation points.

The Team

The "Safety Team" consisted of management for this particular mountain west operator. It was made up of the Director of Operations, Assistant Director of Operations, the Director of Standards, the Flight Safety Officer and included input from the Director of Safety, the Chief Executive Officer and Chief Pilot. Meetings were held as needed, usually on a biweekly basis so assignments could be given and those completed could be reported on. The biweekly meeting was also the time most decisions were made. The first assignment was to decide on which new FRAT to use from the myriad available, and then decide how to implement it. Prior to selection, however, the team set some basic goals for the tool and they are as follows:

1. It needed to be objective. The risks factors listed needed to be easily identified. More specifically, the risk factors needed to be described in a way that made it easy for pilots to determine if they were present or not. The goal was that 10 pilots would come up with 10 identical total risk values/scores for any given flight.
2. It needed to be practical. Pilots have a lot of paperwork. The pilot group simply wouldn't use a FRAT that took 25 minutes to fill out. A good FRAT would be a one- page document or electronic form that took in human, environmental and mechanical factors.
3. Risk factors needed to be at least loosely based on accident statistics. It needed to consider the severity/probability matrix previously mentioned. A FRAT based on accident stats would add the probability side to the matrix.

The Instrument

The team found numerous instruments related to the study topic. There were several FRATs readily available, but the one chosen came straight from the FAA. It was issued in a FAA "InFo" and was developed by the Turbine Aircraft Operations Subgroup as part of the General Aviation Joint Steering Committee. The Subgroup had reviewed accident data to come up with risk factors and the initial "risk values" associated with each factor (FAA, 2007, pp. 1-5). This tool was just what management was looking for. The form itself was divided into three sections: one for the flight crew, one for the environment, and one for mechanical/maintenance. Completing this particular FRAT was easy for crews. Each factor was already scored so that all a crew needed to do was determine if a factor was present. If a factor was present, the pilot simply wrote the risk value indicated by the designers into the column on the right. When finished, the crew added up the totals. It met all three of the original goals and was easily adaptable (See Appendix 1). The next step was implementation and a study to determine company baselines.

Training and Implementation

Once a FRAT was selected, initial implementation was fairly straightforward. Management simply had to define the procedure and then train those employees involved. The managers understood that before they could determine when risk mitigation needed to take place (changing something to reduce risk), they first needed to determine what risk values were "normal" for the operation. To figure out what was "normal," enough data needed to be collected, or in this case enough risk assessments completed and tracked to see what the overall average for a flight was for this particular organization. Options were discussed in several safety management meetings and as a general rule all were in agreement that the best way to come up with an average was to have the pilot group complete risk assessments for every flight they completed. The only dissenter was the company's Flight Standards Officer. The standards officer was fine with mandating the completion of flight risk assessments every flight, just not indefinitely. He wanted a definite sunset date since he believed that the pilots were already required to complete too much paperwork, manifests, weight and balance, engine monitoring, and at the time, reduced vertical separation (RVSM) logs. He believed that if risk assessments were required before every flight on a continuous basis, assessments would become just another task pilots needed to complete. This in turn would severely threaten "buy in" by the pilot group. His opinion was fairly prophetic and will be discussed later in the article. After much discussion, management decided that risk assessments would be collected for three months in the summer and three months in the winter. This timeframe was chosen basically to follow the seasons in which the FAA requires recurrent training. Pilots and dispatchers were trained in the use of the FRAT during recurrent training in the months leading up to process implementation.

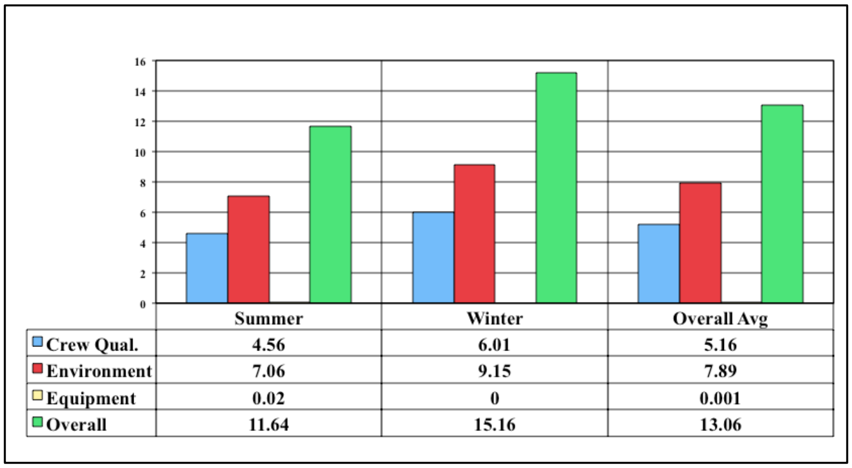
Procedure

At the time for implementation, all of the pilots and crew schedulers had been fully trained. The process was straightforward. Crew schedulers placed an adequate number of forms for each leg of a trip into the trip packets. Once a trip was completed, the trip packets with the fuel receipts, etc. were turned into the accounting department. The safety team placed a file in the accounting office so that as the trip packets were checked and filed, the completed risk assessments could be collected and placed in the file.

Results

Completed risk assessments were collected for all flights between May 15t and September 31st, 2008 and then again for all flights between December 15 and March 31,

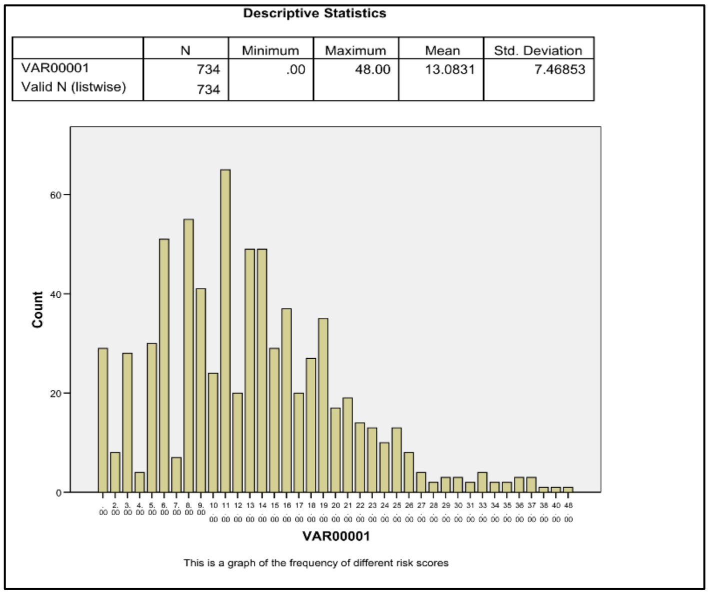
2009. The data from each assessment were then entered into a “Filemaker Pro” database program and compiled electronically. In all, there were 734 assessments entered. Specifically, there were 433 collected during the summer months and 301 during the winter. The overall average risk value for a flight at this operation was 13.06 points. Summer flights had an average risk value of 11.64 while the winter flights averaged 15.16. There were more summer flights than winter. If the seasons were equally weighted, the average risk value per flight was 13.40. At that time, the most frequently indicated risk factors were “Captain & FO less than 100 hours in last 90 days.” The least frequently indicated risk factors, averaging well less than .1 point per flight, were those dealing with mechanical issues (see Figure 2). Appendix 1 is a sample of the FRAT showing details of each risk factor. Although “crew qualification and experience” issues had the most frequency, the “operating environment” category contributed the most to the average risk score. This was due to the fact that the crew qual. category (as it appears in figure 2) had eight separate factors compared to twenty-seven in the environment category.



	Summer	Winter	Overall Avg
🟦 Crew Qual.	4.56	6.01	5.16
🟥 Environment	7.06	9.15	7.89
🟨 Equipment	0.02	0	0.001
🟩 Overall	11.64	15.16	13.06

Figure 2. Average Risk Value Totals by Category. Depicts Average Scores by Category. This chart shows the average totals of each of the three general categories; Crew Qualification and Experience, Operating Environment and Equipment for Summer, Winter and overall.

All data were entered into an IBM SPSS stats program and the following descriptive statistics were the result: Mean total risk value per flight: 13.08, Mode 24.00, Standard Deviation: 7.47. The stats program rounded slightly differently than the Filemaker Pro program, hence the .02 point difference in the mean (see figure 3).



Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
VAR00001	734	.00	48.00	13.0831	7.46853
Valid N (listwise)	734				

This is a graph of the frequency of different risk scores

Figure 3. Descriptive Statistics and Frequency of Different Risk Factors Present. This figure shows how often a particular risk factor was indicated present by a pilot. At the top, it shows the mean, minimum, maximum and standard deviation of total risk values entered per flight. (Output from IBM SPSS software.)

The next task was to decide what to do with the information collected and set usable baselines, triggers and mitigation points.

Setting Baselines and Mitigation Points

The point of determining an operational risk value average for the flight operation was to make it easier for management to decide when they should get involved in the flight decision process and at what point a trip should be turned down or modified. During the meetings that ensued on the subject, one highly experienced manager expressed that he had noticed that in many accident reports that it seemed that it was the addition of "one more thing" that turned the flight into an accident. He suggested that management involvement should occur at a risk value equal to one risk factor with a large score. For example, flights around thunderstorms will increase the total risk value of a flight by 5 points. He suggested that the threshold for management involvement be determined by adding five points to the operational "baseline" risk. This suggestion was much to the chagrin of the Flight Safety Officer (who had spent all night entering risk assessments into an IBM student version of the Statistical Package for Social Sciences [SPSS] stats package). His five-point rule was within a point or two of the standard deviation. Looking at the graph of the data, it is not exactly a bell curve. There were quite a few outliers on the high end of the scale. By using the standard deviation based on the mean around thirteen points, the limits would be fairly conservative and any flights with the higher risk values would automatically require management involvement. The safety management team eventually agreed to a “management involvement” threshold risk value determined by adding a rounded version of the standard deviation to the company average total risk value.

The “mitigation point” or risk value where some kind of change should occur (different airport, extra crew, reposition the night before, etc.) was slightly more complicated to figure out. International flights came with much higher risks and setting an arbitrary point where something had to change could prove to be a nuisance, the company could lose flights, or worse, if too cumbersome could encourage pilots to ignore the procedure. It was decided that since any flight with a score above 22 needed management oversight anyway, the mitigation point could be set high enough to accommodate international risk values. Figure 4 describes the two risk value thresholds and is identical to the way they were presented to the pilots and crew schedulers. This chart depicts the risk values above which some kind of action is required on the part of management and the crew. This chart was included in all training and on the back of every FRAT form.

Trigger Points

One of the best decisions management made concerning the flight risk assessment process was not all that intuitive, at least not at first. As mentioned earlier, part of the management team was very much against requiring crews to fill out risk assessments for every flight except for the time frame of the initial baseline tests. For reasons already explained in the “training and implementation” section, he thought it would ruin the intent

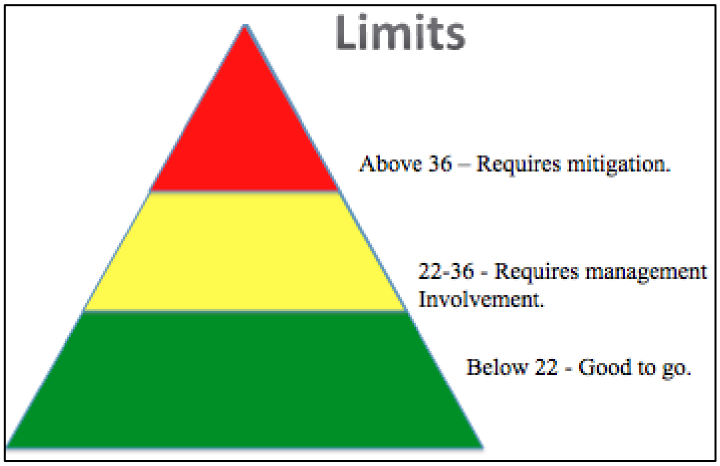


Figure 4. Shows Risk Value Thresholds that require management involvement in the go/no decision (scores between 22 and 36) or risk mitigation (scores above 36). This was

developed in house borrowing the shape and colors from the Heinrich Pyramid (Heinrich, 1941).

of the entire process. He was correct, at least in one operation. The safety team's Flight Safety Officer (FSO) attended a safety symposium at the Air Charter Safety Foundation's (ACSF) headquarters co-located with the National Transportation Safety Board (NTSB) in Washington D.C. He relayed a story that took place in one of the discussions at a reception for flight safety officers and managers from across the United States. One FSO explained how it was almost embarrassing for her. Her company required crews to complete flight risk assessments for every flight. She said crews wouldn't even hide the fact from her that they were completing the risk assessments at the end of the trip simply so they had something to turn in. This was definitely not the case for the operation we are discussing, but that is because well-defined trigger points were set. After deciding when to mitigate risks, management went about deciding when a flight risk assessment completion was required. Again, in a safety management meeting the issue was well discussed. The group was in unanimous agreement on mandating risk assessments for "pop-up trips" (less than four hours notice), international trips, single pilot trips, and anytime someone had a gut feeling factors were adding up. After much discussion, they also decided to mandate completion for trips that occur outside of normal circadian highs, training flights (to check competency), and anytime the "rule of three" (three factors added up: a tired pilot, bad weather, and a maintenance item, for example) occurred. The process was re-visited several times and after a couple years of implementation it was also decided to require risk assessments to be completed for maintenance check and ferry flights and for any flight that was carrying a maintenance item that required a limitation such as "Day VFR." The team also came up with suggestions about who could generate or cause the generation of a flight risk assessment.

After 5 years, the process has reached the point that long-time customers are even asking about the risk values for the flights where they are passengers. Below is a list of the "trigger points" that have evolved over the five-year implementation. These are also listed in the company's Standard Operating Procedures (SOP) and on the back of every FRAT form.

Risk Assessments must be completed for the following operations:

- Pop-up trip with less than 4 hours notice.
- Training flights and checkrides.
- Maintenance checks and maintenance ferry flights.
- MEL or CDL flights requiring Day VMC or non-standard aircraft flight configuration.
- Flight is conducted between the hours of 22:00 – 05:00
  (During the circadian low) appropriate to the time zone you are adjusted to at the time.
- Rule of three occurs.

Other conditions appropriate for the completion of a risk assessment include, but are not limited to:

- Gut feeling
- Interest (idea that things may be stacking up).
- Concern from another crewmember, flight coordinator, operational management
- Night operations into mountainous airports listed in the Mountain Airport Restriction Table
- International flights
- Duty day in excess of 12 hours

Risk assessments may be generated by anyone:

- Captain
- First Officer
- Flight Attendant
- Dispatcher
- Management
- Passenger

Discussion

The discussion section describes what changes have been made five years into the implementation, how the process has evolved and recommendations to those just beginning to build a process of their own.

The Process Five Years In

As with any new process, there was some reluctance by the pilot group early on--not because they disagreed with the process, but rather because they just wanted to understand certain aspects. The safety management team was very proactive in letting the pilots know the reasoning for why the process was put into place. The pilots just had questions about the FRAT itself. One question was, “If the weather forecast is such that we don’t need an alternate legally, why do I have to add points for ‘no alternate selected’?” We explained that the risk factors were based on looking back at accident statistics. Airports are closed sometimes for reasons other than weather and it is always safer to have a plan B, than not. Another question was, “I have a risk value of zero for this flight; does that mean my risk is zero?” Again, a little discussion of “added risk” helped that particular pilot understand what he was looking at. Overall, once pilots started to understand that the FRAT wasn’t a task they “had” to do, but one that could help them, they started to buy into the process. When they realized that they could use the FRAT to back up a decision, it became engrained. What can upper management say about changes such as repositioning the night before to reduce their duty day, or landing at a bigger part 139 “air carrier” airport instead of the regional when you have objective data depicting the higher risk? Being able to put a number to the risk empowered the pilots and there was no way management could complain. See Appendix 2 for examples of risk assessments that were used to back up pilot decisions.

Evolution

Anyone involved with the aviation industry knows how dynamic it can be. Business jet flight operations continually gain and lose airframes as owners upgrade to newer or bigger jets. Pilots change assignments or upgrade to new equipment. The trick is to keep the risk baselines evolving to reflect the changes. The goal is to have numbers that reflect the current company, not just a snapshot of the company five years ago. One downside to only requiring risk assessment completion for trips that meet a certain criteria is that those flight risk assessments, as a general rule, will naturally have higher risk values. If you use the data from mandated assessments to update the database you will slowly skew the baselines towards a higher risk. To continue letting the database evolve and reflect an “average” risk value of the present company, it was decided to randomly select flights for mandatory risk assessment completion. FRAT forms were printed in bright yellow and placed in the box with the other blank forms in the crew scheduling office. Each crew scheduler had a pair of dice and anytime they booked a flight, they rolled the dice. If the scheduler rolled a 7 or an 11 (22% odds), one of the yellow forms was placed in the trip packet with a note telling the pilots for which leg they needed to complete an assessment. Pilots were alerted in a crew “must read” email which required response and again in a “safety news” update. It worked well, but as fun as the dice sounded, the procedure became pretty cumbersome for the schedulers and hard to remember on a busy day. In the end the crew schedulers just shuffled the packets at the end of every workday and picked every 5th packet as a FRAT recipient. So far the baselines have only moved by a few decimals.

Another discovery over the long term was that some of the risk factors listed on the FRAT form were not ever indicated as being present, not even once. In evaluating the many completed risk assessments, the team found that two of the unused factors (Factor number 8 “crew rest” and number 22 “stopping distance”) would be considered violations of the Federal Aviation Regulations (FARs) in some instances. They discovered that pilots, even if they were legal at the time, were not going to admit to exceeding limits that exist in other types of flying. In essence, some of the more restrictive FARS could be considered “best practice.” For example, it is perfectly legal (albeit not all that smart) to exceed a 14-hour duty day when flying privately (FAR part 91); however, when flying on a charter flight under FAR part 135, it is not. Pilots never once admitted to the factor “Crew Rest (less than 10 hours prior to duty)” (CFR14, FAR 91, 135). Another risk factor with FAR-related issues concerned runway length. The factor was labeled as “stopping distance more than 80% of runway available.” Again, this condition is legal part 91 but not part 135, at least in the planning stage (CFR14, FAR 91, 135). The pilots once again avoided this factor completely. After much discussion within the safety management team, it was decided to simply modify the risk factors keeping the initial intent, but presenting the factor in a way that wouldn't require a pilot to admit to violating if not an FAR maybe best practice. The "rest" risk factor dealt with fatigue so the team changed it to "flight during night circadian low." The "stopping distance" factor was put in line with part 135 at 60%. The changes made were not without precedent; when the FRAT was first implemented, for example, the Flight Safety Officer called one of the original developers of the tool (Peter Neff) primarily to ask if an operation that flies almost every other flight in the mountains necessarily needed to use the risk value listed. His advice was indispensable in helping the team understand how the FRAT could be tailored to a specific operation (Neff, 2008). The team eventually decided to leave the values alone and just accept a higher score, but five years in, the team is a little more versed in the process.

Recommendations

Six years after the FAA issued the original InFo containing the turbine operators FRAT, many more options for Flight Risk Assessment Tools are now available to those just developing their process. Automatic FRATs are now available in flight dispatch software packages, flight-planning websites, and as part of the services provided by large flight handlers (FOS, Universal, FltPlan/safety.com, 2013). These systems can greatly simplify the risk assessment process but as with any automation, situational awareness can suffer if not used correctly. The one advantage to using a manual FRAT is that when some form of mitigation is required, the risks can be easily identified because as you manually mark off whether or not a risk factor is present, you also identify them. This makes it easier to analyze and assess the factors that may need to be mitigated (FAA, 2007). This is not to say that risks can't be identified with an automatic FRAT; identification may not be as easy, however. The safety team has had several discussions about automatic FRATs; the recommendation they have for anyone using one is to pay attention to what the numbers tell you. Set your own baselines or benchmarks. When FltPlan.com tells you your risk score is a 14 for instance, pay attention to what a flight with a 14 score is like. Look at the details of the flight so you know what to mitigate when the score is high. Most of all, whatever process you use, make it your own and make it a system that you will use.

Conclusion

Flight risk assessment is a big part of any safety management system. A good process is one that is understood by those who use it, provides results that are easily interpreted, and most importantly, one that crews will use. This case study was not meant to be an all-encompassing primer on flight risk assessment but simply an example of how one operator went about setting up a process. Over the five-year review, there were some unintended consequences both in the good and bad categories, but that is half the fun in designing a process. Sometimes that is where people learn the most. In the end, if a flight department can design a process that pilots will use, that empowers them to back-up their decisions with objective data, and can evolve with the company, it can be considered a success.

