

Building on the Legacy

Charting the Next Century of Flight through Human Factors Research & Engineering



Fiscal Year 2003 Report

**Federal Aviation Administration's
Human Factors Research & Engineering Division**



Our Vision for Today, Our Challenge for Tomorrow



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Our Vision

FAA Human Factors – Our Vision for Today

In 2003, the Human Factors Research and Engineering Program received an appropriation of nearly \$24 million dollars and our people produced high-value results. We were determined to improve performance and efficiency in every research thrust, and take advantage of our deeply rooted strengths – from a solid core of expertise and diverse portfolios, to pacesetter work with new technology, and from our customer orientation to our widely recognized partnership and teamwork skills. Our Number One Goal: To Improve Aviation Safety, Efficiency and Capacity. As the year ended, we knew that we had succeeded.

A Commitment to Success – Powered by People

From the outset, our mission was clear: Provide research, development, and acquisition for products and services that enable the FAA to enhance the safety of the National Airspace System (NAS); and, satisfy current and future operational needs of the U.S. civil aerospace system for national and international operations. To do this, we harnessed the strength of an exceptional group of people who feel personally accountable for delivering outstanding results – people who embody the values of the DOT and FAA, readily share their knowledge with each other, embrace continual change, and quickly identify and adopt the best way to get the job done.

A Value-Driven Portfolio

We invested wisely in research designed to deliver the highest return quickly. By applying rigor and discipline to key projects such as the certification job aid, JANUS, and cabin evacuation, we made our capital work harder and better than ever. Our goals for safety, capacity and efficiency set the bar high, and we delivered high-impact results. An important part of our program was designed to ensure that human factors policies, processes and best practices are integrated in the research and acquisition of all FAA aviation systems and applications. This commitment is strengthening our performance and will have far-reaching impact.

Striving for Top Performance – Technology Led

We perform world-class research, and anything short of that is unacceptable. This attitude provides the potential and incentive to make a substantial impact in everything we do. Through our support of aviation community initiatives and congressional mandates, we have become one of the world's most technologically intensive research organizations. Skilled researchers at the William J. Hughes Technical Center and the Civil Aerospace Medical Institute are developing and testing new ideas, then rapidly putting the best innovations to work. Every part of our research organization benefits from this approach, carried out with a host of partners – from top research universities like Texas and MIT, to diverse small businesses like Research Integrations, Inc, and international organizations such as EUROCONTROL and JAA. Throughout this family of partnerships, technological advances are enhancing human performance and creating an array of promising opportunities for the future.

& Mission

Customer Centered

Our success depends on forging strong relationships with customers. With a disciplined approach to managing resources and research, we stay focused on the fundamentals, but look for opportunities for breakthrough results. We strive to exceed expectations – our own as well as those of our customers and stakeholders. Our strategy is defined by the emergence of new solutions through:

- Identifying and addressing operational needs and problems involving human performance
- Conducting comprehensive and systematic analyses of human causal factors in accidents, and identifying interventions
- Directing and guiding research to address critical needs
- Evaluating pilot, controller, and maintainer procedures required with advanced systems
- Providing human factors guidance for development and implementation of new technologies, training, and procedures
- Supporting notices and regulations applicable to aircraft occupant health and safety
- Developing guidelines in response to public demand
- Preparing recommendations to support seat and restraint certification, emergency medical equipment, and evacuation/life support

Up to the Challenge of Tomorrow

As 2003 ended, human factors and aerospace medicine researchers were fully engaged in developing scientifically validated information and guidance for improving the safety, performance and productivity of air carrier crews, general aviation pilots, aviation maintenance and inspection personnel, air traffic controllers, and NAS system maintenance specialists. New products were coming on line to improve decision support systems, expand human factors considerations in aircrew training systems, and enhance the application human factors in design and certification of new aircraft and equipment as well as upgrades and modifications. In air traffic control, an improved approach to classifying the human factors associated with operational errors resulted in improved investigation techniques. Human factors design guidance led to development of human-centered automation and procedures that will enhance controller decision-making and reduce error-prone conditions. In addition, guidelines and recommendations were developed for aircraft cabin equipment, crew and passenger evacuation procedures, and the cabin environment.

