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The Need for Quality Aviation Safety Graduates: An Educational Challenge for the 21st Century

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The authors investigated a previously unaddressed problem within the curricula of the United States (U.S.) aviation institutions of higher education. Graduates of these institutions were not being prepared to work within the safety departments of the U.S. air carriers involved with one or more of the five current, voluntary programs. To ascertain the need for a solution, a subjective instrument was developed and personally administered to 13 participants within the industry. The qualitative results were interpreted, and, in combination with the knowledge gained from the immersion of a professor within a research organization, resulted in placement of some of the aforementioned content within the curriculum on one campus of one U.S. aviation university in the spring of 2005.

Introduction

The purpose of this paper is to serve as a progress report for the project that was conceived by the authors and enabled by the National Aeronautics and Space Administration (NASA) Faculty Fellowship Program. During the summer of 2004, a professor (also a retired air carrier captain) from Embry-Riddle Aeronautical University (ERAU) and a NASA Ames Research Center program manager commenced a project that would infuse the five, current Federal Aviation Administration (FAA) and U.S. air carrier voluntary safety programs into curricula for aviation institutions of higher learning. Current Air Traffic Control (ATC) programs that address improved efficiency of the National Airspace System (NAS) have not been excluded from the program. They have been scheduled for further investigation during the summer of 2005 as content for a proposed ATC specialization in the Master of Science in Aeronautics (MSA) program at ERAU, Daytona Beach, Florida.

The safety programs are relatively new to the U.S. air transportation system, having matured only since the 1990s. During the 21st century, the FAA and NASA have emphasized a need for the continuous, reliable analysis of the program-derived, large safety/ efficiency databases of both the U.S. air carrier and ATC systems. Two generalizations concerning the analysis, interpretation, and reporting processes associated with the large volumes of data are:

1. The air carrier personnel traditionally involved with the analysis and reporting of the data generated by today's modern safety programs possess considerable operating experience, but have not had scientific backgrounds.
2. The U.S. aviation institutions of higher learning have not had the resources to introduce the new air carrier safety programs to the curricula. More explicitly, the knowledge of, and the materials for, the programs have not been available.

Thus, it was theorized that the NAS would benefit from future graduates of aviation higher education with the desirable scientific knowledge, skills, and attributes associated with the maturing safety and efficiency programs of the 21st century.

Background

Less than 5 years after the Wright Brothers' first controlled, powered flight, the U.S. experienced its first aviation passenger fatality. On September 17, 1908, Orville Wright was demonstrating the Wright flying machine to U.S. Army officials, with a passenger. The aircraft crashed, with resultant fatal injuries to the passenger, an Army Lieutenant (Thomas Etholen Selfridge, n.d.). More public scrutiny occurred when Knute Rockne, a popular football coach from the University of Notre Dame, was killed in a 1931 accident, followed by the 1935 fatal aircraft accident that killed U.S. Senator Bronson M. Cutting of New Mexico (Komons, 1989). Prior to the 1938 Civil Aeronautics Act that derived from these two 1930s accidents involving notorieties, ". . . the mantra seemed to be 'fly it, crash it, redesign it, fly it, crash it . . .' resulting in only modest improvements over time" (Walters, 2002, p. 2). From 1938 through 1974, the U.S. regulation of aviation and the investigation of accidents became structured such that: (a) the FAA is housed within the U.S. Department of Transportation (DOT), and (b) an agency separate and independent of the DOT, the National Transportation Safety Board (NTSB), is assigned the investigation of serious incidents and accidents. A positive result was that the charting of the air carrier accident rate became asymptotic. Then, in 1990, a representative of The Boeing Company announced "If the current rate stays absolutely flat, a projection based on the increase in the number of airplanes in service shows that, by the year 2005, there will be an airline hull loss somewhere in the world approximately every two weeks" (Weener, p. 1). It was an understatement to classify this projected statistic as 'unacceptable to the public.'

Preparing for the 21st Century

Due to very low frequencies, analysis and reporting of accidents and serious incidents have not been good metrics of the NAS system safety. In 2003, the FAA reported that the probability of an air carrier accident per departure/flight was less than $.3 \times 10^{-6}$. Current media reports quote the FAA and NTSB as stating that the rate for 2004 was $.15 \times 10^{-6}$ (Miller, 2005). The industry has recognized the need to look for precursors of accidents in events detectable in routinely-recorded data, reported by operational personnel, observable in training performance, or in disciplined audit of airline safety processes.