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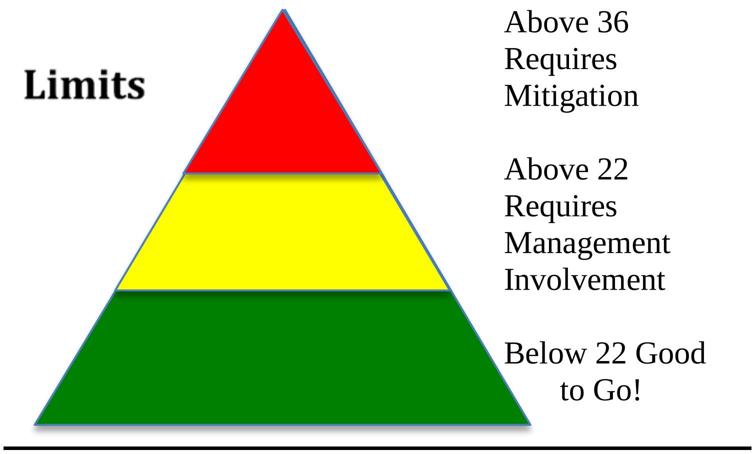
Appendix 1

Flight Operations
Risk Assessment Process



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- Pop-up trip with less than 4 hours notice.
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- Maintenance checks and maintenance ferry flights.
- MEL or CDL flights requiring Day VMC or non-standard aircraft flight configuration.
- Flight is conducted between the hours of 22:00 – 05:00 (during the circadian low) appropriate to the time zone you are adjusted to at the time.
- Rule of three occurs.

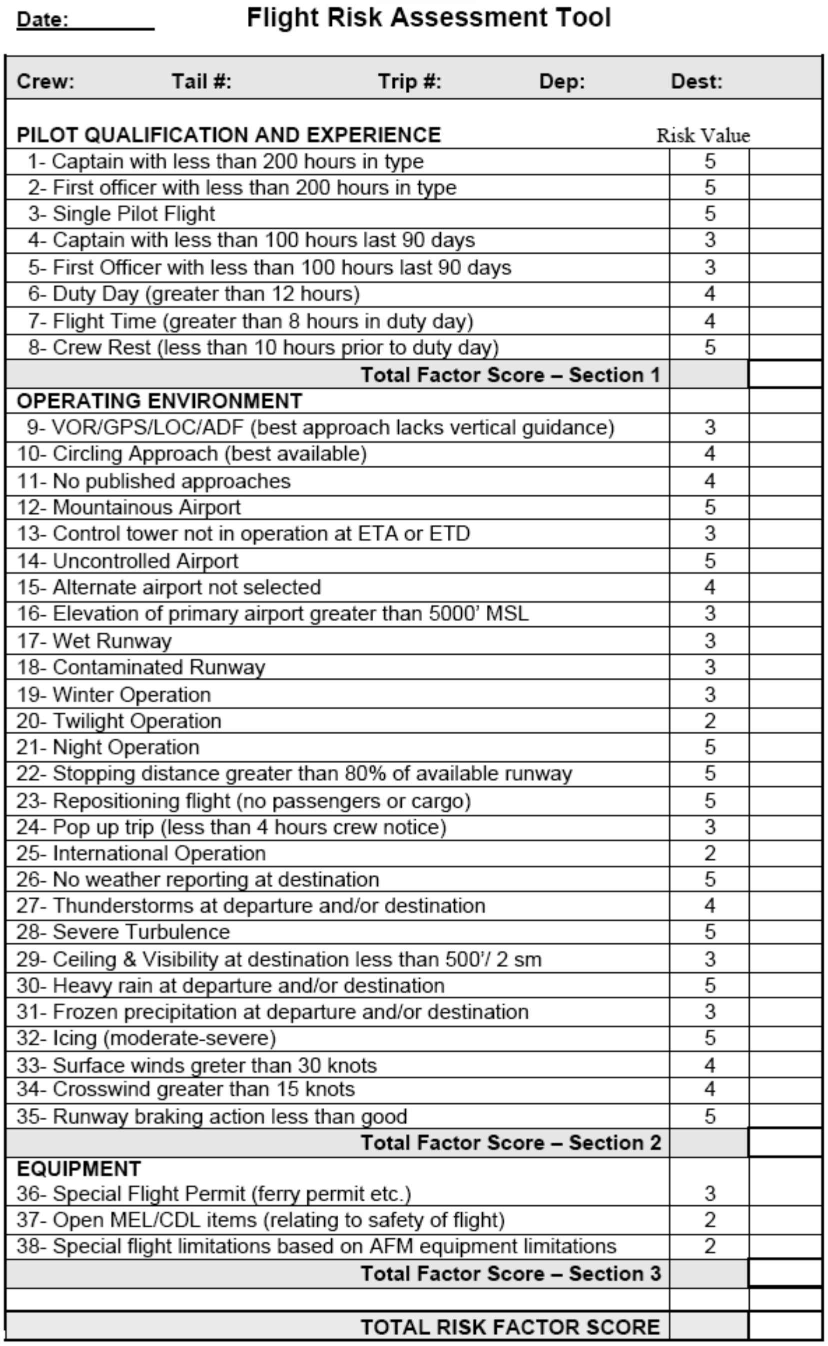
Other conditions appropriate for the completion of a risk assessment include, but are not limited to:

- Gut feeling
- Interest (idea that things may be stacking up).
- Concern from another crewmember, flight coordinator, operational management
- Night operations into mountainous airports listed in the Mountain Airport Restriction Table
- International flights
- Duty day in excess of 12 hours

Risk assessments may be generated by anyone:

- Captain
- First Officer
- Flight Attendant
- Dispatcher
- Management
- Passenger

To complete a risk assessment, write the risk value for a particular risk factor present in the empty box to the right of the indicated value. Total up the risk values for each section then add section totals to determine the total risk factor score.



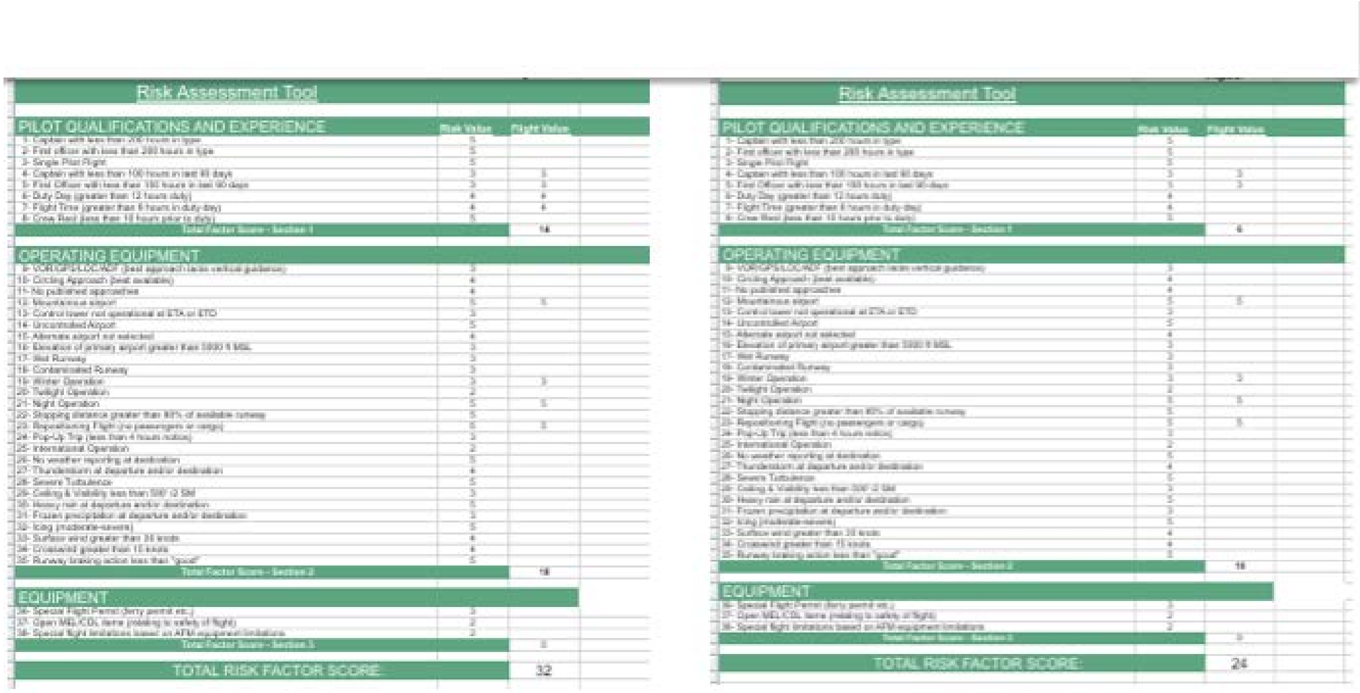
Date: ________

Flight Risk Assessment Tool

Crew: **Tail #:** **Trip #:** **Dep:** **Dest:**

PILOT QUALIFICATION AND EXPERIENCE	Risk Value	
1- Captain with less than 200 hours in type	5	
2- First officer with less than 200 hours in type	5	
3- Single Pilot Flight	5	
4- Captain with less than 100 hours last 90 days	3	
5- First Officer with less than 100 hours last 90 days	3	
6- Duty Day (greater than 12 hours)	4	
7- Flight Time (greater than 8 hours in duty day)	4	
8- Crew Rest (less than 10 hours prior to duty day)	5	
Total Factor Score – Section 1		
OPERATING ENVIRONMENT		
9- VOR/GPS/LOC/ADF (best approach lacks vertical guidance)	3	
10- Circling Approach (best available)	4	
11- No published approaches	4	
12- Mountainous Airport	5	
13- Control tower not in operation at ETA or ETD	3	
14- Uncontrolled Airport	5	
15- Alternate airport not selected	4	
16- Elevation of primary airport greater than 5000' MSL	3	
17- Wet Runway	3	
18- Contaminated Runway	3	
19- Winter Operation	3	
20- Twilight Operation	2	
21- Night Operation	5	
22- Stopping distance greater than 80% of available runway	5	
23- Repositioning flight (no passengers or cargo)	5	
24- Pop up trip (less than 4 hours crew notice)	3	
25- International Operation	2	
26- No weather reporting at destination	5	
27- Thunderstorms at departure and/or destination	4	
28- Severe Turbulence	5	
29- Ceiling & Visibility at destination less than 500'/ 2 sm	3	
30- Heavy rain at departure and/or destination	5	
31- Frozen precipitation at departure and/or destination	3	
32- Icing (moderate-severe)	5	
33- Surface winds greter than 30 knots	4	
34- Crosswind greater than 15 knots	4	
35- Runway braking action less than good	5	
Total Factor Score – Section 2		
EQUIPMENT 36- Special Flight Permit (ferry permit etc.)	3	
37- Open MEL/CDL items (relating to safety of flight)	2	
38- Special flight limitations based on AFM equipment limitations	2	
Total Factor Score – Section 3		
TOTAL RISK FACTOR SCORE		

Appendix 2



These two de-identified flight risk assessments show how one crew used the data from a planned trip with a long duty day to convince upper management to spring for the cost of a hotel room. The crew repositioned the night before reducing the risk value by 8 points.

Integrating Unmanned Aircraft Systems into the National Airspace System

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Abstract

The unmanned aircraft systems (UASs) community is waiting to take full advantage of the U.S. National Airspace System (NAS). One concern that must be addressed before UASs can be integrated into the UAS is whether or not the UASs community is open and receptive to recommendations regarding safety. In April of 2006, a Customs and Border Protection (CBP) MQ-9 Predator B crashed. The National Transportation and Safety Board (NTSB) investigated the accident; the board's final report included a number of recommendations for improving operations of UASs in the NAS. This study discusses the actions taken by the CBP and General Atomics Aeronautical Systems Incorporated (GA-ASI) in response to the NTSB's Safety Recommendations following their accident investigation. The extent to which the board's recommendations were incorporated will provide insight into the feasibility of incorporating UASs into the NAS. Overall findings reveal an age range of 39 to 59 years of age of predominantly white male pilots and sensor operators. Federal Aviation Administration certificated pilots: 41.0% Commercial pilots; 43.6% Air Transport pilots; 51.3% flight instructors; and 74.4% with instrument ratings. Forty one percent of those with a pilot certificate had relied on military experience to acquire those certificates. Eighty eight percent of the respondents were predominantly in agreement that the UAS community was receptive to NTSB safety recommendations. Respondents mostly disagreed that the UAS community was receptive to the recording of conversations. Respondents predominantly disagreed that contemporary aspects of human factors had been designed into operator control interfaces and Ground Control System layout.

Introduction

On April 25, 2006, about 0350 Mountain Standard Time, a MQ-9 (Predator B) aircraft, serial number BP-101, call sign OMAHA 10, collided with the terrain approximately 10 nautical miles northwest of the Nogales International Airport, Nogales, AZ. The UAS was owned by U.S. CBP and operated as a public-use aircraft (Sullivan & Keenan, 2006). This was the first UAV accident that was investigated by the NTSB. Up to that point in time the majority of UAV crashes took place in combat environments or in restricted airspace that are beyond the purview of civilian aviation authorities.

Unmanned Aircraft Systems development has not undergone the same level of scrutiny as manned aircraft system development. For example, while still under development the unarmed Predator A (RQ-1) was put into service and flew its first combat missions in 1995. The RQ-1 underwent many changes in an attempt to keep up with U.S. Air Force demands. The requirement for ever-present eyes in the sky, in various combat theaters around the world, led the Department of Defense to skip the normal test and evaluation process that would have been required to develop a manned aircraft system. Development moved quickly from the RQ-1 to an armed version of Predator A (MQ-1) and shortly thereafter the larger Predator B (MQ-9). The combat driven nature of the UASs' community brought about a "make do" culture that eventually became a contributing factor in the loss of Omaha 10.

This lack of stringent test and evaluation, typical of manned systems development, allowed some design errors in Ground Control Stations (GCSs) to go unnoticed. Lack of human factors engineers in the initial program amplified the problems. Human factors engineers may have seen errors early on and encouraged modification of GCSs to avoid long term problems.

The GCSs were designed more like a computer than an aircraft cockpit. Common tasks for pilots in a cockpit were counterintuitive in computer engineer designed GCSs. Customs and Border Protection used pilots of varying experience levels and backgrounds to control their aircraft. Minimum requirements for CBP pilots in 2006 were approximately 1500 hours of flying time and a commercial pilot license with an instrument rating.

Review of Relevant Literature and Research

Unmanned aircraft (UA) are not a new idea. Unmanned aircraft go back to ballooning and early powered flight. The beginning of unmanned powered flight starts in World War I when the Royal Flying Corps took the gyro stabilized compass and radio controls that were still in their infancy and developed the flying bomb. At the same time the U.S. Army Air Corps was developing the Kettering Bug, another ill-fated project. These projects were not successful, but were the technology base that led to further developments. Germany had the best known unmanned system in World War II with their V-1 buzz bombs. These systems had little strategic success but were excellent terror weapons and caused British forces to spend a large amount of their assets defending against V-1 attacks (Yenne, 2004).

Allied forces also had a number of unmanned systems but they were completely unknown to the public. Modified B-17s and B-24s were launched with flight crews onboard. When the aircraft were at cruise altitude the crew bailed out over friendly territory and control was handed over to a chase aircraft using radio controls (Yenne, 2004).

Unmanned aircraft continued to be developed for military use with each passing world conflict. In 1982 Israel was concerned with Syrian forces controlling a section of Lebanon known as the Bekaa Valley; at that time the most heavily defended airspace in the world. Israeli forces used UASs to beam live video pictures of Syrian forces to Israel. Israeli forces also used UASs as decoys. In an air battle that lasted approximately two hours all Syrian surface to air missile sites were destroyed. There were no manned aircraft lost by Israeli forces. This battle changed how the world looked at UA and has affected the design and use of UASs since that time (Clary, 1988).

Unmanned Aircraft Systems can provide a level of persistence and stamina that far exceeds human capacity and, by removing humans from aircraft, UASs provide options for risk taking and risk avoidance not previously available with a manned platform ("U.S. Department," 2005).

Unmanned Aerial Vehicles have continued to advance and the means by which they are controlled has advanced as well. Initially, Unmanned Aerial Vehicles (UAVs) could only fly within line of site of the control station; satellite telemetry has enabled global control from GCSs that may be fixed or mobile.

The UAV industry grew rapidly based largely upon military demands. Manufacturers of UASs have developed their own proprietary means of communications and control, with little or no standardization between manufacturers. This became problematic, even for the military, and standardization became an issue. Accordingly, the North Atlantic Treaty Organization has accepted STANAG (Standard Agreement) 4586 for increased interoperability for GCSs. Some U.S. manufacturers are using this standard in the development of common GCSs in the hope of developing a common mental model that crosses multiple airframes (Cummings, Kirschbaum, Sulmistras, & Platts, n.d.).

All UASs must have a GCS of some sort and they all perform some or all of three main functions of mission planning, control, and data manipulation. The ability for GCSs to perform these functions is system dependent (Anderson, 2002). Some GCSs are completely automated with pushbutton commands for takeoff and landing. Others require that a pilot manually control aircraft for all or part of the flight. There are as many variations as there are aircraft systems. Some systems have missions planned and sent to UASs prior to launch, while others are planned on the fly (Doherty et al., 2000).

There is a move to develop systems that will coordinate and control multiple aircraft. Coordination of multiple unmanned aircraft will give planners a huge advantage in combat mission planning (McLain, 1999). While some researchers are looking at ways to coordinate and control multiple unmanned aircraft (Diamond, Rutherford, & Taylor, 2009), there needs to be more focus on how to integrate UASs into the NAS.

The manufacturers of UASs are looking to civil and commercial applications for their aircraft, especially applications characterized as dull, dangerous, or dirty. There are many applications such as pipeline inspection, border security, firefighting, agricultural management, communications relay, and air-freight operations that are particularly suited for unmanned aircraft (Hayhurst et al., 2007). Unmanned Aircraft Systems can also act as inexpensive highly mobile satellites for communications and data collection.

Acceptance of UASs into the NAS by the Federal Aviation Administration (FAA) will require that UASs' community improve its safety record. Mishap rates for Predator aircraft are almost 30 times greater than that of manned aircraft (Nullmeyer, Herz, & Montijo, 2009).

Most UASs are flown overseas in combat areas or in restricted airspace in the US. Accidents that happen in those locations are outside the span of influence of the FAA and NTSB. There are a few UASs that are flown in the NAS with FAA approval. Unmanned Aircraft Systems operation within the NAS require a Certificate of Authorization (COA) from the FAA (NTSB, 2007). Accordingly, when Omaha 10 crashed in the Arizona desert the investigation fell under the auspices of the NTSB.

In April of 2006, the NTSB started its first investigation of an UA accident. This investigation resulted in 22 safety recommendations issued to GA-ASI and CBP (Werfelman, 2007). Errors of commission and omission led directly to the loss of Omaha 10. The pilot failed to follow checklist procedures after the pilot payload operator (PPO-1), suffered a rack lock up resulting in an unintended engine shut off and eventual loss of aircraft (Sullivan & Keenan, 2006).

The GCS is the equivalent of the cockpit in a manned aircraft. In a manned aircraft the controls on the left and right position perform the same task. The controls on both sides of Predator GCSs are identical too, however they have different functions depending on whether a position is a designated pilot station or a designated sensor operator station. Changing the designation (pilot/sensor operator) of a station is called a "rack switch." Proper configuration of controls, levers, and switches is essential during rack switch. The position of the condition lever at the time of the rack switch caused the engine to shut down in the Omaha 10 accident (Carrigan, Long, Cummings, & Duffner, 2008).

The Omaha 10 engine failure was not an isolated event. In 2004 a GA-ASI' Altair aircraft encountered a similar rack lock and switch and, with switches in the wrong position resulted in an unintended engine shutdown. The pilot restarted the engine and was able to safely recover the aircraft (Williams, 2006). On another occasion, an Army Shadow was lost when the engine shut off command was accidentally sent to the aircraft while it was returning to land (Williams, 2006).

A cohesive integration of UASs into the NAS is dependent upon the UASs' community to adapt to FAA regulation and scrutiny. The FAA has a mandate to open U.S. airspace to military, commercial, and privately owned UASs by September 30, 2015. Successful integration of UASs into NAS should enable considerable economic growth (Koenig, 2012).

Methodology

Research Model

The researchers' intent was to collect data from UASs' crew members from those sections of UASs' community that are currently operating GA-ASI UASs within the NAS. A mixed method approach to data collection and analysis was used whereby qualitative data was gathered based upon participant's extent of agreement on 19 Likert scale questions and quantitative data was gathered from participants reporting on specific demographic criteria.

Survey population. The total population of pilots and sensor operators currently involved with these specific UASs was fewer than 100 individuals. United States CBP personnel and civilian personnel operating UASs as government employees (Government Contractors), make up the population for this study.

Survey instrument. The data collection device was a mixed method survey designed by the researchers. There were 31 questions that consisted of 10 Demographic questions, 2 Organizational questions, and 19 Operational questions (Likert scale).

The survey instrument was developed through an iterative process between the two researchers. Once the instrument had been reviewed and approved by the Institutional Review Board of Embry-Riddle Aeronautical University the survey was distributed to an expert panel made up of subject matter experts and academics experienced in data collection and analysis. Comments/suggestions of the expert panel were reviewed, incorporated as appropriate, and the instrument was deemed valid.

The Likert questions were based upon a scale of agreement: Strongly Agree; Agree; Undecided; Disagree; and Strongly Disagree. Fourteen of the 19 Likert scale questions were directly related to NTSB recommendations from the Omaha 10 accident investigation, 2 questions were related to contemporary human factors issues, 2 questions were related to recurrent training requirements, and 1 question was related to the implementation of a "Safety Plan" into UASs' operations. The survey was designed to determine the extent to which UASs' community had addressed the recommendations from the NTSB's Omaha 10 accident investigation. Respondents were also provided the opportunity to make additional comments at the end of the survey.

Participant confidentiality was protected to the greatest extent possible. Participants were notified that they could terminate their participation at any time. The survey instrument received appropriate Institutional Review Board approval prior to its use in any capacity.

