BUSINESS CASE FOR CIVIL AVIATION HUMAN FACTORS

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We examined how human factors research and engineering in addressing flight deck and air traffic control issues improves safety and provides tangible cost savings and cost avoidance for Federal Aviation Administration sponsors and industry. The agency spends a limited percentage of its annual budget on research and prioritizes these investments to ensure the best return. This research cuts across a range of human factors considerations spanning selection of applicants for air traffic controller jobs, flight simulator fidelity, generation of scenarios used in pilot training, a new evaluation tool for flight deck certification, design of flight deck operating documents, and design of an air traffic controller information display aid.

INTRODUCTION

Civil aviation human factors research managers face the business challenge, as does our discipline in general (Errington, Reising, Bullemer, DeMaere, Coppard, Doe, & Bloom, 2005), in needing to measure and communicate the benefits from human factors research and engineering. Our success stories need to be continually highlighted including to Congress, the Office of Management and Budget (OMB), research sponsors internal to the Federal Aviation Administration (FAA), and industry stakeholders in order to communicate and demonstrate the value from funding investments. While not every research project yields cost savings or avoidance, many studies do provide tangible benefits. A case study approach serves to highlight FAA human factors projects that help to contain costs, add value, and save money.

Civil aviation human factors research and engineering is a key responsibility of the FAA Human Factors Research and Engineering Group. The Flight Deck/Maintenance/System Integration human factors research program develops requirements, data, tools, guidance and standards for design, certification, operation, and training as the research foundation for FAA guidelines, handbooks, advisory circulars, and rules and regulations affecting pilots, aircrews, inspectors, maintenance technicians, certification teams, airlines, and manufacturers. The Air Traffic Control (ATC) and Airway Facilities human factors research program provides products ensuring safety and efficiency in the National Airspace System (NAS) by assessing and specifying the capabilities and limitations of controllers, traffic flow managers, and maintenance specialists in the human-system integration of operational concepts and system architecture as well as in the acquisition, implementation, operation, and maintenance of ATC systems.

Research Processes

Flight Deck and ATC research programs respond to and address higher priority research needs of FAA internal sponsors. The programs participate in processes that gather research needs, rank them in priority, and apportion funding that determines which needs get executed through research projects. Based in part on the transparency in systematic adherence to these processes, the FAA research program was given a very high performance measurement score by OMB resulting from use of its Program Assessment Rating Tool. This tool includes sections that address strategic planning, program management, and program results and accountability. Due to funding constraints the programs address only the most critical research requirements with consequent pressures to provide quality results, meet schedule milestones, and provide value as criteria by which progress is gauged.

Benefits Analysis

Due to complexities of FAA research needs, the return on investment can conceptually range from direct to indirect. Panelists highlight direct and semi-direct returns involving intended cost savings and increased efficiency. Not all research provides a direct return. An indirect return could involve research that addresses an identified gap and adds to the body of scientific data on a particular human-system integration matter under ongoing FAA review.

PANELIST SUMMARIES

Advanced Weather Displays for Terminal Controllers, Ulf Ahlstrom, FAA Technical Center

Hazardous weather conditions affect the NAS in many ways including flight safety and system effectiveness. Providing controllers with the capability to display advanced weather information could be one way to improve the ability of the NAS to deal with adverse weather.

The architecture and evolution plans for the Standard Terminal Automation Replacement System (STARS) specifies

the use of Integrated Terminal Weather System (ITWS) products for terminal Air Traffic Control (ATC). However, the decision to use ITWS in terminal ATC was not based on an actual evaluation of weather tools on controller displays. No previous research has shown what types of weather information is most useful for controllers, and we have few guidelines for optimal display of weather visualizations (Ahlstrom, 2003). As a consequence, there is little data available for decision makers trying to assess the risks and the cost/benefits of implementing weather information on controller displays.