In 1975, the FAA and NASA signed a Memorandum of Agreement that established the Aviation Safety Reporting System (ASRS), with NASA responsible for the design and implementation of the incident-reporting program. The ASRS has collected, analyzed, and responded to voluntarily submitted aviation safety incident reports in order to lessen the likelihood of all aviation accidents. This has been particularly important as the literature has generally conceded that over two-thirds of all aviation accidents and incidents have their roots in human performance errors.

In the 1990s, the air carrier industry joined with the FAA and NASA in addressing the problem of further decreasing the airline accident rate as the volume of air traffic grew. Collaborating with innovative airline initiatives, the FAA introduced five air carrier safety partnership programs, which are administered by its AFS-230 office and are maturing in the 21st century. The goal of each program is continued improvement for an already very safe U.S. air transportation system. The five voluntary partnership programs, designed to be inter-related, are:

1. The Flight Operational Quality Assurance (FOQA) Program – de-identified digital data obtained from a Quick Access Recorder (QAR) are utilized to target and resolve safety issues.
2. The Aviation Safety Action Program (ASAP) – de-identified, employee self-disclosures are utilized to target and resolve safety issues.
3. The Advanced Qualification Program (AQP) – a training program that contains self-correcting quality assurance components and utilizes de-identified individual performance data to target and resolve training/safety issues.
4. The Internal Evaluation Program (IEP) – entails internal safety audits, in combination with documented organizational responsibilities, safety information acquisition procedures, and continuous quality assurance processes that are designed to increase the likelihood that safety deficiencies are promptly identified and corrected.
5. The Voluntary Disclosure Reporting Program (VDRP) – allows for corporate self-disclosure in identifying and resolving safety issues.

Together, the five programs have continued to generate both objective and subjective volumes of data, all of which require comprehensive analysis and interpretation before reporting. The air carrier FOQA programs have required quantitative data analysis, and several vendors have developed sophisticated data downloading and analysis programs. Subsequent to data validation, the statistical programs allow the creation of a database, to which statistical treatments can be applied. The treatments enable summarization, and interpretation of the data; data reduction within large databases has necessitated the implementation of multivariate statistical techniques. The air carrier AQP programs have required the treatment of both quantitative and qualitative data. The quantitative data have been analyzed with an appropriate statistical program (e.g. general statistical analysis packages, such as SPSS). The qualitative data have been treated in several manners; the implementation of a relational database (e.g., MS Access) appears to have been most appropriate.

The air carrier ASAP programs, with large volumes of subjective data, have generally led to analyses that required reduction, display, and verification of the data before arriving at any interpretations. Examples of the relational database programs that have been used are MS Access and Oracle. Detection of the relationships and hidden patterns in the subjective narratives has resulted in the implementation of text data mining programs (e.g., Clementine from SPSS and PolyAnalyst from Megaputer Intelligence). The IEP and the VDRP require self-auditing. Extensive records are involved with the IEP, and these involve both quantitative and qualitative data. The VDRP qualitative data are derived from self-audit tracking.

In cooperation with the FAA, NASA initiated the Aviation Safety Program (later modified to the Aviation Safety and Security Program [AvSSP]) as an outgrowth of the 1997 White House Commission on Aviation Safety and Security Report – "The Gore Report." The goal for AvSSP, tracked as part of the August 2000 FAA-NASA Integrated Safety Research Plan, is the development of tools that will reduce the fatal accident rate 80% by 2007, and 90% by 2022. Some of the hierarchically structured components of the AvSSP are the:

1. Project: System Safety Technologies.
2. Subproject: Aviation System Monitoring and Modeling (ASMM).
3. Flight Data: Aviation Performance Measuring System (APMS).
4. Radar Data: Performance Data Analysis and Reporting System (PDARS).
5.

APMS has been developing the next generation of tools used by air carrier FOQA personnel for flight data analysis and interpretation. PDARS has been developing networking and analysis tools used by ATC facility-level managers for radar data. The APMS and PDARS tools have analyzed and interpreted the normal, routine operations for situations and trends that might be precursors of incidents and accidents.