Distribution Method

For the greatest possible dissemination and ease of response, an internet-based method of distribution was used. Letters of introduction were sent to CBP and corporate leadership at all known locations asking that they help to promote the research. Direct emails were sent when possible to members of the organizations to encourage the use of the survey with the request that it be shared with co-workers. The survey was made available on March 25, 2012, and it was active for 90 days. The first response was recorded on March 30, 2012, the last response was recorded on May 30, 2012.

Treatment of the Data

Forty-three surveys were returned within 90-days of the survey being made available on Survey Monkey. Two of these responses were readily rejected because they were not completed. Two other responses were rejected due to a number of inconsistencies; responding to multiple choice questions by selecting all of the choices, including “none” and “prefer not to answer.” Accordingly, out of the 43 original responses 39 were determined to be useable. Out of these 39 responses there were two questions in which there were 38 responses, no rationale was provided, and N was adjusted to reflect an accurate response rate.

Findings

The researchers believe that a profile of UAS community is a key component of the overarching question as to whether or not UASs can be safely integrated into the NAS. Who are these rather innocuous individuals, how old are they, what gender are they, what is their experience based upon, and to what extent are they familiar with safe operations within the NAS? These are just a few of the questions posed to those participating in this study. A thorough description of pilot and sensor operators follows.

Background and Demographic Environment

Nineteen of those responding (48.7%) indicated they were in the 25 to 38 year age range, 16 respondents (41.0%) indicated they were in the 39 to 59 year age range, and 2 respondents (5.1%) indicated they were in the 60 years plus age range. Two respondents (5.1%) indicated they "Prefer Not to Answer" the question. Thirty-six (92.3%) of those responding indicated they were male, no respondents indicated they were female, three respondents (7.7%) indicated they "Prefer Not to Answer" the question. Thirty-three respondents (84.6%) indicated post-secondary degrees; 23 (59.0%) having a bachelor’s degree and 10 (25.6%) having a graduate degree. See Table 1 for responses to the question: "Which of the following best describes your racial/ethnic group?”

Table 1

Racial Ethnic Breakdown

Race/Ethnicity	Number Responding	Percentage N = 39
African American/Black	1	2.6%
American Indian/Alaska Native	0	0.0%
Asian American/Asian	0	0.0%
Caucasian/White	33	84.6%
Native Hawaiian/Pacific Islander	0	0.0%
Hispanic or Latino	2	5.1%
Prefer Not to Answer	2	5.1%

See Table 2 for responses to the question: "Please identify the type of Flight Instructor certificates(s) you possess (check all that apply)."

Table 2

Type of Flight Instructor

Certified Flight Instructor (CFI) Type	Number Responding	Percentage N = 39
None	16	41.0%
CFI only	3	7.7%
CFI Instrument	5	12.8%
CFI and Multi-engine	3	7.7%
CFI, Multi-engine, Instrument	12	30.8%

Thirty-four respondents (87.2%) indicated they did not possess any non-pilot FAA issued certificates. Two respondents (5.1%) indicated possession of a Mechanic License with Airframe and Powerplant ratings, one respondent (2.6%) indicated possession of Mechanic

License with Repairman rating, one respondent (2.6%) indicated possession of an Air Traffic Controller certificate, and one respondent (2.6%) indicated possession of a Flight Engineer certificate.

Sixteen respondents (41.0%) indicated that their FAA certificates were based upon military competency, 23 respondents (59.0%) indicated that their FAA certificates were not based upon military competency.

Twelve respondents (30.8%) indicated that some of their UAS/UAV experience was based upon military experience; four of these respondents (10.3%) indicated 100% of their UAS/UAV experience was based upon military experience. Thirty one respondents (79.5%) indicated that some of their UAS/UAV experience was based upon CBP experience; 20 of these respondents (51.3%) indicated that 100% of their UAS/UAV experience was based upon CBP experience. Thirteen respondents (33.3%) indicated that some of their UAS/UAV experience was from a source other than the military or CBP; of these respondents 4 (10.3%) indicated that 100% of their UAS/UAV experience was based upon a source other than the military or CBP; the source of this experience was not provided.

Thirty-three respondents (84.6%) indicated they had logged 38,263 hours as pilot for an average of 1,159.0 hours per pilot, 19 respondents (48.7%) indicated they had logged 14,175 hours as a sensor operator for an average of 746.1 hours per sensor operator, and 3 respondents (7.7%) indicated that had logged 9800 hours as "Other" for an average of 3,266.7 hours each; "other" was not specified.

Organizational

Twenty-six respondents (66.6%) indicated CBP and 13 respondents (33.3%) indicated civilian contractor as their place of employment. Six respondents (15.4%) indicated GA-ASI as their employer, two respondents (5.1%) indicated Crew Training International as their employer, one respondent (2.6%) indicated University of North Dakota/GA-ASI as their employer, and one respondent (2.6%) indicated “Prefer Not to Answer.”

See Table 3 for responses to the question: "Please identify all flight related FAA issued certificates/ratings you possess (check all that apply).”

Twenty-two respondents (57.9%) indicated pilot, seven respondents (18.4%) indicated sensor operator, and nine respondents (23.7%) indicated pilot/sensor operator. One respondent did not answer this question; no rationale was provided and N was adjusted from 39 to 38.

Operational

In this section of the survey 14 of the 19 questions asked were directly related to the NTSB’s Safety Recommendations based upon its investigation into the Omaha 10 accident. Two questions were related to contemporary human factors issues, two questions were related to re-currency training requirements, and one question was related to whether or not a Safety Plan had been implemented. Please see Table 4.

Table 3

Federal Aviation Administration Issued Certificates/Ratings

Certificate/Rating	Number Responding	Percentage N = 39
Certificate		
None	5	12.8%
Student Pilot	1	2.6%
Sport Pilot	0	0.0%
Recreational Pilot	0	0.0%
Private Pilot	9	23.1%
Commercial Pilot[a]	16	41.0%
Air Transport Pilot[b]	17	43.6%
Rating		
Flight Instructor[c]	20	51.3%
Instrument	29	74.4%
Single Engine	27	69.2%
Multi Engine	30	76.9%
Land	31	79.5%
Sea	4	10.3%

Note. [a]Commercial Pilot reported exclusive of Air Transport Pilot certificate. [b]Air Transport Pilot as reported is inclusive of Commercial Pilot with the exception of one Air Transport Pilot only without Commercial Pilot being reported. [c]In the previous question respondents reported a total of 23 Flight Instructor Ratings, responses to this question indicate 20 Flight Instructor ratings. This may be due to duplicate reporting related to Certified Flight Instructor, Certified Flight Instructor Instrument, Certified Flight Instructor Multi Engine, etc.

Table 4

Survey Results: Extent of Agreement

Response (N = 39*)

Question	SA	A	U	D	SD
13. The UAS on which you are a crew member has measures in place to prevent inadvertent engine shutdown.	17	17	2	2	1
14. The UAS on which you are a crew member ensures that the transponder continues to provide beacon code … if an engine shuts down in flight.	23	14	1	1	0
15. The UAS on which you are a crew member has adequate visual indications of safety-critical faults, such as engine-out conditions and console lockups.	9	19	5	5	1
16. The UAS on which you are a crew member has adequate aural indications of safety-critical faults ….	7	17	7	6	2
17. Unit developed lost-link mission profiles to ensure that lost-link mission routes minimize the potential safety impact ….	32	6	0	0	0
18. Organization developed lost-link mission profiles to ensure … the aircraft will proceed to a safe zone for flight termination.	33	6	0	0	0
19. Organization requires that UAS crew members be trained concerning … performance and flight path … during a lost-link mission.	28	10	1	0	0
20. The UAS on which I am crew of has a means of restarting … that is autonomous, not requiring link with the GCS.	15	17	4	2	1
21. Organization participates in periodic operational reviews … for standard and nonstandard UA operations (Continental U.S. operations only).	7	15	10	6	1
22. Organization has taken adequate steps to identify and correct the causes of console lockups.	13	15	7	3	1
23. My organization has implemented a training program to ensure aircrew knowledge and proficiency in executing emergency procedures.	17	13	4	5	0

(continued)

Question	SA	A	U	D	SD
24. My organization requires that a backup pilot … be readily available during UAS operations.	12	14	10	2	1
25. My organization developed a safety plan, which ensures that hazards… are identified and that necessary actions are taken to mitigate the corresponding safety risks to the public.	20	15	3	1	0
26. My organization requires all conversations … be recorded and retained to support accident investigations.	6	10	6	11	6
27. My organization requires that all telephone conversations, to and from the GCS, be recorded and retained to support accident investigations.	0	4	11	17	7
28. Contemporary aspects of HF engineering have been designed into the pilot and sensor operator control interfaces on the UAS ….	2	11	5	10	11
29. Contemporary aspects of HF engineering have been designed into the layout of the GCS of which I am a crewmember.	3	7	7	14	8
30. Organization requires annual re-currency training in aircraft systems and in emergency procedures for the manned aircraft I fly.	14	11	5	4	2
31. Organization requires annual re-currency training in aircraft systems and in emergency procedures for the unmanned aircraft that I fly	18	10	2	6	3

Note. *In question 17 one respondent did not answer the question and N was adjusted to 38.

Discussion

Data was collected using a survey that asked for demographic information, organizational affiliation, and UASs crew member's extent of agreement on UASs' community's response to the NTSB Safety Recommendations from the Omaha 10 accident investigation. Two human factors questions that were not related to the NTSB Safety Recommendation were also included. The survey did not require that those answering the survey to be aware of the accident or the NTSB findings.

Demographics

The data indicates that respondents were predominantly between the ages of 25 to 45 (74.4%), men (92.3%), and Caucasian/white ethnicity (84.6%). Thirty-three respondents

(84.6%) indicated they possessed a post-secondary degree, 10 (25.6%) indicated they had completed a graduate degree.

Survey results indicate a large number of respondents were certificated by the FAA in a variety of pilot and non-pilot categories. In the pilot categories 16 respondents (41.0%) indicated possession of a Commercial Pilot certificate, 17 respondents (43.6%) indicated possession of an Air Transport Pilot certificate, 23 respondents (59.0%) indicated possession of Certified Flight Instructor certificate, 29 respondents (74.4%) indicated possession of an Instrument rating, and 30 respondents (76.9%) indicated possession of a Multi-engine rating. In the non-pilot categories two respondents (5.1%) indicated possession of a Mechanic license with Airframe and Power Plant ratings; one respondent (2.6%) indicated possession of a Repairman's license; one respondent (2.6%) indicated possession of an Air Traffic Controller certificate; and one respondent (2.6%) indicated possession of a Flight Engineer certificate.

An important finding related to the demographic data is the extent of FAA pilot certifications and associated ratings. Thirty-three respondents (84.6%) indicated possession of either a Commercial Pilot certificate or an Air Transport Pilot certificate. Twenty-three respondents (59.0%) indicated they were flight instructor rated and 29 respondents (74.4%) indicated they were instrument rated. These numbers indicate that UASs pilots and sensor operators participating in this study are familiar with FAA policies, procedures, and regulations for the safe operation of aircraft in the NAS. These numbers are important because they reflect extensive qualification and practical experience in the safe operation of aircraft in the NAS. This finding is supported by the literature which indicates that CBP requires FAA Commercial Pilot certificates and Instrument ratings of their UASs pilots.

Organization Affiliation

Sixty-six percent of survey respondents indicated they were employed by CBP and 33.3% indicated Civilian Contractor. This response illustrates the environment from which future pilots and sensor operators will have acquired their experience. This is important considering this government-based experience will establish the foundation for the future of UASs operations in the NAS. Of those respondents indicating employment by a civilian contractor: (a) six (15.4%) indicated GA-ASI; (b) two (5.1%) indicated Crew Training International; (c) one (2.6%) indicated University of North Dakota/GA-ASI; and (d) one Preferred Not to Answer. Survey results indicate the majority of respondents were either UAS pilots (57.9%) or UAS pilots/sensor operators (23.7%). The researchers anticipate that the numbers of pilots and sensor operators will become relatively equal over time.

National Transportation Safety Board Safety Recommendations

Fourteen of the questions on the survey were specifically based upon the NTSB Safety Recommendations following the Omaha 10 accident investigation (NTSB, 2007). These safety recommendations were used to craft either a question or a statement in which respondents could express their extent of agreement on a five point Likert scale. This was done to determine to what extent respondents agreed that CBP had incorporated the recommendations into UASs flight operations. The questions that were developed addressed only those safety recommendations that researchers believed were relevant to the intent of the study. Accordingly, Safety Recommendations A-07-75, and A-07-80 through A-07-83 were not addressed in the study. The findings are reported as they relate to central tendency: Mode and Median are illustrated in Table 5. Calculations of central tendency were based upon those answering each respective question. The alpha-numeric in parenthesis, for example (Q13), provides a cross-reference from the safety recommendations to the corresponding questions.

Recommendation A-07-70 (Q13). Modify the UAS to ensure inadvertent engine shutdown does not occur. Software and hardware were changed by GA-ASI to eliminate inadvertent engine shutdowns. Accordingly, 34 survey respondents (87.2%) "Strongly Agree" or "Agree" that these changes have significantly reduced inadvertent engine shutdowns, 3 respondents (7.7%) disagree, and 2 respondents (5.3%) were undecided.

Recommendation A-07-71 (Q15/16). Establish adequate visual and aural indications of safety-critical faults, such as engine-out conditions and console lockups, and present them in order of priority, based on the urgency for pilot awareness and response. Twenty-eight survey respondents (71.8%) "Strongly Agree" or "Agree" that adequate visual indications of safety-critical faults have been established, six respondents (15.4%) did not agree, and five respondents (12.8%) were undecided. Twenty-four respondents (61.5%) "Strongly Agree" or "Agree" that adequate aural indications of safety-critical faults have been established, eight respondents (20.5%) indicated they did not agree, and seven respondents (17.9%) were undecided.

Recommendation A-07-72 (Q17/18). Develop lost link mission profile routes minimizing safety risk to persons on the ground, optimizing potential to recover data-link of the aircraft, and provide for a safe crash zone if the aircraft cannot be recovered. Thirty-eight survey respondents (100%) "Strongly Agree" or "Agree" that lost-link missions routes minimize the potential safety impact to persons on the ground and optimize the ability to recover the data-link. One survey respondent did not answer this question, no rationale was provided and N was adjusted down to 38 for this question. Thirty-nine respondents (100%) "Strongly Agree" or "Agree" that in the absence of data-link recovery, the UAV will proceed to a safe zone for flight termination. It is interesting to note that there were no "Undecided," "Disagree," or "Strongly Disagree" responses related to Recommendations A-07-72.

Recommendation A-07-73 (Q19). Pilots be trained in expected performance and flight path of the UA during a lost-link mission. Thirty-eight survey respondents (97.4%)

Table 5
Survey Results: Measures of Central Tendency

Question (Q)	Response (N = 39*) Mode	Median
13. The UAS on which you are a crew member has measures in place to prevent inadvertent engine shutdown.	5	4
14. The UAS on which you are a crew member ensures that the transponder continues to provide beacon code … if an engine shuts down in flight.	5	5
15. The UAS on which you are a crew member has adequate visual indications of safety-critical faults, such as engine-out conditions and console lockups.	4	4
16. The UAS on which you are a crew member has adequate aural indications of safety-critical faults ….	4	4
17. My flying unit developed lost-link mission profiles to ensure that lost-link mission routes minimize the potential safety impact ….	5	5
18. My flying organization developed lost-link mission profiles to ensure … the aircraft will proceed to a safe zone for flight termination.	5	5
19. My organization requires that UAS crew members be trained concerning … performance and flight path … during a lost-link mission.	5	5
20. The UAS on which I am a crew member of has a means of restarting … that is autonomous, not requiring link with the GCS.	4	4
21. My organization participates in periodic operational reviews … for standard and nonstandard UA operations (Continental U.S. operations only).	4	4
22. My organization has taken adequate steps to identify and correct the causes of console lockups.	4	4
23. My organization has implemented a training program to ensure aircrew knowledge and proficiency in executing emergency procedures.	5	4
24. My organization requires that a backup pilot … be readily available during UAS operations.	4	4

(continued)

Question (Q)	Mode	Median
25. My organization has developed a safety plan, which ensures that hazards… are identified and that necessary actions are taken to mitigate the corresponding safety risks to the public.	5	5
26. My organization requires that all conversations … be recorded and retained to support accident investigations.	2	3
27. My organization requires that all telephone conversations, to and from the GCS, be recorded and retained to support accident investigations.	2	2
28. Contemporary aspects of human factors engineering have been designed into the pilot and sensor operator control interfaces on the UAS ….	4	2
29. Contemporary aspects of human factors engineering have been designed into the layout of the GCS of which I am a crewmember.	2	2
30. My organization requires annual re-currency training in aircraft systems and in emergency procedures for the manned aircraft I fly.	5	4
31. My organization requires annual re-currency training in aircraft systems and in emergency procedures for the unmanned aircraft that I fly.	5	4

Note. *In question 17 one respondent did not answer the question and N was adjusted to 38.

“Strongly Agree” or “Agree” that UAS operators receive training in how to respond in a lost-link mission scenario.

Recommendation A-07-74 (Q14). Transponders should to continue to operate normally even if the engine shuts down in flight and, if the transponder fails, that the pilot receives a clear indication. Thirty-seven survey respondents (94.9%) “Strongly Agree” or “Agree” that transponders will continue to operate normally, in all modes even if an engine shuts down in flight. The operations handbook states that this is true and that if the aircraft is lost-link, transponders will transmit the code associated with the lost-link mission.

Recommendation A-07-76 (Q20). Develop a means of restarting the UA engine during a lost-link emergency mission profile that is autonomous, not requiring data-link with the GCS. Thirty-two survey respondents (82.1%) “Strongly Agree” or “Agree” that the UA has a means of restarting the engine during a lost-link emergency mission profile that does not rely on line-of-sight control. However, three respondents (7.7%) “Disagree” or “Strongly Disagree” that the improvement to UA software has adequately addressed this recommendation.

Recommendation A-07-77 (Q21). The UASs' community and local Air Traffic Control should participate in periodic operational reviews between UAS operation teams and local air traffic control facilities, with specific emphasis on face-to-face coordination between the working-level controller and UA pilot(s), to clearly define responsibilities and actions required for standard and nonstandard UA operations. Twenty-two survey respondents (56.4%) "Strongly Agree" or "Agree" that this recommendation has been addressed. Seven respondents (17.9%) "Strongly Disagree" or "Disagree." Although these numbers would indicate the majority of respondents agree that the recommendation has been addressed, it is interesting to note that 10 respondents (25.6%) were "Undecided." It would appear that there is either a communications breakdown across CBP or that this recommendation is handled differently at each flight location. The level of confidentiality of the survey prohibits a determination of where each respondent is geographically assigned.

Recommendation A-07-78 (Q26/27). All conversations, including telephone conversations, between UA pilots and air traffic control, other UA pilots, and other assets that provide operational support to UA operations, be recorded and retained to support accident investigations. Sixteen respondents (41.0%) "Strongly Agree" or "Agree," 17 respondents (43.6%) "Strongly Disagree" or "Disagree," and 6 respondents (15.4%) were "Undecided" that all radio transmissions were being recorded and retained to support accident investigations. No respondents indicated "Strongly Agree," 4 respondents (10.3%) "Agree," 24 respondents (61.5%) "Strongly Disagree" or "Disagree," and 11 respondents (28.2%) were "Undecided" that all GCS telephone conversations were being recorded and retained to support accident investigations. The extent of disagreement with these two statements is interesting. These responses are most likely a result of the "security" environment in which the respondents work. However, waving the security flag does not discount the need to record information that can be used in accident investigations. The results of these two questions reveal an area that will need to be addressed to ensure a cohesive existence between UASs' operations and manned aircraft operations in the NAS.

Recommendation A-07-79 (Q22). Investigate and resolve the cause of console lockups. Twenty-eight survey respondents (71.8%) "Strongly Agree" or "Agree" and four respondents (10.3%) "Strongly Disagree" or "Disagree" that adequate steps to identify and correct the causes of console lockups have been taken. Although seven respondents (17.9%) indicated they were "Undecided" on the corrective action taken the number of respondents in agreement indicates this recommendation has been addressed to a significant extent. However, the numbers of undecided, disagree, and strongly disagree responses should not go unnoticed. Contractors showed a higher positive response than CBP employees. This may be due to their greater longevity in the program and their having seen improvements in console lock-ups over time. Education in console lock-ups and ways to prevent them should be stressed in basic and refresher training.

Recommendations A-07-84 (Q23). Revise U.S. CBP's pilot training program to ensure pilot proficiency in executing emergency procedures. Thirty survey respondents (76.9%) "Strongly Agree" or "Agree" that emergency procedures training has been implemented. There were five respondents (12.8%) that "Disagree" and four respondents (10.3%) that were "Undecided." This data implies that emergency procedure training has been put into place and is currently incorporated as part of the normal flying practices at CBP. These responses are perplexing and quite diverse. A vast majority of respondents recognized the implementation of emergency procedures while nine respondents either disagree or were undecided that emergency procedures had been implemented.