To investigate the benefits and human factors issues associated with displaying weather information on controller displays researchers from the NAS Human Factors group conducted a severe weather avoidance simulation at the Research and Development Human Factors Laboratory. In an initial project phase, we conducted a cognitive work analysis (CWA) of the terminal domain to assess terminal controllers' weather information needs (Ahlstrom, 2005a). Six commercial airline pilots and five terminal controllers participated. Next, we used the CWA analysis result to drive the development of weather display tools and a high-fidelity simulation capability (Ahlstrom, Keen, & Mieskolainen, 2004). In a third project phase, we conducted a human-in-the-loop weather simulation where we manipulated the display of advanced weather information (i.e., storm motion forecasts) and compared this to a control condition where controllers had no weather information (current field operations). The advanced weather information (i.e., storm motion, gust front, wind shear, microburst, and echo tops) consisted of pre-recorded ITWS data and specifically developed prototypes of dynamic storm motion forecasts. Eleven non-supervisory, full-performance level TRACON controllers volunteered as participants. To allow an examination of the effects of advanced weather information, we included a procedure that assigned responsibility for keeping aircraft away from weather Levels 4, 5, and 6, to the controller.

The results showed that when controllers had access to dynamic storm forecast tools at their workstation, they increased the average sector throughput by 6-10% compared to conditions where no weather information was available (Ahlstrom, 2005b). Furthermore, because weather tools were available, controllers handled more aircraft without a corresponding increase in workload ratings (Ahlstrom & Friedman-Berg, 2006). By providing enhanced weather information at the workstation, we enhanced controllers' ability to detect approaching weather, monitor its movement, and understand its effect on future operations.

This study is important in that it improves the chances for FAA to procure weather products with real operational value. Furthermore, it shows that by reducing the uncertainty about weather conditions, controllers can make better decisions that will positively affect safety and efficiency of terminal ATC operations.

Flight Simulator Fidelity Assessment, Judith Bürki-Cohen, DOT Volpe National Transportation Systems Center

Challenges for today's air carrier pilot training and evaluation include pilot demographics (e.g., increasing turnover, heterogeneity with decreasing prior experience) and complexity of flight deck and air traffic management (e.g., increasing automation, decreasing separation). Consequently, the FAA has established the Advanced Qualification Program, a flexible, needs-based training program with emphasis on integration of cognitive and motor flying skills in realistic scenarios. A revision of the traditional pilot-training regulations is expected to embrace a similar philosophy, which presumably will render zero-flight-time training and evaluation (ZFTT) mandatory. To ensure that simulators effectively substitute for the aircraft, the simulator qualification requirements (currently contained in Advisory Circulars) are being codified into Federal Aviation Regulation Part 60.

To keep ZFTT affordable for all airlines, regulations should specify only those cues that are necessary for transfer of skills to the airplane. A 1998 Volpe Center literature review found no conclusive scientific evidence that simulator-platform motion improves transfer (Bürki-Cohen, Soja, & Longridge, 1998). Consequently, the Volpe Center conducted three studies examining the effect of platform motion on airline pilot training and evaluation. They all tested the effect of being trained and evaluated in an FAA-qualified simulator with motion versus without motion on quasi-transfer to the simulator with motion as a stand-in for the airplane. Control over extraneous variables offered by quasi-transfer avoided shortcomings of previous studies such as insufficient statistical power.

The first two studies tested recurrent pilots. The first study found no effect of motion for engine failures, and indicated that training simulators may routinely have attenuated motion (Bürki-Cohen, Boothe, Soja, DiSario, Go, & Longridge, 2000; Go, Bürki-Cohen, & Soja, 2000; Longridge, Bürki-Cohen, Go, & Kendra, 2001). The second study, using reengineered motion, also found no advantage of motion after transfer, although during training, the motion pilots had reacted 0.4s faster to an engine failure (V_1-cut) (without effect on flight precision). However, pilots trained *without* motion had fewer control inputs and better localizer compliance (1/4 dot) even after transfer for a difficult landing with shifting winds (Go, Bürki-Cohen, Chung, Schroeder, Saillant, Jacobs, & Longridge, 2003; Bürki-Cohen, Go, Chung, Schroeder, Jacobs, & Longridge, 2003). The third study, using initial pilots, failed to replicate the reaction-time advantage of motion to the V_1-cut ($p<.10$), but again, pilots trained without motion used a steadier control strategy for the landing after transfer (Bürki-Cohen & Go, 2005).

If these results were interpreted as "training and evaluation without motion is as safe as training with motion," significant savings could be achieved. Taking a $75-hourly-saving in simulator rental costs and 90,000 airline pilots requiring 10 hours training per year, airlines would save over $67M per year on recurrent training alone. Although this figure may shrink with airline-operated simulators, it does not account for initial training due to retirements and employment increases.

Accounting for the latter, the cumulative savings would rise exponentially to billions in just a few years. More savings may ensue from disappearance of lost time from inoperative motion systems and simplified qualification procedures. Finally, easier access to simulators may overall improve training.