An Exploratory Approach

To address the need for curricular change at ERAU and introduce the voluntary safety programs to U.S. academic institutions, the first author was immersed within the APMS group at the NASA Ames Research Center, and some industry safety practitioners. An interview protocol with 11 safety program managers at 3 U.S. airlines with whom NASA had Space Act Agreements (SAA), and 2 individuals at a software vendor with a SAA, was conducted during a 2-week period in June 2004. The emphasis of the interview instrument was upon defining the needed skills for future employees working in air carrier safety; it was designed so as to be two pages in length and to result in a semistructured administration. The environments were familiar and comfortable for the interviewee (and the interviewer); both parties had the 2-page instrument in front of them, and were free to make any notes; and the order of discussion of the items was introduced as not being important. Generally, the interviewer moved back and forth between the first page (the personal data of the interviewee) and the second page (the air carrier's current practices) with his note-taking, while the interviewee occasionally glanced at the items as they were discussed. The personal data began with date, time, and name of the interviewee, and progressed through the corporate relationships with other stakeholders and the levels of control and decision-making for the interviewee.
The second page was titled "Current Carrier Safety/ Quality Practices" and comprised 10 items. One item addressed the "desired personal attributes" for the job of the interviewee; another addressed the "desired personal skills." Both of these items included short lists – attributes and skills, respectively. None of the desirable attributes and skills listed was disagreeable to the interviewees; several additions to the short lists were made by some of the interviewees.

The time for each interview was forecast to be 15-30 minutes; however, most made more time and enjoyed the discussion (average time with each interviewee approximated 45 minutes). The 'pencil-and-paper' notes were later entered into a word-processor at the earliest opportunity. Analysis of the resulting documents was done by hand, and consisted of tallying the responses to those items that directly related to the future students of aviation safety education. Investigation continued for an additional 8 weeks utilizing phone conversations and e-mail (and one data analysis working group meeting) with the air carrier personnel, software vendors, hardware manufacturers, and the FAA's AFS-230 office. Non-proprietary materials for course content were provided willingly by several of the individuals.

The sums of the replies to the qualitative queries confirmed an industry need for future safety employees versed in data acquisition, analysis, interpretation, and reporting required by the current safety programs. Curricular placement of the content was reasoned to be a course at the graduate level. Interviewees, and subsequent contacts, were in unanimous agreement that statistical knowledge and presentation skills were highly desirable, and that a course in a master's degree program appeared to best fulfill the requirements. Knowledge of the air carrier/aviation system and its components (e.g., ATC, operations, maintenance, and dispatch) would be a must. Communication skills, both oral and written, honed in a graduate program, were deemed beneficial. Unanimous agreement existed as to the desirable attributes (and abilities) of the students. The requisite credibility (mentioned by numerous interviewees and subsequent contacts) would demand trustworthiness, honesty, reliability, integrity, assertiveness, etc. In addition to familiarity with a number of software (ideally statistical and database) applications, several interviewees and contacts expressed the need for an understanding of computer logic. Skill with at least one programming language would be helpful. The proposed future integration and pooling of data from different software and servers reinforced the need for some knowledge of computer logic.

The ERAU Seminar

During the spring of 2005, an advanced graduate research course, utilizing the results of the summer 2004 fellowship, has been implemented as a graduate seminar in the MSA. The facilitators for the seminar have been the aforementioned researcher/professor and a U.S. major air carrier pilot doing his dissertation research for a doctoral program in adult education at another university. The course was capped at 12 students (11 actually enrolled), with the current core research and statistics course as the prerequisite (a course taught by the same professor). The five voluntary air carrier safety programs (including their interrelationships) serve as the archetype for the advanced research.

An appropriate text for this aviation-specific research seminar appeared to be the 'guide,' centered upon applied aviation research methods, by Wiggins and Stevens (1999). The research students have been assigned précis of the text's chapters, consisting of presentations as well as papers. Two chapters of the text provide a review of the statistical procedures (through the Analysis of Variance [ANOVA] and Chi-Square tests) that were course material in the prerequisite core research course. Power analysis and Principal Components Analysis (PCA) will be introduced with chapters from the multivariate text by Tabachnick and Fidell (2001). The process of data text mining has been addressed within student research assignments. Quasi-experimental research methods will be introduced with chapters from the 2002 design text by Shadish, Cook, and Campbell.