Recommendation A-07-85 (Q24). Make backup crew members available. Twenty-six survey respondents (66.6%) "Strongly Agree" or "Agree" and three respondents (7.7%) "Strongly Disagree" or "Disagree" that this recommendation has been addressed. Ten respondents (25.6%) indicated they were "Undecided." Although this number is relatively small, when combined with respondents that indicated some level of disagreement, a total of 13 respondents representing 33.3% of those responding, have reservations regarding the implementation of corrective measures that address this issue.

Human Factors

Participants were asked two questions related to contemporary aspects of human factors. These two questions (Q28/29) do not pertain to a specific NTSB Safety Recommendation. However, researchers believed it was pertinent to ask UASs Pilots and Sensor Operators their opinion on these two contemporary aspects of human factors.

Thirteen survey respondents (33.3%) "Strongly Agree" or "Agree," 21 respondents (53.8%) "Strongly Disagree" or "Disagree," and 5 respondents (12.8%) were "Undecided" that contemporary aspects of human factors have been designed into the pilot and sensor operator control interfaces. Twenty-one respondents (53.8%) "Disagree," or "Strongly Disagree," that human factors have been addressed in the design of pilot and sensor operator control interfaces; 5 respondents (12.8%) were undecided.

Ten survey respondents (25.6%) "Strongly Agree" or "Agree," 22 respondents (56.4%) "Strongly Disagree" or "Disagree," and 7 respondents (17.9%) were "Undecided" that aspects of human factors have been designed into GCSs layout. Twenty-two respondents (56.4%) "Disagree," or "Strongly Disagree," that human factors have been addressed in the design of GCS layout; 7 respondents (17.9%) were undecided.

The responses to these two questions indicate, as far as those responding to the survey are concerned, that the majority of UASs' pilots and sensor operators are undecided or disagree that contemporary human factor aspects have been incorporated into the design of UASs. Although not related to a specific NTSB Safety Recommendation, these responses are an important finding of the study. The attention and commitment to Human

Factors in UASs/GCSs will need to mirror that of the FAA and manned aircraft systems to ensure a cohesive integration of UASs into the NAS.

Recurrent Training Requirements

The survey also addressed recurrent training requirements for manned and unmanned aircraft as a comparison to determine the need for annual recurrent training. These two questions (Q30/31) were specifically designed to compare UASs recurrent training requirements and FAA recurrent training requirements from the perspective of the UAS community.

Twenty-five survey respondents (64.1%) "Strongly Agree" or "Agree," six respondents (15.4%) "Strongly Disagree" or "Disagree," and five respondents (12.8%) were "Undecided" that their organization requires annual re-currency training in aircraft systems and in emergency procedures for the manned aircraft flown. A majority of respondents believe recurrent training is required by their organization for the manned aircraft they fly.

Twenty-eight survey respondents (71.8%) "Strongly Agree" or "Agree," nine respondents (23.1%) "Strongly Disagree" or "Disagree," and two respondents (5.1%) were "Undecided" that their organization requires annual re-currency training. A majority of respondents believe recurrent training is required. Although the number of respondents that do not agree increased, what is most interesting is that the UASs community is more inclined to believe recurrent training is required for unmanned aircraft than manned aircraft.

Unmanned Aircraft Systems Operations Safety Plan

One additional question (Q25) not related to NTSB Safety Recommendations was added to solicit input on the development of a “safety plan.” Respondents were asked to respond to the following statement: “My organization has developed a safety plan, which ensures that hazards to the National Airspace System and persons on the ground introduced by UAS operations are identified and that necessary actions are taken to mitigate the corresponding safety risks to the public.” Thirty-five respondents (89.7%) indicated “Strongly Agree” or “Agree” with this statement. Three respondents (7.7%) were undecided and one respondent (2.6%) was in disagreement with the statement. This is an important finding in that it is indicative that the UASs community recognizes the implementation of a safety plan.

Conclusion

The overarching view of this study indicates that CBP has addressed the safety recommendation identified in the NTSB’s Omaha 10 accident investigation. Overall, survey respondents are in agreement with most of the actions taken to address the NTSB's Safety Recommendations. The data reported in Tables 4 and 5 clearly indicate that those within the UASs community believe that their organizations have taken a proactive approach to an external review of their operations. There is only one safety recommendation that respondents indicated disagreement that their organization had taken appropriately measures to correct. It is understandable that there are reservations regarding the recording of radio transmissions and telephone conversations, and the potential dissemination of "classified" information. The researchers do not believe this is reflects an inability of the UASs community to safely operate UA in the NAS. Overall, the UASs community has demonstrated a professional approach to the NTSB Safety Recommendations that parallels their civil aviation counterparts. In fact, as the data indicate, the majority of UASs pilots and sensor operators have FAA qualifications and practical experience operating aircraft in the NAS; the widespread acceptance of the NTSB's Safety Recommendations is not surprising.

What may be the most interesting finding of the study is the extent of disagreement that contemporary aspects of human factors have been addressed by the UASs community. As it relates to the answer to the underlying question of this study: Is the safety culture within the UASs community congruent with the culture of safety that exists among the civil aviation community; thereby enabling cohesive and safe operations within the NAS, the response to these two questions alone would indicate that the UASs community needs to address human factors to the same extent as do their counterparts in the civilian aviation community.

Areas for further research would include a determination on whether or not UASs Pilots and Sensor operators should be certificated. Also, the question of if Pilots and Sensor operators should also be required to have a Medical certificate, and what class, needs to be answered.

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Estimating Cost Savings for Aviation Fuel and CO_2 Emission Reductions Strategies

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Abstract

Achieving reductions in aviation greenhouse gas emissions while growing the aviation industry is both a national and a global challenge. This paper discusses and summarizes the suggestions for reducing emissions, and both the short-term and long-term emissions goals for three aviation industry groups, the European Union and United States aviation regulatory agencies, and the United Nations specialized agency for civil aviation. Reducing fuel consumption affects an air carrier's bottom line by reducing fuel costs and carbon emissions. Investments may be required in aircraft or procedural changes to reduce demand for fuel by reducing consumption while still providing the same level of air service. Investing in reducing fuel consumption is not only important to comply with any emission trading scheme, but will also become a major factor for survival in the present competitive air transportation market. A general method to estimate cost savings is developed that presents a comparison method independent of the specific type of fuel reduction method. This method uses the percentage of fuel reduced to analyze cost savings using a range of fuel prices and non-discounted payback period. Analysts may use this method for calculating the savings specific methods of reducing fuel consumption.

Introduction

The global nature of aviation is made particularly clear as aviation emissions are a global concern in today's world. The aviation industry is now part of emissions regulations affecting the European Union and it is expected to become global through the International Civil Aviation Organization (ICAO). "Sustainable development is one of the greatest challenges and opportunities facing the aviation industry in the 21st century" (European Aviation Safety Agency, 2013, para. 1). "Although the aerospace industry has already made significant efforts to reduce its environmental footprint, further technological and operational improvements are necessary to outweigh the impact of traffic growth" according to the European Aviation Safety Agency (EASA, 2013).

Aviation's role in potential effects on the environment is becoming more important due to global air traffic forecasted to grow 4 to 5% yearly (EASA, 2013). According to IATA (International Air Transport Association, 2013), 2% of global carbon dioxide emissions in 2012 were due to aviation. The United States Government (USG) is one government among many worldwide that is participating in global efforts to reduce emissions. "The USG has set a goal of achieving carbon neutral growth for U.S.

commercial aviation by 2020, using 2005 emissions as a baseline" (United States Government, 2012, para. 1). "Carbon neutral growth means that aviation's net CO_2 emissions stop growing, even when demand for air transport continues to grow. In other words, net CO_2 emissions from aviation would peak in 2020 and would decline after that" (IATA, 2009, 4). "Between 1978 and 2011, U.S. airlines improved fuel efficiency by 120 percent, which has resulted in a savings of 3.3 billion metric tons of carbon dioxide (CO_2) savings" (Airlines for America, 2013, para. 2). In June 2013, to reach agreement before ICAO meets in early fall 2013, and to avert trade wars and a plethora of emissions trading schemes throughout the world, "airlines representing 85 percent of global traffic urged governments to adopt a single market-based system designed to offset growth in their post-2020 emissions against the funding of projects to cut emissions deemed harmful to the environment" (Reuters, 2013).

In general, the aviation industry has presented a common position consisting of three main elements: "an average improvement of 1.5% per year in terms of fuel efficiency, a carbon neutral growth from 2020 onwards, and an absolute reduction of net CO_2 emissions by 50% in 2050, compared to 2005 levels" (Fonta, 2010, p. 11). "Green House Gas (GHG) emissions trading and offsetting were introduced in 1997 as part of the Kyoto Protocol, which provided for three distinct mechanisms to regulate and control the emission goals: Emissions Trading, Clean Development Mechanism (CDM), and the Joint Implementation (JI)" (ICAO Secretariat, 2010d. p. 128). The development of these three mechanisms supported by emissions limitations and reduction commitments resulted in the establishment of the global carbon market (ICAO Secretariat, 2010d). New Zealand and the European Union are the only two active Emission Trading Systems (ETS), Japan has a voluntary national ETS and it is in the process of becoming mandatory, a U.S. ETS system is being considered at federal level, and Australia has postponed the implementation of the ETS (ICAO Secretariat, 2010b). Calculating estimates for aviation carbon emission is complex, may be accomplished by more than one method, and is based on the amount of fuel consumed by the aircraft (Johnson, Gonzalez, Kozak, & Sperlak, 2013). Aviation ETS, carbon trading, and cap and trade are complex subjects with regard to structure of the policy, fairness and effectiveness of implementation, and nature of the economic, environmental, and political implications (Adler & Gellman, 2012; Krammer, Dray & Kohler, 2013; Lee et al., 2009; Meltzer, 2012; Sgouridis, Bonnefoy & Hansman, 2011).

This paper discusses and summarizes the suggestions for reducing emissions, and both the short-term and long-term emissions goals for three aviation industry groups, the European Union and United States aviation regulatory agencies, and the United Nations specialized agency for civil aviation. Highlights of aviation related carbon emission policies are compared from the Federal Aviation Administration, EASA, ICAO, International Air Transport Association (IATA), Airlines for America (A4A), and Air Transport Action Group (ATAG). In May 2013, both ICAO and ATAG signed a joint statement on reducing aviation emissions that recognizes the need to stabilize carbon dioxide emissions in times of increasing demand for aviation and to improve fuel efficiency by innovating and adopting best practices and technologies (ICAO, 2013a). Reducing fuel consumption affects an air carrier's bottom line by reducing fuel costs and, if the consumption of fuel and emission of carbon results in a cost for carbon such as under an ETS, then carbon emissions costs. Investments may be required in aircraft or procedural changes to reduce demand for fuel by reducing consumption while still providing the same level of air service. Investing in reducing fuel consumption is not only important to comply with any emission trading scheme or reducing emissions for altruistic reasons, but will also become a major factor for survival in the present competitive air transportation market. A general method to estimate cost savings is developed that presents a comparison method independent of the specific type of fuel reduction method. This method uses the percentage of fuel reduced to analyze cost savings using a range of fuel prices and non-discounted payback period.

Literature Review

A literature review of carbon emission information from a total of six governmental and industry groups was conducted. This section discusses the published viewpoints of ICAO, FAA, IATA, EASA, A4A, and ATAG with regard to aviation carbon emissions.

International Civil Aviation Organization

The International Civil Aviation Organization (ICAO) is a United Nations agency that is responsible for the development of international civil aviation. "In 2004, ICAO adopted three major environmental goals, to: limit or reduce the number of people affected by significant aircraft noise; limit or reduce the impact of aviation emissions on local air quality; and limit or reduce the impact of aviation greenhouse gas emissions on the global climate" (ICAO, 2013b, para. 2). Two important key elements from the 36th and 37th ICAO Assemblies are the goals of improving fuel efficiency by 2% per year until 2050, and stabilizing carbon dioxide emissions at the 2020 level (Hupe, 2010). The Group on International Aviation and Climate Change (GIACC), a sector of ICAO, works under the United Nations Framework Convention on Climate Change (UNFCC) and the Kyoto Protocol to achieve these goals (Hupe, 2010). The Committee on Aviation Environmental Protection (CAEP) is a technical committee of the ICAO Council, responsible for conducting studies and recommending measures to minimize and reduce aviation's impact on the environment, including setting certification standards for aircraft noise and aircraft engine emissions (Hupe, 2010).

ICAO predicts 4.8% passenger traffic per year through the year 2036; although noise, emissions, and fuel consumption prediction is less than 4.8% (ICAO Secretariat, 2010). In 2006, 187 million metric tons (MT) of fuel was consumed globally (ICAO Secretariat, 2010). Approximately 62% of global aviation fuel consumption is from international flights (ICAO Secretariat, 2010). Meanwhile, it is expected that global aircraft fuel consumption will increase between 3% and 3.5% per year (ICAO Secretariat, 2010).

"Environmental standards set by ICAO and the investments in technology and improved operational procedures are allowing aviation's noise, local air quality, and CO_2 footprints to grow at a rate slower than the demand for air travel" (ICAO Secretariat, 2010, p. 18). Cooperation between ICAO and the UN's Intergovernmental Panel on Climate Change (IPCC), "is key to obtain a better scientific understanding of aviation's impact on the global climate" (ICAO Secretariat, 2010, p. 31).

"The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent an irreversible change in the global climate system" (ICAO Secretariat, 2010, p. 33). According to the Intergovernmental Panel on Climate Change (IPCC), "climate change refers to any change in climate over time, whether due to natural variability, or as a result of human activity" (IPCC, 2007, para. 2). According to the IPCC, "global climate change is caused by the accumulation of greenhouse gases (GHG) in the lower atmosphere… the GHG of most concern is carbon dioxide (CO_2)" (ICAO Secretariat, 2010a, p. 38).

Aircraft engines produce emissions that are "…released directly into the upper troposphere and lower stratospheres where they are believed to have a different impact on atmospheric composition than emissions at lower altitudes…" (ICAO Secretariat, 2010a, p.38). Engine combustion of jet fuel and aviation gasoline produces emissions with approximately 70% carbon dioxide (CO_2), 30% water vapor, and 1% of other emissions (ICAO Secretariat, 2010). CO_2 and water vapor are greenhouse gases (GHG) (ICAO Secretariat, 2010). Aviation emissions of CO_2 emissions are expected to increase 3% to 4% annually (ICAO Secretariat, 2010). Aviation also emits nitrogen oxides (NOx), sulfur oxides (SOx), hydrocarbons (HC), and black carbon (BC) particulate matter (ICAO Secretariat, 2010a). Since 2008, ICAO provided a Carbon Emissions Calculator on their website and mobile application that uses a methodology developed by CAEP. The calculator methodology also uses aircraft types, route data, passenger load factors, cargo, and other data provided by the airline industry (ICAO Secretariat, 2010a).

IPCC issued guidelines to assist countries in developing GHG national inventories, including GHG from aviation (ICAO Secretariat, 2010a). "The 2006 IPCC guidelines suggest collecting the fuel consumption for domestic and international aviation by surveying airline companies or estimating it from aircraft movement data and standard tables of fuel consumed, or both" (ICAO Secretariat, 2010a, p. 40). ICAO's Fuel Efficiency Rules of Thumb are stated as:

- On average, an aircraft will burn about 0.03kg of fuel for each kg carried per hour. This number will be slightly higher for shorter flights and for older aircraft and slightly lower for longer flights and newer aircraft.
- The total commercial fleet combined flies about 57 million hours per year; so, saving one kg on each commercial flight could save roughly 170,000 tonnes of fuel and 540,000 tonnes of CO2 per year.

- Reducing the weight of an aircraft, for example by replacing metal components with composites, could reduce fuel burn by as much as 5%.
- Average fuel burn per minute of flight: 49 kg.
- Average of fuel burn per nautical mile (NM) of flight: 11 kg. (ICAO Secretariat, 2010a, p. 41)

According to ICAO, aircraft designed after 2010 should be 15% more fuel efficient and release 40% lower emissions than comparable aircraft designed earlier (ICAO Secretariat, 2010b). Improvements in aircraft technology have had the most impact on increasing fuel efficiency, but there are additional gains possible through improved operations, air traffic control and aircraft efficiency (ICAO Secretariat, 2010b).

"Historic trends in improving efficiency levels show that aircraft entering today's fleet are around 80% more fuel efficient than they were in the 1960's" (Fonta, 2010, p. 72). In order to improve aircraft performance it is needed to reduce aircraft weight, improve airplane aerodynamics to reduce drag, improve engine performance to reduce fuel burn (Fonta, 2010). "Friction drag is the area which currently promises to be one of the largest areas of potential improvement in aircraft aerodynamic efficiency over the next 10 to 20 years" (Fonta, 2010, p.74). In order for air traffic improvements to be realized, an interoperable global air traffic management (ATM) system that can be used by all users during all phases of flight is necessary (ICAO Secretariat, 2010c). Examples of other national and regional systems with goals of improving flight operations and reducing emissions include NextGen from the FAA, Single European Sky ATM Research (SESAR) from the European Union, the Atlantic Interoperability Initiative to Reduce Emissions (AIRE) a partnership between the FAA and the European Commission, and the Asian Pacific Initiative to Reduce Emissions (ASPIRE) an agreement between Airservices Australia, Airways New Zealand, the FAA, Japan Civil Aviation Bureau, and the Civil Aviation Authority of Singapore. All these programs have the same objective of improving flight operations and reduce emissions (ICAO Secretariat, 2010c).

Currently, the offset of aviation emissions is a voluntary system addressing passengers and not cargo, non-revenue passengers and repositioning flights (Kråkenes & Keldusild, 2010). ICAO's Committee on Aviation Environmental Protection (CAEP) received 50 voluntary replies from 24 States and regions including 37 airlines; Boeing was the only US company that replied. (Shimizu, 2010). More than 30 IATA member airlines offer voluntary carbon offsets to passengers. The carbon offset program gives passengers the option to purchase carbon credits to offset emissions from booked flights (Steele, 2010). In this IATA program, carbon credits are generated by projects with Certified Emission Reductions (CERs) issued through the Clean Development Mechanism (CDM) and approved under the United Nations Framework Convention for Climate Change (Steele, 2010). Passengers may pay for projects by estimating the carbon credits per passenger using the ICAO Carbon Emissions Calculator and may select one project from a maximum of three projects offered by the airline (Steele, 2010).

Federal Aviation Administration

The Federal Aviation Administration (FAA) is the US agency that regulates and oversees commercial aviation. The FAA sustainability's goal for the future is "To develop and operate an aviation system that reduces aviation's environmental and energy impacts to a level that does not constrain growth and is a model for sustainability" (Federal Aviation Administration, 2012b, p. 9). The United States Government (USG) has committed to addressing the climate change impacts of commercial aviation by using multiple approaches to achieve commercial aviation carbon neutral growth by 2020, a reduction of 115 million metric tons of carbon dioxide emissions from the 2005 baseline (United States Government, 2012).

The FAA identified the following areas for improvement to reduce CO_2 emissions from aviation: aircraft and engine technology, operational, alternative fuels development and distribution, policies, standards, measures, scientific understanding, and modeling analysis (United States Government, 2012). The biggest contributor to carbon neutral growth is expected to be aircraft technology and operational innovations, with an estimated reduction of 47 MT of CO_2 by 2020 (United States Government, 2012). CO_2 reductions from alternative fuels are uncertain, but could be as high as 34 MT of CO_2 (United States Government, 2012).

The FAA released the Aviation Environmental Design Tool (AEDT2a) in 2012, to measure and evaluate how new aircraft technologies, operations, and alternative fuels, will impact noise, emissions and fuel burn (Federal Aviation Administration, 2012a). The U.S. positions on CO_2 standard, operational measures, and alternative fuels were previously accepted at ICAO assemblies (Federal Aviation Administration, 2012a). The FAA will continue cooperation with key aviation countries and stakeholders to enforce a global ETS standard through ICAO (Federal Aviation Administration, 2012a). The FAA is focused on reducing noise and emission impacts of aviation through supporting new technologies, sustainable alternative fuels research, and innovations (Federal Aviation Administration, 2012b).

Programs such as The Continuous Lower Energy, Emissions, and Noise (CLEEN) launched by the FAA and NASA's Environmentally Responsible Aviation (ERA) focus on engine technology and aircraft structures that will benefit the commercial industry (United States Government, 2012). CLEEN's goal is to develop and demonstrate, by 2015, technology that will reduce fuel burn by 33 percent. ERA's goal is to reduce mission fuel burn by 50 percent before 2020 for passenger and cargo transport aircraft (United States Government, 2012).

CLEEN is one part of NextGen, a multi-agency redesign of the National Airspace System to dramatically increase the efficiency of aircraft operations and reduce GHG emissions (United States Government, 2012). The FAA implementation of NextGen is intended to support the overall goal of carbon neutral growth by reducing 1.4 billion gallons jet fuel consumption that contributes 14 MT of carbon dioxide (United States Government, 2012).

International Air Transport Association

The International Air Transport Association (IATA), an industry trade association that represents, leads, and serves more than 200 international airlines. IATA's goal on emissions is as follows "Our industry has a vision to achieve carbon neutral growth on the way to a carbon free industry. The strategy for this is based on four pillars: technological progress, operational measures, infrastructure improvements and economic instruments" (IATA, 2013). According to IATA, "Fuel efficiency improved by 16% between 2001 and 2011. An additional efficiency gain of 17% is expected between by 2020" (IATA, 2013, para. 5). "It is estimated that up to 8% of all jet fuel is wasted as a result of inefficient routes" (IATA, 2013, para 7).