As we move into a new year, and the future, our Number One Goal remains unchanged: Improve Aviation Safety, Efficiency and Capacity. We are committed to superior performance, and to being the partner of choice with industry, academia, and government organizations because of our reputation for integrity and our ability to meet the most difficult challenges. We are committed to achieving high impact results, ensuring that the envelope of human performance capabilities and limitations is fully recognized and understood as new systems, procedures and training come on-line. Of equal importance, we will continue making improvements in integrating human factors engineering in FAA system acquisitions, and we will continue research into improving tomorrow's workforce and workplace. In aeromedical research, we will emphasize mitigation of accidents and reduction in severity of injuries encountered in aircraft evacuation in order to make air travel safer and more secure.



Building on the Legacy

Air Transportation Human Factors research and products are enhancing the safety of the National Airspace System through improved crew training and safety data collection and analysis. This research provides methods and guidance for effective pilot training and valid and reliable assessment of crews and training programs. The research also provides methods for airlines to collect and analyze different sources of operational safety related information.

To be successful and provide valuable products to industry and the FAA, air carrier training research must consider distinct segments of aviation systems. Individuals comprising the crew, instructors who train and evaluate crews in the classroom and the simulator, line operations personnel, as well as the management culture responsible for the air carrier safety climate are all areas of high interest. Researchers are studying the variables important to Line-Oriented Flight Training (LOFT) and Line-Oriented Evaluation (LOE) development, implementation, and evaluation. This research focuses on (a) crew training and assessment; (b) instructor training; (c) LOFT/LOE development strategies, and (d) organizational and systematic influences on pilot performance, including the use of flight deck automation. In conducting this research, many sources of data are considered. This program employs data from airline simulator sessions, airline flight deck observations, and traditional laboratory studies. Its research examines methods to enhance the reliable and valid collection of operational safety data by providing taxonomies that incorporate human factors components of everyday airline incidents. This allows airlines to accumulate data that can be systematically analyzed to determine safety threats.

Situationally-Oriented Crew Resource Management (CRM) Training

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: One of the goals of the FAA's Advanced Qualification Program (AQP) is to encourage the use of new and innovative training approaches for CRM. AQP fosters CRM integration into each component of pilot training by requiring that the jeopardy Line Oriented Evaluation must contain operationally oriented flight scenarios integrating CRM. However, AQP has not provided guidance on how airlines should consider all the external variables, such as conditions and phase of flight, that can affect the performance of the crew. Historically, traditional CRM training programs focused on the transfer of pilot skills through a common learning model, but separate from situational factors. The major goal of this project is to determine how situational factors can be incorporated into a CRM model and then trained under an AQP program.

Methodology: Most air carriers consider CRM curriculums as separate from other training program components. However, researchers believe CRM needs to be integrated into air carrier technical training. To accomplish this, current training is being examined to determine how situational variables can be included in a CRM model. Once this assessment is complete, a high-level summary of the implications of incorporating situational factors into CRM training will be developed.

Results: Work on this effort began in September 2003.

Recent Accomplishment: Researchers have completed their examination of a number of air carrier CRM programs and have initiated preliminary development work on a CRM model.

Primary Investigator: Susan Mangold, Battelle Memorial Institute, Columbus, Ohio

Analysis of Pilot Procedures and Practices for Automated Flight Decks

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: This research is focused on the following: identifying relevant operational questions about pilot/crew performance by evaluating crew performance using automated systems; identifying model pilot/crew procedures and processes for two or three focal automation problems; and assessing automation use in an air carrier fleet.

Methodology: Working with a major carrier, researchers reviewed incident reports to gauge the type and magnitude of problems crews encountered while using automated systems. Based on the data collected, a computational cognitive model was developed that could interact with a simulated system for a single pilot. A second model simulated two crewmembers interacting in a highly automated and proceduralized cockpit.

Results: The computational model produced a number of performance measures: total time for all tasks; average time for each task; checklist steps skipped, repeated or performed out-of-order; automation programming delayed, skipped, or incorrect; and the omission of required communications. Researchers observed qualitative results, such as step skipping, repetition, and intrusion of incorrect steps, at lower levels of simulated expertise. Emergent results included crew miscommunication, differential situation awareness, and forgetting relevant goals under certain conditions of delays and interruptions.

Recent Accomplishment: The cognitive modeling effort shows promise in identifying performance bottlenecks and potential interventions that can improve performance. This work also spotlights the importance of industry and FAA collaboration with the translation of research into the operational environment.