Multivariate analysis, specifically PCA, has been a statistical tool used by NASA's APMS for the FOQA program. Similarly, the PCA and ANOVA have been utilized in combination with survey and correlational techniques in addressing pilot safety and training (Baker, Beaubien, & Mulqueen, 2002; Hunter, 2005). The Baker et al. report also addresses the critical importance of qualitative analysis for those safety programs that provide subjective data (i.e., all but those generated by the QAR and FOQA).

The aforementioned, adult education Ph.D. candidate has obtained his committee's approval to continue as a seminar researcher/developer/instructor (with some attendant, self-developed evaluations of the seminar students) during the three semesters that the course has been scheduled to be offered as a developmental seminar. At the beginning of this spring's first seminar, a pretest of knowledge in several domains that would be desirable for future safety personnel in the air carrier industry was developed and validated by three researchers/practitioners from industry. The pretest was administered to the 11 master's students (mean ages and years of aviation experience were 28.91 and 8.32, respectively) during the first hour of the seminar's first meeting on January 14, 2005. The posttest, utilizing the same instrument, is scheduled to be administered during the first hour of the last meeting on April 22, 2005. The same pretest-posttest instrument will be used during the fall 2005 and spring 2006 semesters. Limiting confounds do exist with this design (Campbell & Stanley, 1963). Some of these are maturation, pretest sensitization, and differential selection (although the course is not currently required of any students). A history effect – the measurement is being performed three times with three groups over a timeframe of 16 months – in combination with the aforementioned threats and the pretest-treatment interaction weaken the validity of this pre-experimental design. In spite of a less than robust study, we believe that the data will reveal a favorable trend and lend support to the theory that academia can be of assistance in the preparation of future air carrier quality safety personnel.

Following the pretest, the first seminar meeting featured a discussion led by Dr. Douglas Farrow of the FAA's AFS-230. The relationships that exist between the programs were stressed in a manner that is currently nonexistent within the literature – a most valuable experience for the seminar. During the summer of 2004, there was no shortage of volunteers to speak in front of the graduate research seminar that would result from this project. Thus, other guests from the research community and industry have been scheduled to present before this spring's initial seminar. This 'access to expertise' has been designed to be a component of the students' research assignments. The students, in accordance with their interests, have been assigned to research the five programs. The resultant written reports, and presentations, will be compiled and distributed to the participants of the seminar on a Compact Disc (CD).

The 'computer logic and associated technology' that was mentioned by a number of industry's summer 2004 interviewees has been addressed by assigning a student (and manager of Information Technology on the campus) to research a course solution. (It appears that future seminars/classes would benefit from similar students.) A précis of a suitable chapter, combined with two iterations of the research progress and the final report, will begin to address the goal of familiarity with a sequential programming language. Progress toward the achievement of this problematic, lofty, and worthy goal should bear some rewards along the way.

The adult-structuring of the seminar has enabled collaborative learning, exposure to expertise and technology, and a mentoring relationship versus the apprenticeship model traditionally associated with graduate students and professors (Brookfield, 1988; Bye & Henley, 2003). The current seminar students should possess the required advanced technical skills for future safety data analysis and interpretation.

Future Outcomes

The spring of 2005 has the multi-year project on track. The overall academic program at ERAU's Daytona Beach campus has the graduate seminar continuing to be offered in the fall of 2005 and the spring of 2006 as it is developed for inclusion in the fall 2006 catalog as a second research course in the MSA core. Graduate interns that are selected from the program should be more valuable to more organizations than those currently being provided by ERAU's MSA for the air carrier safety departments.

Recommendations

Within two of the five current MSA specializations, safety systems and human factors, there appears to be the need for 'stand-alone' course content that would combine the maturing air carrier safety programs with quality management (Stolzer & Halford, 2004.) Farrow (personal communication, January 14, 2005) noted that a new model (and its associated acronym) has been discussed – the Safety Quality Management System (SQMS). It is recommended that in the fall of 2006, with the second core research course in place, the development of a SQMS seminar be investigated. An ATC specialization within the MSA that would utilize PDARS has been recommended and is being considered for evaluation during the summer of 2005.

Additionally, it is recommended that the results and outcomes of this research be shared with other institutions of aviation higher learning. To that end, current plans call for presenting the progress of the overall project to members of the following organizations: the International Society of Air Safety Investigators, the Human Factors and Ergonomics Society, and the University Aviation Association.

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