According to IATA, a strong commitment from aviation system components such as airlines, fuel companies, airports, and regulators is required to achieve carbon neutral growth which may be reached through either aviation emissions reductions or offsetting aviation emissions with emissions reductions in other industries (IATA, 2009). IATA asserts that airlines must have the capacity to invest in emissions mitigation measures for carbon neutral growth to work (IATA, 2009). Investments in retrofits, production updates, and new aircraft designs are expected to reduce emissions 7% to 13%, 7% to 18%, and 25% to 50%, respectively (IATA, 2009).

Technology improvements such as aircraft and engine designs, lighter and stronger materials, and biofuel are projected to reduce aviation emissions by 20% to 35% are identified on IATA's Technology Roadmap (IATA, 2009). IATA estimates that by 2020, airlines will spend $1.5 trillion on about 5,500 aircraft to replace 27% of the total fleet resulting in a 21% reduction in CO_2 emissions (IATA, 2009). For example, retrofits such as winglets and drag reduction could reduce emissions by 1% by 2020 if $2 billion are invested; and sustainable biofuels could reduce CO_2 emissions by 80% over the entire lifecycle (IATA, 2009).

To reduce the 6% inefficiency identified by IPCC in 1999, IATA formed teams of experts in 2005 to make recommendations to airlines on fuels and emissions savings such as reducing use of auxiliary power units and improved flight procedures, (IATA, 2009). IATA projects that these teams will reduce emissions by 3% by 2020, and estimates that 11 MT of CO_2 was saved in 2008 (IATA, 2009). Inefficiencies in air transport infrastructure were reduced from 12% in 1999 to 4% according to IPCC estimates (IATA, 2009). An investment of $58 billion for more efficient Air Traffic Management systems, such as SESAR, and airport infrastructure are expected to reduce emissions by 4% by 2020 (IATA, 2009).

Airspace improvements such as Performance-Based Navigation (PBN) and Continuous Descent Arrival (CDA) will play major roles on reducing CO_2 emissions (IATA, 2009). “Using CDA rather than the traditional stepped approach methods for landing can save up to 630 kg of CO_2 per landing” (IATA, 2009, no page number). IATA calculated that in 2025, a yearly amount of 90 million metric tons of CO_2 will need to be reduced in order to maintain 2020 levels and will require $7 billion per year in investments (IATA, 2009). IATA estimates that in order to achieve carbon-neutral growth from 2020 onward, airlines will have to invest approximately $1.6 trillion (IATA, 2009).

European Aviation Safety Agency

The European Aviation Safety Agency (EASA) is the European Union agency that regulates and oversees commercial aviation safety. EASA has the following view on emissions: “Europe’s Flight path 2050 officially supports the Air Transport Action Group (ATAG) target of reaching carbon-neutral growth in 2020 and reducing aviation’s overall CO_2 emissions by half between 2005 and 2050” (EASA, 2013, para. 1).

Many governments around the world are working through the United Nations Framework Convention on Climate Change (UNFCCC) and the International Civil Aviation Organization (ICAO) to reduce climate change due to aviation while growing aviation (EASA, 2013). While the Kyoto Protocol excludes international aviation, aviation traffic is expected to increase 4% to 5% annually and is expected to contribute significantly to global warming by 2050 due to this growth and reductions in global warming in other industries due to energy efficient technologies (EASA, 2013).

According to EASA, the inclusion of aviation in the EU Emissions Trading Scheme (ETS) is an essential to meet carbon neutral growth goals (EASA, 2013). A major obstacle to aviation biofuels is the existence of a reliable and cost effective supply for commercial aviation (EASA, 2013). EASA states that “The ultimate aim for the industry must be sustainable development, where the environment is not sacrificed for growth and future generations will be able to continue to benefit from air travel” (EASA, 2013, para. 8).

Airlines for America

Airlines for America (A4A) is a US trade organization that sponsors airlines growth and well-being (A4A, n.d.) A4A supports a global approach under ICAO to aviation climate change policy, and technological advances throughout the aviation system (A4A, n.d.). A4A was a co-founder of the Commercial Aviation Alternative Fuels Initiative (CAAFI) in 2006 and remains an active member. A4A member airlines are actively looking for methods to reduce aircraft emissions through new aircraft, alternative fuels, and operational performance.

Air Transport Action Group

The Air Transport Action Group (ATAG) is composed of aviation industry experts that focus on aviation sustainability. ATAG guided a group of aviation leaders so that aviation became “the first industry to have a long-term plan to tackle its climate change impacts” (ATAG, 2013, para. 2). In 2009, the ATAG Board developed three environmental goals that IATA agreed to follow: 1.5% yearly improvement in fuel efficiency from 2009-2020, carbon neutral growth from 2020, and 50% reduction in net aviation emissions by 2050 with a 2005 baseline (ATAG, 2013). These targets have also influenced ICAO and the United Nations Framework Convention on Climate Change (UNFCCC) (ATAG, 2013). ATAG (2012) identifies four recommendations for future climate change agreements:

1. Post-2020 global climate agreements should include aircraft CO_2 emissions coordinated through ICAO.
2. ICAO should adopt a global aviation emissions approach that does not affect fair competition and does treat aviation as a sector, not by country.
3. A global aviation emissions inventory should reliably track actual emissions versus targets, and avoid double counting and using each credit more than once.
4. Using the 2005 baseline levels, carbon neutral aviation growth beginning in 2020 and 50% lower emissions in 2050 is possible through improving air traffic management, aircraft and operations improvements, biofuels, and a multilateral market-based aviation emissions system.

Other recommendations include ICAO to develop emission (including GHG, noise, and local air quality) mitigation measures allowing carriers to decide what measures to use to meet their CO_2 targets; carriers prioritize reinvestment of revenues on cost effective measures to reduce emissions; administration and implementation should be taken by both government and industry; and special needs should be taken into consideration for developing countries (ATAG, 2012). In order to achieve all these recommendations governments should be involved in the modernization of air traffic management, fleet and operations technology improvements through academic and companies, availability of biofuels for aviation, and development of multilateral markets for global aviation emissions (ATAG, 2012). ATAG recommends global multilateral measures coordinated through ICAO and comments on the use of unilateral measures as “It also puts aviation at risk of being caught in a web of uncoordinated, costly and ineffective measures and countermeasures imposed by governments, which will benefit no one but may harm economies and environments worldwide” (ATAG, 2012, p 4).

Summary of Aviation Organization Carbon Emissions Viewpoints

In summary, examination of the carbon emissions discussion of the aviation bodies associated with the UN, US, EU, and airlines reveals that there are similarities and differences in suggested methods to reduce fuel consumption and in environmental targets. Table 1 highlights the suggested methods for reducing fuel consumption for the six agencies in this study. There are similarities at the high level in the suggestions of technological improvements, operations improvements, and alternative fuels. Differences are noted in the contrasts between the ICAO market based measures and the IATA positive economic measures. The FAA suggests scientific understanding, modeling and analysis. Table 1 identifies the high level suggestions and shows that there is consensus on many methods, but there are differences across the agencies.

Similarly, in Table 2, the short-term and long-term emissions targets are summarized for the six agencies in this study. The comparison of baseline years used by the agencies is important for consistent measurements of progress toward the emissions targets. Table 1 identifies the high level targets and shows that there is consensus on many measures, but there are differences_across the agencies in timelines and percentages. For instance, EASA, IATA, A4A and ATAG are in alignment with each other on long-term goals. In contrast, ICAO expresses the long-term goal in terms of a percent reduction per year and the FAA's long-term goal in terms of a specific amount emission reduction.

Methodology

In search of a more general method to estimate cost savings, the authors developed a comparison method that is independent of the specific type of fuel reduction method. This method uses the percentage of fuel reduced to analyze cost savings. Analysts may use this method for specific routes or groupings of routes of interest. For convenience, this method is illustrated using 5,000 and 10,000 gallons of fuel consumed per flight and specific fuel consumption reduction percentages of 3%, 4% and 5%. Payback period is calculated by determining the number of roundtrip flights required to payback a $1 million dollar investment. This method may be adapted to the needs of specific analyses by changing the fuel consumption or the fuel reduction percentages to match a specific investment.

The primary limitations of this method are that it does not predict future costs for fuel or carbon; it does not identify capital expenditures such as aircraft modifications or fleet changes, nor non-capital expenses such as equipment changes, ground costs for adding a stop, any adverse maintenance events; it considers all ETS costs as those costs above any free allowances, and it does not include time value of money, tax, or financing considerations.

Table 1

Suggested Methods to Reduce Fuel Consumption

ICAO[a]	FAA[b]	EASA[c]	IATA[d]	A4A[e]	ATAG[f]
Green aircraft technologies	Aircraft/engine technology improvement	Technological improvements	Improved technology	Fuel efficient aircraft	Aircraft modifications
Operational measures	Operational improvements	Operational improvements	Effective operations	Operational performance	Operational improvements
Alternative fuels for aviation	Alternative fuels development and deployment	Alternative fuels	Sustainable biofuels	Alternative fuels	Sustainable alternative fuels
Market based measures	Policies, standards and measures		Positive economic measures		Carbon markets/economic measures
	Scientific understanding modeling/analysis		Efficient infrastructure		New technologies
					Special needs for developing countries

Note. [a](ICAO, 2010f). [b](USG, 2012)(FAA, 2012). [c](EASA, 2013). [d](IATA, 2009)(IATA, 2013). [e](A4A, 2013). [f](ATAG, 2012)(ATAG, 2013).

Table 2

Environmental Targets by Aviation Agencies

Agency	Short Term Target	Baseline Year	Long Term Target
ICAO[a]	CO_2 stabilized at 2020 levels.	2020	2% fuel efficiency up to year 2050.
FAA[b]	CO_2 stabilized at 2005 levels thru 2020. One billion gallons of renewable jet fuel is used by aviation by 2018. 2% fuel efficiency per year.	2005	Further 60 MT reduction by 2026 2% annual fuel efficiency.
EASA[c]	1.5% fuel efficiency per year from 2009 to 2020. CO_2 stabilized at 2020 levels.	2005 and 2020	50% less emission by 2050 compared to 2005 levels.
IATA[d]	1.5% fuel efficiency per year from 2009 to 2020. CO_2 stabilized at 2020 levels.	2005 and 2020	50% less emission by 2050 compared to 2005 levels.
A4A[e]	1.5% fuel efficiency per year through 2020.	2005	50% less emission by 2050 compared to 2005 levels.
ATAG[f]	1.5% fuel efficiency per year from 2009 to 2020. CO_2 stabilized at 2020 levels.	2005 and 2020	50% less emission by 2050 compared to 2005 levels.

Note. [a](ICAO, 2010f). [b](USG, 2012)(FAA, 2012)(FAA, 2012a). [c](EASA, 2013). [d](IATA, 2009)(IATA, 2013). [e](A4A, 2013). [f](ATAG, 2012)(ATAG, 2013).

Results and Discussion

A baseline analysis of the ETS costs and fuel costs for a trip in or out of an EU airport that requires 5,000 or 10,000 gallons of jet fuel is shown in Table 3. Fuel consumed by flight is converted into equivalent carbon credits. Both the fuel cost and the emissions costs are based on the consumption of 5,000 and 10,000 gallons of jet fuel. To estimate the total amount of CO_2 emissions in metric tons, the gallons of fuel must be converted into metric tons using the EPA Emission factor for Jet Fuel of 00975. To calculate the total allowance cost, multiply the CO_2 metric tons by the allowance price. Using the carbon credit price of $5.44, the emissions costs would be $265 and $530 respectively.

Table 3

Emissions Cost Analysis

Jet Fuel Consumption	Emission Factor[a]	Total Emission of CO_2Eq	ETS Allowance Price[b]	Allowance Cost
5,000 Gallons	0.00975	48.75	\$5.44	\$265
10,000 Gallons	0.00975	97.50	\$5.44	\$530

Note: [a]Environmental Protection Agency (2013) Metric tons of CO_2Eq per gallon. [b]Intercontinental Exchange (2013) Allowance price €4.19 per Metric ton as of March 22, 2013. Total Emission of CO_2 in metric tons. ETS Allowance Price and costs in U.S. Dollars. Currency exchange from Euro to U.S. Dollar 1.298 from Yahoo! Finance (2013).

Tables 4 and 5 show the total costs of jet fuel and allowances from flights consuming 5,000 and 10,000 gallons. In these tables, calculations were conducted using fuel prices ranging from \$2.00/gal to \$4.00/gal to provide estimates when fuel prices are not tied to specific years.

Table 4

Round Trip Cost Including 5,000 Gallons of Jet Fuel and Allowances

Jet Fuel Price per Gallon[a]	Total Jet Fuel Cost	Total Round Trip Cost
\$2.00	\$10,000	\$10,265
\$2.50	\$12,500	\$12,765
\$3.00	\$15,000	\$15,265
\$3.50	\$17,500	\$17,765
\$4.00	\$20,000	\$20,265

Note. [a]International Air Transport Association (2012a). Jet Fuel Price per Gallon is average per year. Total Round Trip Cost includes Allowance and Gasoline Expenses.

Table 5

Round Trip Cost Including 10,000 Gallons of Jet Fuel and Allowances

Jet Fuel Price per Gallon[a]	Total Jet Fuel Cost	Total Round Trip Cost
$2.00	$20,000	$20,530
$2.50	$25,000	$25,530
$3.00	$30,000	$30,530
$3.50	$35,000	$35,530
$4.00	$40,000	$40,530

Note. [a]International Air Transport Association (2012a). Jet Fuel Price per Gallon is average per year. Total Round Trip Cost includes Allowance and Gasoline Expenses.

Once the baseline is established, possible improvements may be considered that reduce fuel consumption and therefore, fuel costs and emissions costs. The cost of the improvement is then compared to the cost savings generated. In this example, the authors selected a $1 million investment. The investment is not required to be a capital investment such as an aircraft modification nor an added expense such as a flight operation change. This method is independent of the particular improvement because the method only considers the impact of reducing fuel consumption and not the implications from the specific method. For example, a capital investment to modify the wings or fuselage may also include tax, time value of money and depreciation. Table 6 demonstrates the cost reduction and number of roundtrips needed to payback for a $1 million investment to reduce fuel consumption by 3, 4 and 5 percent. This payback period is non-discounted meaning that the time value of money is not considered. Decision-making personnel need to include the time value of money for their company which is specific to each company.

Table 6

One Million US Dollars Investment to Reduce Fuel Consumption Analysis Using 10,000 gallons per Roundtrip Flight

Fuel Price	$2.00	$2.50	$3.00	$3.50	$4.00
Total Trip Cost	$20,530	$25,530	$30,530	$35,530	$40,530
Fuel Reduction	3%	3%	3%	3%	3%
Savings	$616	$766	$916	$1,066	$1,216
Roundtrips to Payback	1,624	1,306	1,092	938	822
Payback in Years	1.1	0.9	0.7	0.6	0.6
Total Trip Cost	$20,530	$25,530	$30,530	$35,530	$40,530
Fuel Reduction	4%	4%	4%	4%	4%
Savings	$821	$1,021	$1,221	$1,421	$1,621
Roundtrips to Payback	1,218	979	819	704	617
Payback in Years	0.8	0.7	0.6	0.5	0.4
Total Trip Cost	$20,530	$25,530	$30,530	$35,530	$40,530
Fuel Reduction	5%	5%	5%	5%	5%
Savings	$1,027	$1,277	$1,527	$1,777	$2,027
Roundtrips to Payback	974	783	655	563	493
Payback in Years	0.7	0.5	0.4	0.4	0.3

Note. Payback in years is calculated using an average of round trips per year estimate of 1,460. Payback is calculated using savings.

The fuel costs per gallon range from $2.00/gallon to $4.00/gallon. For example at $3.00/gallon, it would take 1,110 roundtrips to payback a $1 million investment that reduces fuel consumption by 4%. The more expensive the fuel is per gallon, the fewer trips required to pay back the $1 million. To illustrate this, compare the 1,054 roundtrips needed at $2.00/gallon versus the 1,085 at $4.00/gallon. Payback is also calculated in years, this was done by assuming there are 4 daily trips per day on a 365 day year. For example using roundtrips to payback of 1,645 over the assumed 1,460 round trips per year equals 1.1 years for payback. Figure 1 presents the payback in years for fuel prices ranging from $2.00 to $4.00 for 3%, 4%, and 5% reduction in fuel consumption.

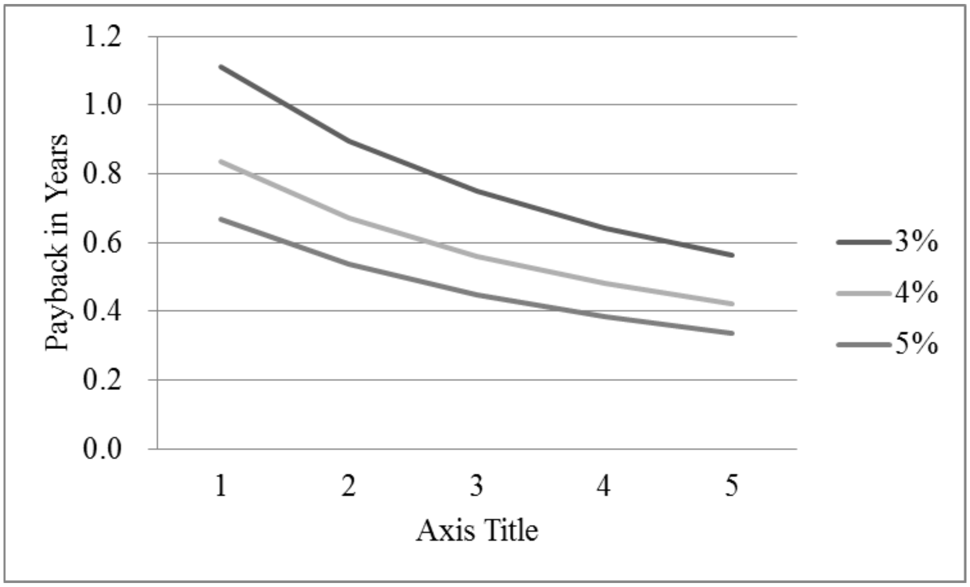

Figure 1. Comparison of payback using a range of fuel prices.

The jet fuel prices shown in Table 7 and 8 are average price per gallon for each year from 2008 to 2012 (U.S. Energy Information Administration, 2013). The jet fuel costs are calculated by multiplying the average jet fuel price each year by 5,000 and 10,000 gallons. Because fuel prices fluctuated from $1.70/gallon to $3.11/gallon, the fuel cost fluctuates from $8,765 to $15,815 for 5,000 gallons and $17,530 to $31,630 for 10,000 gallons each flight. By keeping the carbon credit cost the same, it is easier to see that fuel cost per gallon far exceeds the carbon credit cost at 2013 prices. For instance, the jet fuel cost is $15,550 for 5,000 gallons of fuel in 2012, and the cost of the credits for 5,000 gallons of fuel is $265. Therefore, the impact of the fuel cost is far greater than the carbon credit cost at these price levels. Table 9 uses the same methodology as in Table 6, a 3% to 5% fuel reduction analysis with current prices and a fuel consumption of 5,000 gallons. Figure 2 is a graphical depiction of the payback period information presented in Table 9. As expected, the greater the reduction in fuel consumption, the lower the payback period. The longest payback period presented is for the year 2009 because that is the year with the lowest average fuel price in this study. The shorter payback periods presented for the years 2012, 2011 and 2008 reflect the higher prices of the fuel in those years.

Table 7

Round Trip Cost Including 5,000 Gallons of Jet Fuel and Allowances

Year	Jet Fuel Price per Gallon[a]	Total Jet Fuel Cost	Total Round Trip Cost
2012	$3.11	$15,550	$15,815
2011	$3.05	$15,250	$15,515
2010	$2.20	$11,000	$11,265
2009	$1.70	$8,500	$8,765
2008	$3.02	$15,100	$15,365

Note. [a]U.S. Energy Information Administration (2013). Jet Fuel Price per Gallon is average per year. Total Round Trip Cost includes Allowance and Gasoline Expenses.

Table 8

Round Trip Cost Including 10,000 Gallons of Jet Fuel and Allowances

Year	Jet Fuel Price per Gallon[a]	Total Jet Fuel Cost	Total Round Trip Cost
2012	$3.11	$31,100	$31,630
2011	$3.05	$30,500	$31,030
2010	$2.20	$22,000	$22,530
2009	$1.70	$17,000	$17,530
2008	$3.02	$30,200	$30,730

Note. [a]U.S. Energy Information Administration (2013). Jet Fuel Price per Gallon is average per year. Total Round Trip Cost includes Allowance and Gasoline Expenses.

Table 9

One Million US Dollars Investment to Reduce Fuel Consumption Analysis Using 10,000 gallons per Roundtrip Flight

Year	2012	2011	2010	2009	2008
Total Trip Cost	$31,630	$31,030	$22,530	$17,530	$30,730
Fuel Reduction	3%	3%	3%	3%	3%
Savings	$949	$931	$676	$526	$922
Roundtrips to Payback	1,054	1,074	1,479	1,901	1,085
Payback in Years	0.7	0.7	1.0	1.3	0.7
Total Trip Cost	$31,630	$31,030	$22,530	$17,530	$30,730
Fuel Reduction	4%	4%	4%	4%	4%
Savings	$1,265	$1,241	$901	$701	$1,229
Roundtrips to Payback	790	806	1,110	1,426	814
Payback in Years	0.5	0.6	0.8	1.0	0.6
Total Trip Cost	$31,630	$31,030	$22,530	$17,530	$30,730
Fuel Reduction	5%	5%	5%	5%	5%
Savings	$1,582	$1,552	$1,127	$877	$1,537
Roundtrips to Payback	632	645	888	1,141	651
Payback in Years	0.4	0.4	0.6	0.8	0.4

Note. Payback in years is calculated using an average of round trips per year estimate of 1,460. Payback is calculated using savings.