Training and Evaluation Simulation Scenario Development, Florian Jentsch, University of Central Florida

The Rapidly Reconfigurable Line-Oriented Evaluation (RRLOE) software is a tool developed by the University of Central Florida (UCF), for the FAA, to aid in the creation of evaluation scenarios, that in the past took weeks or even months to create, and reduce that creation time down to mere hours.

FAA regulations require airlines to conduct Line-Oriented Flight Training (LOFT) and/or Line-Oriented Evaluation (LOE) simulation sessions that last anywhere from one to three hours. In addition to airlines conducting LOFTs under "traditional regulations" (i.e., FAR Part 121 App. H, I, J), approximately 40 Advanced Qualification Program (AQP) airline fleets must adhere to the LOE regulation, and that means creating at least 6 new scenarios for evaluations every year, approximately 240 total new scenarios each year in the industry. In the past, it would take a considerable amount of time and cost to develop each scenario manually (approximately 4-6 person weeks per scenario). Furthermore, it was difficult for the FAA to approve the scenarios individually, as each required a lengthy and thorough examination for approval, which translated into labor cost at the FAA. To help reduce these cost and provide a more efficient means of developing usable evaluation scenarios, the FAA employed the researchers at the UCF to develop an electronic means quickly create scenarios that incorporated a number of specific events within them for use by AQP airline training departments (nearly all of the AQP airlines utilize this software), other air carrier training sites, and even researchers in the aviation field.

To this end, researchers at UCF created RRLOE, an easy-to-use, software tool that allows users to quickly develop and create LOE scenarios, by simply filling in a few pieces of key information. RRLOE has the ability to work for any number of aircraft and can generate completely random scenarios, aid in the creation of completely customized scenarios, with each event planned out, or even create a logical scenario around one specific event required in the evaluation. Scenarios created using the RRLOE software can be created in as little as five minutes, and the software itself can be updated to include new aircraft and new flight routes and regulations.

In addition to the major time savings the RRLOE software can affect, labor cost savings for using this software should be significant. For example, the increased standardization of scenario generation under RRLOE allows FAA inspectors to conduct scenario review much faster than before (from approximately 2 hrs to only a few minutes). This alone would save the FAA as much as $25K annually on review time labor. In the private sector, savings in scenario development time could save AQP airlines alone approximately $4.6M per year, and a much higher amount when all scenario-based airline training is considered, industry-wide. Clearly, using the RRLOE software has shown a number of benefits ranging from increased usability, to reduced cost and labor, all which benefit the aviation system.

Human Factors Design of Operating Documents, Barbara Kanki, NASA Ames Research Center

Air carriers have been working toward the paperless cockpit for more than ten years. The transition from paper to electronic documents brings the promise of improved systems and efficiency, safety benefits and cost reductions. At the same time, this transition will force numerous changes for different user groups including the pilots in the cockpit, the data managers within flight operations, and the FAA personnel involved in the approval of new information systems and those working with the resulting accelerated data revision process. The design of new information systems must answer some critical questions.

- Will the pilots be able to access needed information more rapidly and accurately than is currently possible with paper documents?
- Will the operators' data managers be able to take full advantage of electronic updates and revisions and will the transition to electronic data improve standardization across fleets?
- Will the FAA inspectors be able to review and evaluate how the new information system impacts crew performance, usability and procedural compliance and will they know what training and procedures should be required?

The NASA/FAA Operating Documents Project began in 1997 bringing together air carriers (including regionals and cargo operators), manufacturers, and the FAA to work on a human-centered approach to the design and implementation of operating document systems. Industry workshops were held in order to identify most important issues, share innovative solutions and lessons learned, and support the development of industry standards. Over the years, the emphasis of the Operating Documents Project has been to work toward industry standards and guidance that benefit manufacturers, operators and regulators (Seamster & Kanki, 2002, 2003, 2005).

Industry transition to electronic documents has been slow, partly due to the lack of agreement on industry standards for the format and exchange of electronic data. Additionally, the industry has tended to emphasize engineering solutions at the expense of more usable products and procedures for the operators and the FAA regulators. Despite these difficulties, operators have estimated annual savings from using electronic operating and training documents to be from $5M to $10M for the major US carriers if they are able to transition to standard and usable electronic document systems.

In addition to these cost savings, safety can be improved through the development of more efficient cockpit procedures

and training made possible by these integrated electronic information systems. Advanced Qualification Programs can leverage the benefits of improved pilot performance and reduced crew error as non-standard and out of date information is replaced with more standard, more accurate, and easier to access electronic information. FAA personnel can also increase the accuracy and efficiency of the document review and approval process by working with standard and easier to use data formats. This Operating Documents Project has helped the entire industry to look beyond the implementation of yet another computer to the development of new information systems that can improve crew, data managers and regulator performance.

Aircraft Certification Industry Perspective, Beth Lyall, Research Integration, Inc.

Design-related human error has been cited as a contributing factor in 60-80% of aircraft accidents. The Flight Deck Human Factors Job Aid provides FAA certification team members with the capability for more standardized, rapid, and robust assessment of potential human factors vulnerabilities in Applicants' flight deck design submissions, and the ability to provide more complete, technically sound guidance to aid Applicants in demonstrating means of compliance with flight deck human factors regulatory requirements. Development of Version 6 of the Job Aid for Part 25 Transport Category and Part 23 aircraft has a cumulative expenditure of approximately $6M. Annual benefits based on time-derived cost savings are estimated to be at least $3M for the agency for certification engineers and $6M for industry certification Applicants

Air Traffic Selection and Training (AT-SAT) Test Battery, Carol Manning and Ray King, FAA Civil Aerospace Medical Institute

Organizations use selection procedures to identify job applicants likely to be able to learn to perform a job and subsequently perform it effectively. Additionally, organizations want to eliminate less promising applicants early on to minimize the expenditure of time and money on unproductive training. The criticality of the air traffic control specialist (ATCS) job makes it important to maximize the accuracy of the selection decision while minimizing costs by selecting and training only candidates who will be able to learn to perform the job satisfactorily.

This is the second time that the FAA has selected and trained large numbers of applicants during a short time period. The first occasion followed President Reagan's firing of 10,438 striking FAA ATCSs (out of a workforce of about 15,000). In 1981, ATCS selection procedures consisted of a written test battery and a nine-week screening program. It cost about $200 per person to administer the written tests; and about $10,000 for the screening program. While this selection procedure was expensive, it was very effective at reducing the time before failure occurred. Previously, 38% of ATCS hires left the agency between 2-3 years into field training (Manning, Collins, & Kegg, 1989). After the screening program was implemented (but before the 1981 strike), the total loss rate was 38%, but 30% occurred at the Academy and only 8% during training. After the strike, total losses increased to about 50% with 40% occurring at the Academy and only 10% in field training. Thus, while the cost of this selection procedure was high, it was lower than paying to train candidates who were ultimately unsuccessful (as the FAA's cost for providing three years of ATC training was about $100,000).

The second occurrence of increased ATCS selection will replace the controllers hired after the 1981 controller strike who are now nearing retirement age. Members of this cohort will retire concurrently, as most were hired over a period of 4 years, were between ages 21 and 30 when hired, and are required to stop controlling traffic at age 56. Thus, FAA will replace about 12,500 retiring controllers over the next decade (FAA, 2004). In preparation for this new wave of hiring, the FAA developed a 6.5 hour pre-hire computerized test battery, Air Traffic Selection and Training (AT-SAT). AT-SAT has equivalent or better validity than did the former selection procedure (Ramos, Heil, & Manning, 2001), and costs much less to administer (currently only about $800 per applicant). The FAA invested about $6.9 M in AT-SAT development over eight years, including $1M spent recently to develop an alternate form and update the operating platform.

Few controllers have been selected by AT-SAT since its designation in May 2002 as the official Civil Service ATCS selection test. It is expected that using AT-SAT will reduce administration costs (by an estimated $11M per year) and lower training attrition. When sufficient data are available to measure actual benefits, FAA will determine whether AT-SAT provides a significant improvement over the previous selection process

DISCUSSION

Aviation human factors research and engineering supports FAA objectives and responsibilities. The Flight Deck research program develops requirements, data, guidance and standards for design, certification, and training as the research foundation for FAA guidelines, handbooks, advisory circulars, rules and regulations effecting pilots, aircrews, inspectors and maintenance technicians. ATC research and engineering provide information, data, capabilities and tools contributing to safety and efficiency in the National Airspace System by assessing and specifying the capabilities and limitations of controllers and maintenance specialists in the human-system integration of operational concepts, system architecture, acquisition, operation, and maintenance of ATC systems.

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