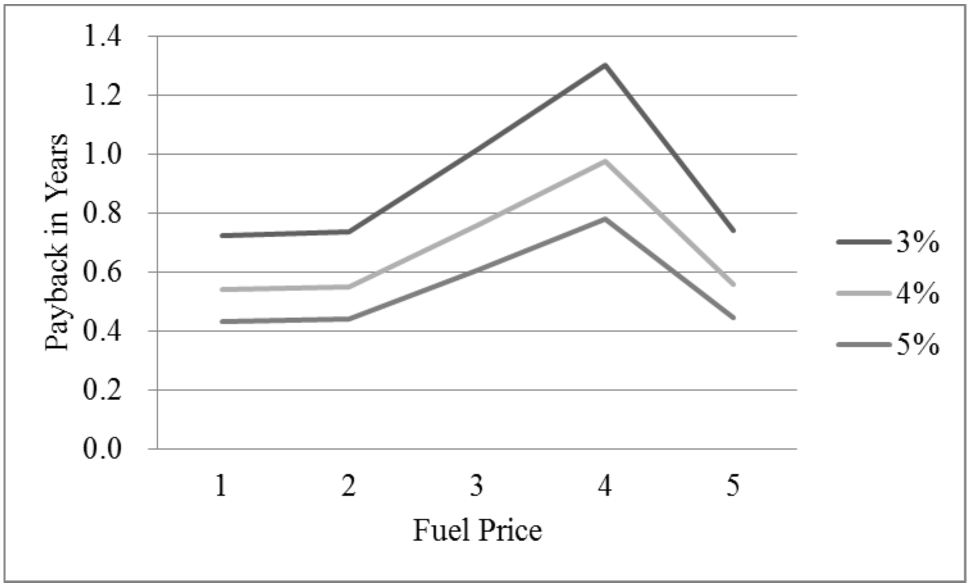

Figure 2. Comparison of payback using actual average fuel prices.

Conclusion and Suggestions for Future Research

Based on this analysis, investments to reduce fuel consumption are more effective when fuel prices are high. At current prices for carbon credits and fuel prices, the cost of emissions does not contribute to the savings as greatly as fuel savings does. If the carbon credit price increases dramatically, the contribution of carbon credits to reduce payback period will increase. The amount of fuel consumed drives these analyses such that price per gallon of fuel is added to the carbon credit cost per gallon. The percentage of fuel saved dramatically impacts the payback due to the cost of fuel being much higher than the cost per carbon credit. These investments may be either capital investments or operational expenses as the methodology does not consider cost of capital, depreciation, or tax benefits of investments.

The number of governing bodies that track and impose carbon regulations is expected to increase in the next decade as aviation organizations seek a global approach to the environmental impacts of aviation. Commercial aviation CO_2 emissions are currently adding imposed costs to flights within the European Union. The stated purpose of the EU ETS is to reduce carbon emissions. A very effective way to reduce emissions is to reduce fuel consumption, as the EU ETS uses fuel consumption as the variable in carbon emission estimates. Reducing fuel consumption provides a win-win situation by reducing fuel costs and carbon emissions; therefore, having positive effects on the bottom line and the environment. Changes to aircraft or procedural changes may be implemented to reduce demand for fuel by reducing consumption while still providing the same level of air service. Investing in reducing fuel consumption is not only important to comply with any emission trading scheme, but will also become a major factor for survival in a competitive market. Future research is planned to include taxes, depreciation, and flight comparisons using flight crew calculations to augment the ICAO fuel consumption estimates.

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An Investigation of the Effects of Carrier Groups on Airline Quality Rating Components Using a Two-way Analysis of Variance

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Abstract

The Airline Quality Rating is a quantitative determination of the quality of U.S. domestic air carriers based on parameters published by the U.S. Department of Transportation. The rating is unique in that it is of interval scale and is comparable across carriers and time periods (Bowen & Headley, 2012). In order to gain insight into the relationship of the AQR metric to the carriers to which it is applied, it is helpful to group the carriers and examine the effects of those groupings on the four individual factors that comprise the AQR. Such a methodology allows one to better understand the relationship of the AQR metric to each of the carrier groups and ultimately improve the predictability of the metric. The authors employ a two-way analysis of variance to determine differences between carrier group means for each of the four AQR factors while examining longitudinal effects, along with post-hoc difference testing. While the post-hoc test results indicate significant differences between some groupings, suggesting that separate econometric models for those groupings might be created with the goal of more accurately forecasting the metric, some of the assumptions upon which the ANOVA is predicated are violated. This article will examine those violations and suggest that further research using nontraditional methods (e.g., Bayesian analysis) is indicated.

Background

The Bureau of Transportation Statistics, a unit of the Research and Innovative Transportation Administration, which is itself an agency of the U. S. Department of Transportation, has collected operational performance data from U. S. domestic air carriers since 1987 (USDOT, 2013). Among this data are key metrics consisting of on-time arrival, denied boarding, mishandled baggage, and customer complaint frequencies. These metrics, which constitute a primary portion of the dataset, can have critical effects upon both airline customer loyalty and profitability.

The Airline Quality Rating, an annual analysis that provides an overall ranking of quality of service among air carriers with at least 1% of the domestic passenger volume in a given year, combines these four primary reporting metrics, which themselves consist of a total of 15 elements, into a formula that provides a consistent measure, thereby allowing comparisons both longitudinally and across carriers (Bowen and Headley, 1991).

The potential for predicting the AQR rankings using an econometric model seems considerable. Such predictions could be utilized by managers to better allocate resources in an effort to improve the metrics that comprise the overall measure. For example, if certain economic conditions correlate with an increase in denied boardings, company revenue management policies related to no-show passengers (i.e., overbooking percentages for specific flights) could be adjusted in such a manner as to mitigate denied boarding consequences. This would presumably result in an increase in the perception of quality of the particular carrier among passengers.

It is reasonable to assume that AQR comparisons across carriers could be facilitated by partitioning those carriers into distinct service groups, as this would tend to increase correlations of the independent predictor variables with the overall AQR index. This assumption is intuitive, in that it is clear that carriers providing different levels of service utilize different operational procedures, while there is a high degree of procedural similarity among carriers providing service at the same level. This study attempts to determine, with the goal of econometric model development in mind, whether this assumption is correct; that is, whether separate econometric models are appropriate for different carrier groups.

A challenge in making longitudinal comparisons across the AQR dataset is that incumbent carriers are occasionally dropped from the rankings, either because they have merged with another carrier or because they fail to meet the required 1% domestic volume criterion for inclusion in the AQR. The carriers used in this study were selected in order to maintain consistency across the study period, as noted below.

Literature Review

The Airline Deregulation Act (P.L. 95-504) of 1978 did more than allow market forces to set prices and carriers to select routes based on traveler demand; deregulation also permitted the determination of the level of service quality provided to customers (Tiernan, Rhoades, & Waguespack, 2008). After the passage of the Act, the U. S. government began to collect various metrics of airline service quality; however, since these records were not publicly available, data-driven understanding of competitors' service and performance could not be used as a competitive advantage by carriers in order to gain customers. Airline passengers had little knowledge about which airlines performed better than their competitors or which provided a higher quality of service. Passenger knowledge consisted solely of personal experience or the latest information reported in the news media (Rhoades & Waguespack, 2008).

The publication of the first Air Travel Consumer Report (ATCR) in 1987 resulted in a significant impact on commercial air transportation as a result of increased awareness of carrier performance by the traveling public. The ATCR is a monthly product of the U. S. Department of Transportation that is "designed to assist consumers with information on the quality of services provided by the airlines" (USDOT, 2011, pg. 2). The ATCR allowed the public to view for the first time reported data for on-time performance, mishandled baggage, denied boarding, and customer complaints.

The ATCR has served as a base for researchers to explore quality in the U. S. airline industry. One group of researchers investigating quality in the U. S. airline industry includes Bowen and Headley, who published the first Airline Quality Rating (AQR) in 1991 (Bowen & Headley, 2012). The Airline Quality Rating (AQR) has for the past 23 years ranked U. S. air carriers that account for at least 1% of the domestic passenger volume. The AQR provides a month-by-month measure of quality using a weighted average of metrics representing on-time arrivals (OT), involuntary denied boardings (DB), mishandled baggage (MB), and a combination of 12 customer complaint categories (CC). The 12 customer complaint categories are flight problems; oversales; reservations, ticketing, and boarding; fares; refunds; baggage; customer service; disability; advertising; discrimination; animals; and other (Bowen & Headley, 2012).

The AQR quality measure is determined as follows:

$$Q = ((8.63 \text{ x } OT) + (-8.03 \text{ x } DB) + (-7.92 \text{ x } MB) + (-7.17 \text{ x } CC)) / ((8.63 + 8.03 + 7.92 + 7.17))$$

where on-time arrivals are reported monthly, involuntary denied boardings are reported quarterly per 10,000 passengers, mishandled baggage is reported monthly per 1,000 passengers, and customer complaints are reported monthly per 100,000 passengers (Bowen & Headley, 2012).

The original AQR quality metric was extended to include statistical process control concepts in an effort to provide an additional tool that industry managers could use to "monitor quality, identify problems, and provide timely feedback on the effectiveness of tactics to improve quality." (Bowen, Headley, & Lutte, 1993, p. 38). Headley and Bowen (1997) also offered development considerations for facilitating the adaptation of the AQR's weighted average approach to the international airline industry.

More recently, a second group of researchers at Embry-Riddle Aeronautical University employed the ATCR in a somewhat different manner. Waguespack and Rhoades separated safety, service, and financial performance and simply normalized safety and service data by total departures. Separating these metrics allowed the researchers to examine service quality and safety independently and explore the relationship between the parameters. Their Service Disquality Index (SDI) has been used both to provide a 20-year perspective on service quality performance at the major U. S. carriers (Rhoades & Waguespack, 2008), and to measure service quality issues between carriers in different industry segments (Rhoades & Waguespack, 2000a, 2000b).

Research Methodology

This study was conducted using the four initial metrics that were part of the original ATCR and which comprise the AQR measure (OT, DB, MB, and CC). The data spans a six-year period from 2006 to 2011 (Bowen & Headley, 2007 – 2012). As mentioned previously, longitudinal studies using AQR data are somewhat difficult to conduct because of a lack of a consistent carrier base over the period. Because of these inconsistencies, the present research focused on the fourteen airlines that have been included in the annual AQR reports over the period. These fourteen carriers have been classified according to their business models into one of three service groups: legacy (or network) carriers, regional carriers, and low-cost carriers. The fourteen airlines and their groupings are presented in Table 1.

Table 1
Carrier Groupings

Legacy Carriers	**Regional Carriers**	**Low-Cost Carriers**
Alaska Airlines	American Eagle Airlines	Air Tran Airways
American Airlines	Atlantic Southeast Airlines	Frontier Airlines
Continental Airlines	Mesa Airlines	Jet Blue Airlines
Delta Airlines	Sky West Airlines	Southwest Airlines
United Airlines		
US Airways		

Legacy carriers operate large route networks primarily using a hub-and-spoke route model. Their networks include international destinations and medium-to-large domestic cities (Erstad, Jednachowski, Bowen, Meehan, & Bowen, 2013). In addition, legacy carriers operate diverse fleets of aircraft with approximate capacities of from 100 to over 300 passengers.

Regional carriers often operate under code-sharing agreements with legacy carriers. They operate flights primarily from smaller cities to their respective partners' hubs using smaller, more efficient aircraft carrying approximately 9 to 99 passengers (Forbes & Lederman, 2006). Regional carriers have the most dynamic scheduling and overhead cost models, due to their need to support service from their hubs to medium and large cities by their respective legacy carriers. This service is intended to complement the legacy carrier's routes by adding additional frequency during off-peak times to ensure higher load factors.

Low-cost carriers often employ both point-to-point and hub-and-spoke models. They typically serve medium-to-large cities. These carriers generally have lower load factors when compared with legacy carriers, and therefore have more dynamic scheduling needs as the passenger demand changes (Erstad, Jednachowski, Bowen, Meehan, & Bowen, 2013). Low-cost carriers operate larger aircraft equipped with approximately 125 to 175 seats.

As a classical relative-frequency approach to the research question was desired, a repeated measures analysis of variance (ANOVA) of the data was conducted using IBM SPSS statistical software. Such an analysis is used to determine whether there are any statistically significant differences between the population means of three or more related groups. The REPEATED statement in the SPSS General Linear Model provides automatic computation and analyses for several common choices of contrast variables (Lund & Lund, 2013). The data must be in multivariate form in order to perform this analysis.

Each of the four metrics was treated as a separate dependent variable, and the independent variables were the carrier service level groups and the year groupings. While the use of a one-way ANCOVA (versus the two-way repeated measures ANOVA) would allow the control for variance in the year groupings, since the primary interest in this study is the difference in the carrier service level group means, the two-way repeated measures ANOVA was chosen due to potential correlation between the independent variables that can create difficulty in interpretation of the results.

One studying the carrier groupings in Table 1 will realize that the proposed use of 14 carriers (with two additional legacy carriers) leads to an unbalanced analysis, which presents considerable complexity in the two-factor design, as the orthogonality property of main effects does not carry over to the unbalanced case, meaning that the *F*-ratios are dependent on the order in which the sources of variation are considered (Shaw & Mitchell-Olds, 1993). While this can be corrected using the Type III sum-of-squares in SPSS, such a correction can lead to biased results, as main effects may be distorted in the presence of significant interactions.

The hypotheses that were used for this study are as follows:

- H_o: There is no statistically significant difference between the means at the given α level.
- H_a: There is a statistically significant difference between the means at the given α level.

A significance level of $\alpha = 0.05$ was applied in all tests.

Results

Four multivariate repeated measures analyses of variance were conducted to determine whether there were statistically significant differences between carrier group means for each of the four AQR factors (on-time arrivals, mishandled baggage, denied boardings, and customer complaints) over the course of six years. While the research data included few, if any, outliers, a Shapiro-Wilk test ($p < .05$) indicated that the data was not normally distributed for any of the carrier groups. Fortunately, the repeated measures ANOVA is reasonably robust to violations of normality, meaning that minor violations of the normality assumption will still provide valid results. (Lund & Lund, 2013).

First, on-time performance was analyzed. A test of between-subjects effects for the carrier service level variable indicated a significant difference between the service levels, F (2,165) = 3.846, p = .023. A Tukey-Kramer post-hoc difference test indicated significant differences between the regional and low-cost carrier groups (p = .032). Levene's test of homoscedasticity indicates that the between-subjects variances are homogeneous for five out of the six years; 2006 was the only year in which significant heteroscedasticity was indicated (Table 2).

Mauchly's Test of Sphericity, χ^2 (14) = 38.67, p = .001, indicated that the data violated the sphericity assumption. As a result, a Huynh-Feldt correction was applied (ε = .961). With the correction, statistically significant changes in on-time arrivals were indicated over the six years, F (4.803, 792.575) = 60.027, $p < .0005$, partial η^2 = .267. The means and standard deviations over the six year period can be found below in Table 3.

Table 2
Levene's Test of Equality of Error Variances for On-Time Arrival

Year	*F*	df1	df2	*p*
2006	5.099	2	165	.007
2007	1.853	2	165	.160
2008	.135	2	165	.874
2009	1.955	2	165	.145
2010	.032	2	165	.968
2011	.936	2	165	.394

Secondly, mishandled baggage was analyzed. There was a significant difference between carrier service levels suggested by the between-subject effects test, F (2,165) = 190.984, p = .001. All six years were significant in the Levene's test, suggesting that the between-subjects variances are not homogeneous (Table 4). Tukey-Kramer post-hoc testing indicated significant differences between the legacy and regional (p = .001), legacy and low-cost (p = .001), and regional and low-cost carrier groups (p = .001).

Mauchly's Test of Sphericity, χ^2 (14) = 414.23, p = .001, suggested a sphericity violation. Because of this, a Greenhouse-Geisser correction was applied (ε = .549). With this correction, statistically significant changes in mishandled baggage were indicated over the six years, *F* (2.743, 452.617) = 354.635, $p < .0005$, partial $\eta^2 = .682$. The means and standard deviations are presented in Table 5.

Table 3

Descriptive Statistics for On-Time Arrival

Year Group	Carrier	Mean	Std. Deviation	N
2006		.7488	.04093	72
Legacy		.7197	.06512	48
	Regional	.7707	.05831	48
	Low-cost	.7468	.05691	168
	Total			
2007		.7198	.06863	72
Legacy		.7086	.08174	48
	Regional	.7620	.07811	48
	Low-cost	.7287	.07790	168
	Total			
2008		.7515	.07486	72
Legacy		.7486	.07911	48
	Regional	.7736	.07995	48
	Low-cost	.7570	.07782	168
	Total			
2009		.7995	.05254	72
Legacy		.7751	.06608	48
	Regional	.7857	.06387	48
	Low-cost	.7886	.06047	168
	Total			
2010		.8237	.05390	72
Legacy		.7968	.05578	48
	Regional	.7989	.05954	48
	Low-cost	.8089	.05721	168
	Total			
2011		.8092	.05537	72
Legacy		.7873	.06154	48
	Regional	.7907	.06683	48
	Low-cost	.7976	.06106	168
	Total			

.

Table 4

Levene's Test of Equality of Error Variances for Mishandled Baggage

Year	*F*	df1	df2	*p*
2006	28.273	2	165	<.001
2007	14.401	2	165	<.001
2008	16.588	2	165	<.001
2009	23.595	2	165	<.001
2010	26.078	2	165	<.001
2011	22.246	2	165	<.001

Next, denied boardings were analyzed. A test of between-subjects effects suggested a significant difference between the carrier service levels, F (2,165) = 83.231, p = .001. The Tukey-Kramer post-hoc test again revealed significant differences between the legacy and regional (p = .001), legacy and low-cost (p = .001), and regional and low-cost carrier groups (p = .001). Levene's test also indicated between-subjects heteroscedasticity for all six years of the study (Table 6).

Mauchly's Sphericity Test, χ^2 (14) = 502.40, p = .001, again indicated that the data violated the sphericity assumption. Therefore, a Greenhouse-Geisser correction was applied (ε = .391). With this correction, statistically significant changes in denied boardings over the six years were indicated, F (1.957, 322.961) = 6.961, $p < .0005$, partial η^2 = .040. Table 7 summarizes the relevant means and standard deviations.

Lastly, customer complaints were analyzed. A test of between-subjects effects for the carrier service level variable indicated a significant difference between the service levels, F (2,165) = 52.983, p = .001. Levene's test indicates a higher degree of homogeneity of between-subjects variances in four out of the six years of the independent variables; the two years that are significant in the test are 2007 and 2009. Tukey-Kramer post-hoc test indicated significant differences between the legacy and regional (p = .001), legacy and low-cost (p = .001), and regional and low-cost carrier groups (p = .001).

Mauchly's Test of Sphericity, χ^2 (14) = 107.52, p = .001, once again indicated that the data violated the sphericity assumption. As a result, a Huynh-Feldt correction was applied (ε = .820). With the correction, statistically significant changes in customer complaints were indicated over the six years, F (4.099, 676.397) = 14.326, $p < .0005$, partial η^2 = .080. The means and standard deviations over the six year period are displayed in Table 9.

Table 5

Descriptive Statistics for Mishandled Baggage

Year Group	Carrier	Mean	Std. Deviation	N
2006		6.1697	1.73837	72
Legacy		13.2077	4.03767	48
	Regional	4.8398	1.28341	48
	Low-cost	7.8006	4.29026	168
	Total			
2007		6.7678	1.84949	72
Legacy		11.5696	3.12272	48
	Regional	5.3283	1.65751	48
	Low-cost	7.7285	3.35653	168
	Total			
2008		5.0108	1.49106	72
Legacy		8.8425	2.81798	48
	Regional	3.8394	1.28880	48
	Low-cost	5.7709	2.77142	168
	Total			
2009		3.8288	1.11966	72
Legacy		6.5075	2.19484	48
	Regional	2.5379	.77098	48
	Low-cost	4.2253	2.10695	168
	Total			
2010		3.1832	.79181	72
Legacy		5.6942	1.93822	48
	Regional	2.5392	.77069	48
	Low-cost	3.7166	1.77093	168
	Total			
2011		3.0747	.59611	72
Legacy		5.4798	1.58115	48
	Regional	2.4242	.80225	48
	Low-cost	3.5643	1.60600	168
	Total			

Table 6

Levene's Test of Equality of Error Variance for Denied Boarding

Year	*F*	df1	df2	*p*
2006	29.911	2	165	<.001
2007	23.217	2	165	<.001
2008	57.505	2	165	<.001
2009	40.678	2	165	<.001
2010	29.736	2	165	<.001
2011	41.174	2	165	<.001

Table 7

Descriptive Statistics for Denied Boarding

Year	Carrier Group	Mean	Std. Deviation	N
2006		1.1862	.60402	72
Legacy		2.1313	1.59763	48
	Regional	.3869	.38905	48
	Low-cost	1.2279	1.16390	168
	Total			
2007		1.2217	.77840	72
Legacy		2.2844	1.42382	48
	Regional	.5606	.52627	48
	Low-cost	1.3364	1.15890	168
	Total			
2008		1.1442	.44564	72
Legacy		2.3781	1.22177	48
	Regional	.5850	.51981	48
	Low-cost	1.3370	1.03475	168
	Total			
2009		1.3392	.57502	72
Legacy		2.1375	1.31447	48
	Regional	.8406	.82083	48
	Low-cost	1.4248	1.03137	168
	Total			
2010		1.2092	.67706	72
Legacy		1.9706	1.52391	48
	Regional	.9756	1.03612	48
	Low-cost	1.3600	1.14458	168
	Total			
2011		.9171	.38187	72
Legacy		1.5394	.88332	48
	Regional	.5550	.37635	48
	Low-cost	.9914	.68182	168
	Total			

Table 8

Levene's Test of Equality of Error Variance for Customer Complaints

Year	*F*	df1	df2	*p*
2006	3.549	2	165	.031
2007	11.553	2	165	<.001
2008	2.533	2	165	.083
2009	10.267	2	165	<.001
2010	4.255	2	165	.016
2011	5.453	2	165	.005

Table 9

Descriptive Statistics for Customer Complaints

Year Group	Carrier	Mean	Std. Deviation	N
2006		1.0406	.36774	72
Legacy		.9283	.52879	48
	Regional	.4196	.24783	48
	Low-cost	.8311	.47305	168
	Total			
2007		1.7551	.97122	72
Legacy		.9631	.52858	48
	Regional	.6306	.40791	48
	Low-cost	1.2075	.87669	168
	Total			
2008		1.4246	.63629	72
Legacy		.7910	.49795	48
	Regional	.7665	.52394	48
	Low-cost	1.0555	.64963	168
	Total			
2009		1.1926	.52479	72
Legacy		.6121	.22220	48
	Regional	.7306	.39514	48
	Low-cost	.8948	.49386	168
	Total			
2010		1.4137	.58790	72
Legacy		.6752	.37561	48
	Regional	.9179	.56351	48
	Low-cost	1.0611	.61508	168
	Total			
2011		1.5103	.67401	72
Legacy		.9056	.55948	48
	Regional	.7217	.39974	48
	Low-cost	1.1122	.67129	168
	Total			

Discussion

There are a number of assumptions associated with the repeated measures analysis of variance that must be made by the researcher. Requirements that the dependent variable be continuous and the independent variables be categorical in nature are clearly met by the data being analyzed. Further assumptions that the differences between groups be free of outliers and normally distributed and that the differences between all combinations of groups be homoscedastistic are met to varying degrees, as described below.

Normality of the differences in the dependent variable between groups can be evaluated using Q-Q plots and the Shapiro-Wilk test (Kinney, 2002). In this study, both the Shapiro-Wilk test ($p < .05$) and the Q-Q plots indicated that the data was not normally distributed for any of the carrier groups. Fortunately, as noted previously, repeated measures ANOVA is reasonably tolerant of violations of normality (Lund & Lund, 2013). Figure 1 below provides one example of a Q-Q plot that shows evidence of the data being not normally distributed.

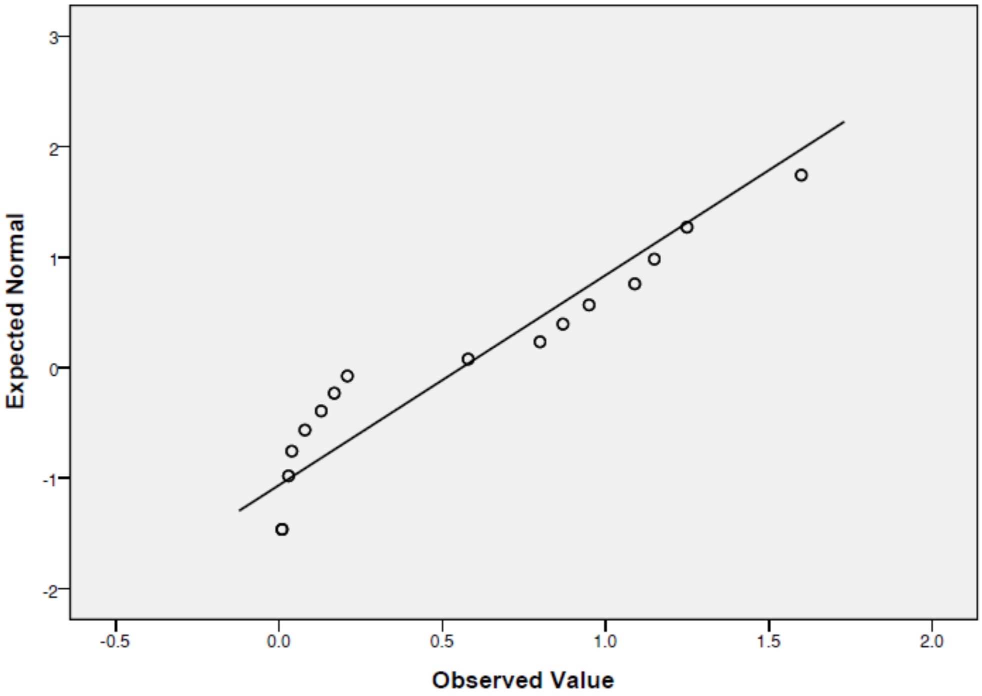

Figure 1. Normal Q-Q plot of low-cost carriers for 2007.

A Levene's test was conducted to determine the level of between-subjects homogeneity of variance for each of the four AQR components over the six year study period. This testing indicated varying degrees of between-subjects homoscedasticity for each of the components. Likewise, the assumption of sphericity was examined using Mauchly's test and found to be violated for each of the four components. While the repeated measures analysis of variance is much more susceptible to sphericity violations than it is to lack of normality, there are corrections that may be employed in such cases to produce a more valid critical *F*-value; among these are the Greenhouse-Geisser and the Huynh-Feldt corrections (Lund & Lund, 2013). Nonetheless, due to the lack of both homoscedasticity and normality among the carrier groups, other statistical methods that do not require such assumptions are worthy of consideration for the analysis of this dataset.

Given that the analysis is reasonably tolerant to the lack of normality and using the appropriate corrections for lack of sphericity, the researchers proceeded to examine the differences between legacy, regional, and low-cost carriers to determine whether a significant difference between the groups exists relative to the four primary AQR components (OT, DB, MB, CC) over the six year study period. Based on the post-hoc test results, significant differences in on-time arrivals were not indicated between legacy and regional carriers or legacy and low-cost carriers; however, such differences were indicated between regional and low-cost carriers. It should be noted that the resulting *p*-value ($p = .064$) for the legacy-regional post-hoc comparison was quite close to the fixed α value of .05; therefore, further research using Bayesian methods is suggested.

With regard to mishandled baggage, denied boardings, and customer complaints, significant differences between legacy, regional, and low-cost carriers were indicated, implying rejection of the null hypothesis, H_o. This suggests that there is sufficient evidence to support the premise that separate econometric predictive models are needed by airline managers to facilitate quality of service improvements.

Managers within the different carrier groups will be able to utilize predictive modeling to better forecast the AQR components. In addition, the results presented herein also describe longitudinal changes in the marginal means of each of the components (Figures 2 through 5). For example, Figure 2 indicates that significant improvement has occurred among the legacy carriers over the study period with regard to on-time arrivals, while a lesser degree of improvement has occurred among low-cost carriers. The longitudinal changes in the slopes of the marginal means and the attendant interactions imply the difficulty of constructing accurate predictive models for these components; that difficulty is clearly compounded by the failure to partition the carriers into groups.

Conclusion and Further Research

In this Frequentist study of the four primary components of the Airline Quality Rating over a six-year period, two-way analyses of variance in conjunction with Tukey-Kramer post-hoc difference testing have shown that separate predictive models are appropriate, based on the differences between the carrier groups. Utilizing these predictive models, airline managers will be able to more accurately forecast the components and thus the overall quality rating, thereby allowing them to refine resource allocation methods in an effort to improve quality of service. It is suggested that future research be conducted using Bayesian statistical methods rather than the null hypothesis significance testing (NHST) methods used in this study. Bayesian models do not depend on corrections to ensure that test assumptions are met; instead, Bayesian methods rationally mitigate statistical error based on the data itself (Kruschke, 2010). In addition, when using

Bayesian hierarchical modeling, any concern regarding the robustness of the analysis technique is reduced.

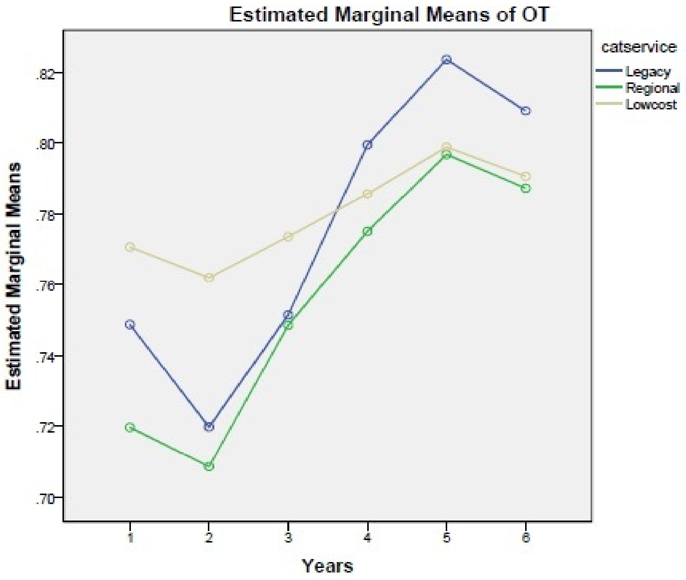

Figure 2. Estimated marginal on-time arrival means plotted against study year.

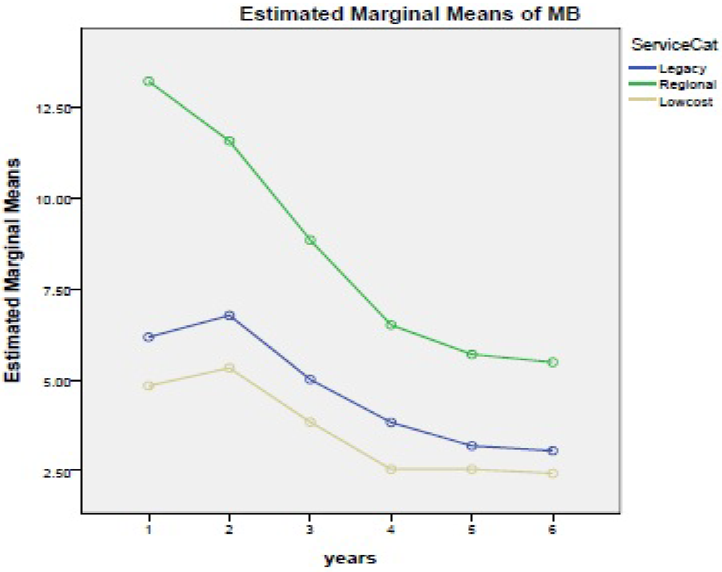

Figure 3. Estimated marginal mishandled baggage means plotted against study year.

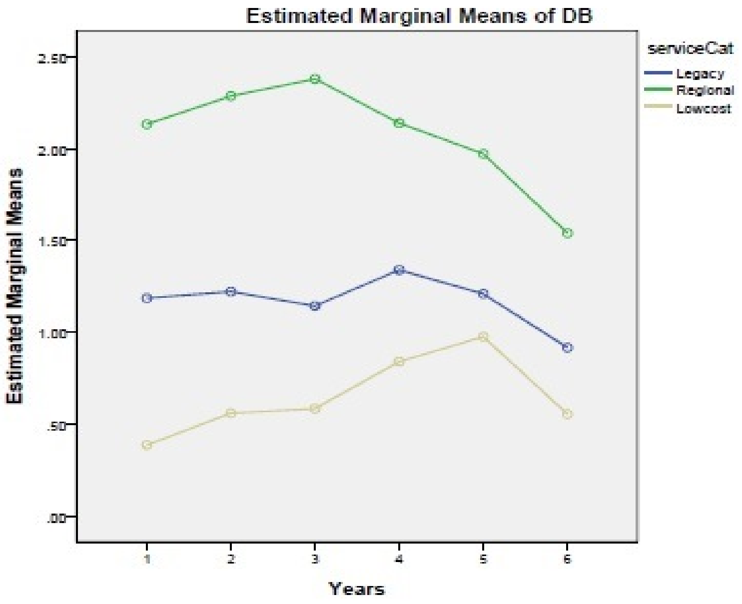

Figure 4. Estimated marginal denied boarding means plotted against study year.

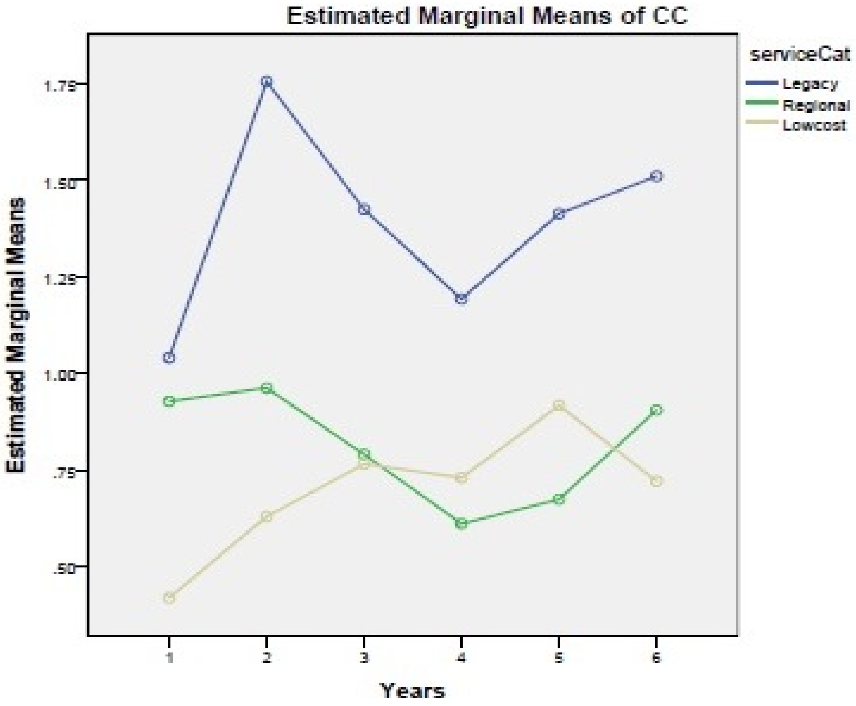

Figure 5. Estimated marginal customer complaint means plotted against study year.

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Optimizing the Event Set for Collegiate Aviation FOQA Programs

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Abstract

Flight Operations Quality Assurance or FOQA is a proven tool in the effort to enhance aviation safety. Employed by air carriers as early as the 1960's, FOQA allows aviation operations and safety managers to objectively monitor how their aircraft are being operated. This data can then be translated into informed decisions to improve the safety and efficiency of the overall operation. While FOQA has proven itself in the world of airlines and other commercial aviation ventures, these flight data monitoring programs have largely been absent in the area where the vast majority of flight operations occur, general aviation. Advancements in technology allow those in general aviation management positions the ability to apply the same techniques in general aviation. This study attempts to further the body of knowledge of Flight Operations Quality Assurance (FOQA) programs by examining the unique requirements of a FOQA program adapted to the university flight-training environment. The methodology employed are qualitative in nature employing a Delphi study to gather data from a group of subject matter experts on both FOQA and general aviation flight instruction. Qualitative observations gathered by the researcher from the direct observation of flight instruction will be used to supplement the data gathered from the Delphi Study. Through the analysis of these two data sets, this study determines what events and parameters should be monitored in a collegiate FOQA program.

Introduction

Reports produced by the National Transportation Safety Board (NTSB) and the Air Safety Institute (ASI) have shown that aviation accidents have decreased sharply since the 1960s, but the data also shows that between 60 and 80 percent of accidents are attributed to human error. (NTSB, 2012). Advancements in technology, both mechanical and electronic in nature, have contributed to the decrease in the overall accident rate, however, the high percentage of human error that remains shows that in order to decrease the accident rate further we must focus on mitigating the behaviors that often result in aviation accidents.

Flight Operational Quality Assurance (FOQA) programs present a solution to this problem; already in place in many airlines and commercial aviation enterprises throughout the world, they have proven their ability to break the chain of mistakes that lead to an accident. FOQA provides aviation managers a proactive method of safety management through the monitoring of recorded data showing trends in pilot behaviors.

FOQA programs are generally limited to airlines and large commercial aviation ventures, and are largely absent from university aviation programs and the general aviation community. There is an array of reasons why FOQA is not in wide use in general aviation, the most prominent of which is the initial cost to implement a FOQA program. Implementation costs include the analysis software and administrative processes required to manipulate the recorded flight data as well as equipment in the aircraft that will record the in-flight data. Previous studies have explored the efficacy of using the built-in data recording functions found in modern EFIS or "glass cockpit" avionics packages as the technology platform of an FOQA program. (Lau, 2012). What is lacking from the body of knowledge is a study of the unique situations faced in collegiate flight training, and how an FOQA program can be tailored so they not only increase the overall safety of an organization, but also to aid students in attaining the flight proficiency required of a commercial aviator more quickly and efficiently.

The results of this study can be used to help the management of a collegiate flight training organization determine how best to focus its resources to correctly monitor flight training activity. The methodology used in this study places an emphasis on determining the set of events that must be developed and monitored by a university FOQA program in order to provide program administrators and safety personnel a snapshot of trends that could potentially lead to an accident.

Review of Literature

FOQA is a voluntary safety program that intends to make aviation safer through the gathering and analysis of objective and quantitative data (Vala, 2011). FOQA programs have been commonplace in European air carriers since the 1980s and US air carriers since the 1990s. Since the early 2000s, FOQA programs have begun to take root in smaller commercial aviation operations and will eventually be applicable to the larger general aviation community. Expansion of FOQA into General Aviation (GA) is not without its challenges, but research shows that FOQA and the opportunity it provides to objectively review day-to-day flight operations represents the most realistic solution for reducing general aviation incidents from their current levels (Mitchell, Stoly & Stolzer, 2007).

The causal factor of roughly 80% of accidents in both civil and military aviation are mistakes made by the flight crew (Ramana, n.d.). By addressing these accidents related to human error through the proactive data collection FOQA enables, aviation managers hope to significantly reduce aviation accidents. Most of these accidents are attributed to deviation from standard operating procedures, failure to conduct operations critical to the flight at the prescribed time, and rushed performance during critical phases of flight (Harrah & Kaseote, 1999). FOQA allows aviation managers to view this substandard performance in the aggregate. With FOQA aviation managers can track trends, conduct statistical analysis, and quantify the areas of pilot performance that require additional safety training or a change to the company's standard operating procedures. Through this simple concept, aviation managers have the opportunity to influence pilot behaviors that could lead to an accident prior to the accident happening.

This study focuses on FOQA and its use in general aviation. General aviation is commonly defined as “all air traffic that is not either military or scheduled air service and comprises the majority of aviation operations that take place in the U.S. on a daily basis. (Wensenveen, 2011) In contrast to the safety enhancements and reduced accident rates attributed to FOQA programs and their use in the air transportation industry, the general aviation community has not enjoyed the same benefits. The current technological environment provides a means to change this fact due to emerging technologies.

> S. Lau’s study (2007) states: Currently, there is a confluence of events that make FDM practical for General Aviation aircraft. These events include a new sophisticated approach to aviation safety by operators and the FAA, affordable computing power and storage, high-speed internet connectivity, precise GPS navigation capabilities, open aircraft systems architecture that allows data acquisition from a digital avionics data bus and the miniaturization of sensors to create new lightweight low- cost devices with accuracy that rivals more expensive inertial measurement units. (pg. 4)

The application of these new technologies will allow the general aviation community to share in the benefits of FOQA which include safety, efficiency, and enhanced maintenance management.

As research points to the benefits of GA FOQA, collegiate aviation provides the perfect proving ground for GA FOQA programs due to the comparatively large size of university aircraft fleets. Some of the first steps in the advancement of GA-FOQA as it applies to collegiate flight programs were taken by the University of North Dakota, Purdue University, and Embry Riddle Aeronautical University. (Lau, 2012) These initial studies provided a proof of concept in relatively low cost GA-FOQA using the flight data monitoring capabilities of the Garmin-1000 digital cockpits as well as Lightweight Aircraft Recording Solutions (LARS) from companies such as Alakai and Appareo. This proof of concept has shown that FOQA programs can increase the efficiency of general aviation operations through reduced maintenance troubleshooting costs and decreased aircraft on ground (AOG) times. (Lau, 2012).

FOQA is important to collegiate flight programs for reasons apart from the safety and efficiency gains that can be realized. According to a 2007 newsletter published by the Aviation Accreditation Board International an industry panel suggested that students expected to function effectively in an industry where flight data monitoring is the norm should be exposed to FDM and FOQA at the university level (AABI, 2007). By developing and maintaining an FOQA program, a university can train its students in flight data monitoring techniques and expose them to the data mining process.

Universities can also improve students' perceptions toward their future employer's FOQA programs through exposure to FOQA in their initial flight training.

A challenge facing collegiate FOQA programs is the relative newness of the technologies that make general aviation FOQA possible. There have been few studies completed on collegiate FOQA (Vala, 2011). This challenge establishes the need for this study; for an FOQA program to be an important part of collegiate flight training and general aviation it must be structured so that aviation managers are viewing data that is optimized to their operation

Methodology

This study employs two qualitative methods. A Delphi study and a series of qualitative observations were run concurrently. The methods were employed simultaneously, but could have been employed sequentially had more time been allotted for the conduct of the study.

Part one of the study includes a Delphi study to gain a consensus from a group of recognized subject matter experts in the areas of flight instruction and FOQA. Two primary characteristics of a Delphi study are that it is a multi-round study that provides feedback to the participants, and that the participants are anonymous to one another. A Delphi study fit this particular study nicely allowing the researcher to collect data from a panel of experts, and the anonymity between participants allowed each participant to express their views without those views being skewed by other participants. The panel is made up of eight participants of various backgrounds, in order to pull data from the diverse range of general and collegiate aviation. The panel includes university flight safety officers, university flight and ground instructors, and aviators with a background in flight-testing and the airline industry.

Delphi studies are characterized by the small size of their panel of participants. Therefore, a Delphi study is not designed to produce statistically significant results, but to produce a snapshot of the opinions of a given panel of subject matter experts. Due to this fact participant selection for a Delphi study is of utmost importance. (Gordon, 1994) 10 individuals were selected and asked to participate in the study, of which eight responded favorably to the request and agreed to provide data. Of the eight individuals who provided data for round one of the Delphi Method, only six updated their responses for round two, with the remaining two participants electing to leave their round one responses unchanged. The resulting data was adequate for the purposes of the research as the responses were very similar in nature and pointed to clear conclusions. This researcher believes that any richening of the data set that could have been provided by a larger panel is offset by the data provided by the qualitative observations employed during this study that strongly correlated with the data from the Delphi study.

Selecting the appropriate subject matter experts was crucial to the study. Participants were selected that had experience in collegiate aviation and understood its challenges and environment. These subject matter experts were either actively employed as flight instructors in a university aviation program, or were active researchers or safety managers of a collegiate aviation program. Secondly, participants were selected for their knowledge and experience with general aviation FOQA. This researcher believed the study required participants who had either research or practical experience in the fields of GA and collegiate aviation FOQA in order to provide data that would directly support the research questions. Lastly, this researcher wanted to include a few individuals who were outside the spheres of collegiate aviation and FOQA. Participants were selected who had practical experience in the research topic, but could provide outside experience and a divergent view on FOQA. It was believed that participants of this type would provide differing viewpoints that would serve to richen the resulting data. The final panel selected fit the Delphi Methodology requirement of a small panel of experts in their field and was comprised of four collegiate FOQA managers or researchers, two senior collegiate flight instructors, a flight test engineer with experience in military and airline FOQA, and a GA writer and advocate.

Only two rounds of response and feedback were required in this Delphi Study due to the relatively unchanging nature of the responses from the participants and their similarity to one another. An analysis of the feedback to each question was completed by finding the amount of times a similar theme appears in the responses to each survey question and dividing by the total number of panel members. This analysis gave the researcher a percentage based score that was used to judge the similarity of the survey responses. Through this process this researcher was able to draw conclusions based on the relative frequency of a particular response.

Qualitative observations were used to supplement the data gathered in the Delphi study. The data collected from the Delphi study is the more important dataset given the expertise and diversity of the panel members, but qualitative observations taken by the researcher from actual flight training situations worked to overcome the small sample size inherent to the Delphi study.

The methodology behind the qualitative observations involved this researcher observing training flights from the rear seat of a training aircraft to record interactions between the flight instructors and students. The researcher recorded corrections made by the flight instructor to counter mistakes made by the students. These corrections were of a verbal nature or in the form of physical manipulation of the flight controls. The researcher coded the various corrections observed on a thematic basis with the theme denoted by the maneuver being corrected and the type of mistake made by the student during the maneuver. Following the coding of the observations, the researcher analyzed the observed corrections in aggregate. It was assumed that mistakes that were commonly made by students would be marked by an increased number of corrections made by the flight instructor and those student pilot behaviors most often corrected by the flight instructor should be monitored by the FOQA program.

Results

The findings of the Delphi Study are presented in this section and organized to show the responses of the panel members grouped into themes. The responses in this section are paraphrased to more clearly portray the data provided by the respondent and presented in a question and answer format that fits the survey instrument used in the study.

Question 1: What specific flight maneuvers or types of flight maneuvers are difficult for a flight instructor to objectively evaluate and critique.

100% of respondents stated that complex maneuvers with multiple variables such as a chandelle or lazy eight are the most difficult for a flight instructor to objectively evaluate. Every participant also stated that ground reference maneuvers are difficult to judge. Steep spirals were specifically mentioned by all participants due the difficulty in the instructor's determination of the precise ground track during the course of the maneuver.

Five out of six participants in round two indicated that approaches of various types are difficult to objectively evaluate. The approaches discussed varied from steep VFR approaches to instrument approaches. The reasons indicated by the participants center on the number of variables present during the approach. Participants indicated that a synthesized picture of the approach recreated for use during the flight debrief would be helpful to both students and instructors.

Outlying responses mentioned by two or fewer of the participants include emergency maneuvers and holding pattern entries and procedures. It was indicated by these participants that emergency procedure training such as landing site selection could benefit from recorded ground tracks and synthesized playback.

Question 2: Discuss some of the limitations you regularly see exceeded while flying with student pilots. (These limitations can either be specific to a standard operating procedure or specific to the aircraft)

Five out of eight participants responded to this question by indicating that flap extension speeds are the most common aircraft limit exceeded by student pilots. The same number of participants report that altitude and heading are two other very common maneuver limits exceeded by students. 50% of the participants indicate that engine RPM over-speed is a common occurrence. Outlying responses provided by only one participant are bank angles in the traffic pattern and autopilot engagement altitudes.

Question 3: From the event list provided in the survey instructions, what other events do you believe should be included (a copy of the KSU Salina FOQA event set was provided to the study participants). To clarify, what should be monitored that is not captured in the listed events? (Do not focus on "how" something could be monitored with the listed parameters, but list "what" you believe should be monitored)

The responses from this question were not as similar as the responses to the previous questions where a clear majority of participants provided the same response. The responses do however correlate with the responses given to previous questions. The most common responses to Question 3 indicated that events monitoring unstabilized approaches and flap extension speeds are very important to a collegiate FOQA event set. Participants further recommend that events monitoring how the aircraft is controlled in the landing phase be added. Specifically, three participants recommended events be developed to monitor the G loading of the aircraft when it is landed to track "hard landings" as well as examining the length of the landing to monitor how often the aircraft is landed beyond the intended touchdown point. Responses given by two or fewer participants include the addition of events that track compliance with the school's operations or procedures manual. Bank angles during turns in an airport's traffic pattern are also provided as an issue that requires monitoring.

Participants mentioned he Nall report prepared by the Air Safety Institute as a document from which events could be developed, the Nall report is an annual document that outlines General Aviation accidents from the previous year. (Air Safety Institute, 2012) The accident data contained in this report provides data on the most frequent general aviation accidents and could provide a guide for what should be monitored by a general aviation FOQA program.

Question 4: The G1000 provides the capability to record parameters such as fuel flow, EGT/CHT, RPM, OIL Temp, and Outside Air Temp (see parameter list in the attached survey instructions). How could this data concerned with engine operation be used in a collegiate flight-training program?

All participants agreed that parameters relating to the power plant of the aircraft should be used to monitor the leaning and fuel efficiency of the engine. Participants further explain this answer by indicating that the grouping of multiple parameters such as fuel flow, GPS location, and altitude could be used to monitor mixture leaning during ground operations. The majority of participants also respond that engine parameters could be used to develop an engine health-monitoring program or to monitor the efficiency of operations such as tweaking the locations where flight training is conducted or how the aircraft's performance is managed to make the overall operation more efficient.

Question 5: What is the primary safety related concern of the flight training operation in which you are/were involved?

The participants in the survey all answered this question in differing ways but the responses coalesce around two primary themes. The first theme is that a primary safety concern for many aviation operators is the deviation of pilots from standard procedures found either in operations manuals and/or local procedures guides. Other events cited include improper landing of the aircraft and unstabilized approaches.

Question 6: What student action(s) do you believe are most often related to the incidents or accidents experienced in a flight-training program?

The majority of participants respond that poor task management or judgment on the part of the student contributed to the majority of incidents and accidents in flight training programs. Poor judgment is expanded upon to refer to students who knowingly operated the aircraft outside of policies and procedures established by the school. This could include flight into bad weather, landings conducted with excessive crosswind components, or intentional aggressive maneuvering not required by the flight conditions.

Pilot complacency is another danger identified by the participants; this statement led into discussions of improper task management during periods of high workload. It was suggested by one participant that FOQA could be used to track minor excursions outside of established standards and that data studied against perceived workload levels.

Question 7: The Garmin G1000 provides the ability to record parameters such as which navigation source is selected, when the autopilot is engaged/disengaged, CDI deflection, etc. (See list of available parameters in the survey instructions) How could these measurements concerned with resource and avionics management be used by flight instructors and training program managers to improve safety and training efficiency?

All participants agree that this information could be used to monitor automation usage. By monitoring automation usage, program managers and instructors could determine if students are using the automation correctly and not over-relying on a particular function of the automation. Through the monitoring of automation usage to this level of detail program managers could determine if students displayed an over-reliance on one function of the automation without learning the system in detail. Autopilot usage could also be determined with the goal of monitoring the amount of autopilot usage and whether the autopilot is used in accordance with manufacturer and local procedures.

The results of the qualitative observations are presented in graphic form where possible. The goal of the qualitative observations was to determine what trends were present in the mistakes and corresponding corrections made by students and instructors during actual flight training so that those results could be compared to the feedback from the Delphi study. 35 flight hours of observations were taken over the course of two months during collegiate flight instruction. The students observed include those who were receiving primary, commercial, or instrument training.

The corrections and student mistakes are coded thematically based on the nature of the correction and compared on a percentage basis against the total number of corrections observed. This simple comparison provides insight into what mistakes are most common among student pilots in collegiate flight training and subsequently where the focus of collegiate flight training FOQA programs should lie. Figure 2 provides a graphic depiction of the categories of corrections observed and how they relate on a percentage basis to the other categories.

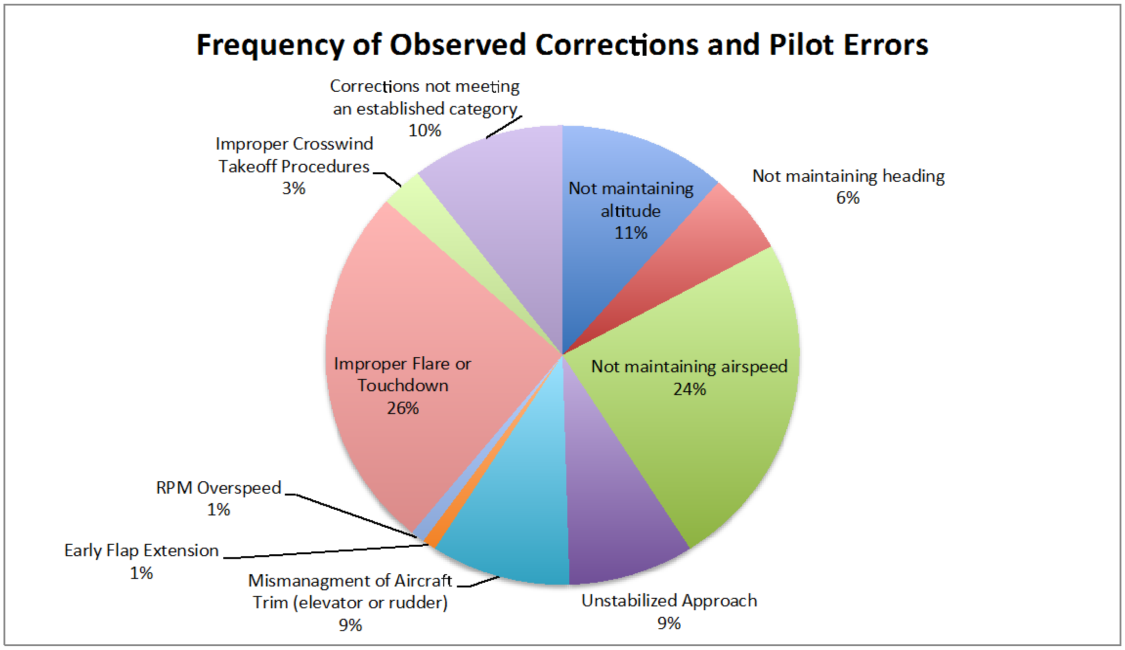

Figure 1. Frequency of Observed Corrections and pilot errors.

The above figure describes the nature of mistakes made by student pilots. A pilot action is classified as an error if it results in a situation where the aircraft is operated outside of established local or FAA standards for the maneuver being performed. The researcher expands the analysis of pilot behavior to account for the skill level of the student pilot. A pilot's skill level refers to the level of airman certificate held or level of training being conducted such as private or commercial pilot. Pilots operating at or training for the commercial pilot skill level must operate the aircraft to a more stringent set of standards than those pilots operating at the private pilot skill level.

50% of the total corrections and mistakes observed are comprised of mistakes related o the landing of the aircraft from the landing flare to touchdown and mistakes relating to insufficient control of airspeed comprising 26% and 24% of the total number of corrections respectively. Errors involving insufficient maintenance of aircraft altitude, the trimming of both the aircraft's elevators and rudder, and those involving the student conducting an un-stabilized approach each accounted for approximately 10% of the total number of observed pilot errors. Of the other themes in pilot errors that are observed, each accounts for less than 10% of the total number of observed errors.

Additionally, many actions were observed that do not fit into any of the established categories. These actions generally relate to situations where the pilot action was incorrect but did not result in the aircraft being operated outside of a local or FAA standard. These incorrect actions relate to generally accepted safe operating practices such as aircraft bank angles or engine management procedures. The researcher believes that the creation of a separate category for each of these errors might have made the overall analysis of the data less clear to the reader.

The researcher believed that to provide an analysis of the pilot errors observed relating to improper flare and touchdown the observed errors should be shown graphically to provide insight into the exact nature of the error made by the student pilot during the landing phase. This breakdown is shown in figure two.

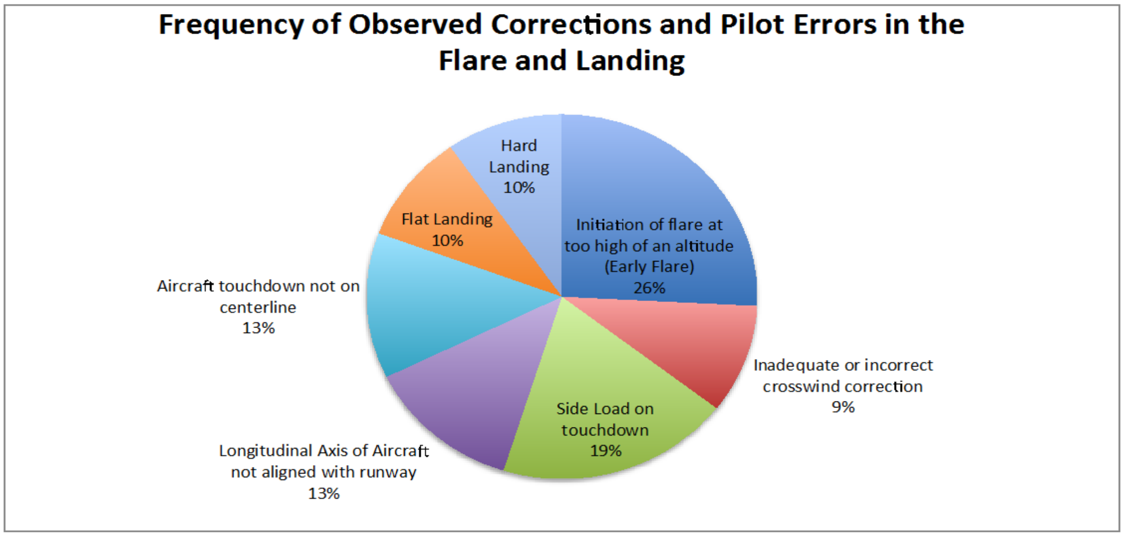

Figure 2. Frequency of Observed Corrections and Pilot Errors in the flare and landing.

The reader should note that of the corrections observed during the landing phase, many are the result of interrelated factors such as the flaring the aircraft at too high of an altitude resulting in a hard landing. To decrease any confusion in the interpretation of the data, each pilot error or instructor correction is viewed as a single event.

The majority of pilot errors observed during the landing phase relate to the student pilot initiating the flare maneuver too early or at too high of an altitude above the runway accounting for 26% of the overall errors observed. Landing of the aircraft with lateral "G" forces or a "side-load" attribute to the second most often observed error at 19% of the total errors observed. Other errors observed each account for between 9% and 13% of the total number of observed errors.

Conclusion

This researcher endeavored to present an event set that is specific enough to be useful to the collegiate FOQA manager. However, there are multiple flight data recording solutions available that are viable for use in light airplanes, and the researcher did not attempt to tailor an event set for multiple data recording solutions. It is up to the individual FOQA manager to assemble the available parameters of their recording solution to meet the events recommended by this study. The suggested collegiate FOQA event set as defined by this study is contained in table 1.

Though not the traditional objective of FOQA programs, it was suggested by Delphi study participants that the use of recorded flight data could prove very beneficial while debriefing the training flight to the student pilot. This information could allow the CFI to construct either a virtual model of the flight to the student, or a graphic of the aircraft's track across the ground during the maneuver to aid in objectively explaining the performance of the maneuver. The difficulty in using a FOQA program and recorded flight data in this manner is the rapidity with which the information must be retrieved from the recording device in the aircraft. Furthermore, the flight data recording and analysis system in use must be compatible with the software used to display the flight information in the graphic format required of student debriefs. Stated another way, the technology used to record and analyze the flight information must be able to retrieve the information from the aircraft and process it quickly enough to be used to debrief the student immediately following the flight.

The use of recorded flight data during student debriefs is an area where further research is required. Aviation managers should investigate how to integrate this technique into a flight-training syllabus. It is this researcher's hypothesis that through the proper use of recorded flight data the average training time required for a student to attain pilot certificates could be reduced.

The use of FOQA programs is a promising method in the effort to reduce the training time and resources required in a collegiate flight-training syllabus. FOQA represents a very realistic opportunity to reduce the number of accidents in the general aviation community as a whole. Collegiate aviation with its relatively large fleets of training aircraft and large student population provides an excellent proving ground for general aviation FOQA techniques, and the lessons learned from collegiate FOQA programs can be applied to the general aviation community as a whole. This study provides a template and recommendations on FOQA events that are best suited to a collegiate FOQA program, but leaves the final analysis of the importance of each event to the FOQA manager. This is an important distinction because although at their core the FOQA programs of all flight-training operations will share many similarities, each program is different in terms of training goals and environments and therefore will require a slightly different approach from the FOQA manager.

Table 1

Recommended events in a collegiate FOQA program.

Event Title	**Event Logic**	**Parameters Used (suggested)**
Unstabilized Approach	Greater than 500FPM descent, too fast on final approach	airspeed, vert. speed
Flap Extension	Flaps extended above Vfe	airspeed, flap indications
RPM Overspeed	Engine RPM above maximum level	Engine RPM
Bank Angle in Traffic Pattern	Greater than 30 degree bank in traffic pattern	bank angle, geo-location
Fuel Mixture Leaning	Mixture not leaned in cruise flight	fuel flow, Altitude
Fuel mixture leaning (ground)	Mixture not leaned during ground operations	fuel flow, altitude, geo-location
Autopilot Usage	Autopilot not used below minimum altitude	autopilot, altitude
Excessive Bank	Bank Angle greater than 60 deg	Bank angle
Excessive Pitch	Pitch Angle greater than +30 deg or -15 deg	Pitch attitude angle
VNE Max	Airspeed greater than aircraft Vne	Airspeed
Excessive G Loading	G loading greater than 2.5	Vertical G Force
Fuel Low	Fuel level below 1 hour of normal cruise fuel burn	fuel level
Hard Landing	Landing with a momentary G loading of greater than 1.5	Vertical G force, altitude
Side Load on Landing	Landing with lateral G forces	Lateral G, altitude
Excessive float on landing	Touchdown beyond the 1000' marker on the runway	Altitude, Location, Airspeed
Flat Landing	Touching down on nose wheel simultaneous with main gear	Altitude, location, pitch
CHT Max	CHT above aircraft maximum level	CHT
EGT Max	EGT above aircraft maximum level	EGT
High Oil Temp	Oil Temp above manufacturer's specified level	Oil Temp
Oil Pressure Low	Oil Pressure below manufacturer's specified level	Oil Pressure
Cont'd	**Cont'd**	**Cont'd**

Event Title	**Event Logic**	**Parameters Used (suggested)**
Oil Pressure High	Oil Pressure above manufacturer's specified level	Oil Pressure
Voltage Low	Voltage below manufacturers specified level	Voltage
Amperage Low	Amperage discharging after a given amount of time in flight	Amperage, elapsed time

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