Primary Investigator: Deborah A. Boehm-Davis, George Mason University, Fairfax, Virginia

Improving the Training of Automated Flight Deck Skills

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: This research seeks to find if there are accurate and cost-effective alternative evaluation methods to measure a pilot's knowledge of automation as well as the skills required to fly today's modern automated aircraft. Options such as card sorting and concept mapping are examples of concepts being considered to replace traditional methods such as written exams and oral evaluations.

Methodology: The Team Performance Laboratory at the University of Central Florida created a new software tool, Team Performance Lab Knowledge Assessment Tool Set (TPL-KATS), for assessing complex knowledge structures and mental models necessary for the operation of advanced transport category aircraft. Researchers are using this tool to evaluate pilot automation training. The goal of the project is to develop a system that will allow evaluators to diagnose problem areas within knowledge structures based on the mental models being represented.

Results: In cooperation with several airlines, researchers are examining the capabilities of the TPL-KATS to evaluate pilots' knowledge of automation. These investigations yielded results that show the concept mapping and card sorting techniques are comparable to traditional testing methods.

Recent Accomplishment: As a result of this work, researchers provided training recommendations to the Air Transport Association Automation Subcommittee with respect to what air carriers should focus on in automation training.

Primary Investigator: Clint Bowers, University of Central Florida, Orlando, Florida

Interruptions, Distractions, and Lapses of Attention in the Cockpit

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Interruptions and distractions are among the most common factors in pilot error, and lapses of attention contribute to many accidents. Airlines need ways to train pilots and to design operating procedures to reduce pilots' vulnerability to this common form of error. To develop countermeasures, researchers must first characterize the patterns of interruption and distraction that occur in typical line operations and the cognitive demands underlying lapses of attention. This study is providing observational data on patterns of interruption, analyzing how interruptions affect execution of operating procedures, and exploring potential countermeasures for error.

Methodology: This is a collaborative project, co-sponsored with NASA. Jump seat observations are being used to identify patterns of occurrence of interruptions and distractions in typical cockpit operations, crew response, and resulting types of errors. Researchers collected data from 60 flights on two major U.S. airlines flying Boeing 737s, and analyzed the operating procedures used by these airlines to determine points of vulnerability. In addition, researchers analyzed Aviation Safety Reporting System (ASRS) reports and National Transportation Safety Board (NTSB) accident reports to identify forms of error, contributing factors, and consequences. These complimentary approaches allow the FAA to characterize typical cockpit demands on attention, identify points of vulnerability, and suggest ways that training and procedures can be modified to reduce vulnerability. The research will also reveal real-time interruptions and distractions that can be incorporated into simulation training to realistically challenge crews' task management skills.

Results: Researchers discovered a substantial disconnect between the way training and flight operations manuals describe cockpit tasks and the way actual operational demands shape execution of procedures. These manuals portray the execution of procedures as serial, predictable, and under the moment-to-moment control of the crew. However, jump seat observations revealed that crews must manage multiple tasks concurrently rather than serially, that demands from people outside the cockpit are often not predictable or controllable, and that crews must sometimes defer tasks so that they are performed outside of the normal sequence. As a result of this work, researchers can describe the types of error that commonly occur in these situations and the operational consequences of these errors, and are now characterizing the demands these real-world aspects place on human cognitive abilities. Countermeasures to reduce crews' vulnerability to error in these situations are being developed.

Recent Accomplishment: Presentations and publications of these early results generated substantial interest in the airline community, resulting in invitations to present this research at major industry forums such as the Air Transport Association's annual Advance Qualification Program meeting and the annual International Safety Seminar conducted by the Flight Safety Foundation. A major U.S. air carrier is drawing substantially upon this research in its overhaul of normal operating procedures.

Primary Investigator: Key Dismukes, NASA Ames Research Center, Moffett Field, California

Training and Assessing Aircrew Skills: Methods to Achieve Reliable and Valid Performance Data

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Researchers worked on six different projects that were mostly aimed at improving the evaluation of pilot performance. These efforts focused on the ability of the Instructor/Evaluator (IE) to reliably grade pilot performance, and the methods used by IEs to assess this performance. Toward this end, researchers (a) developed software to facilitate the calibration of IE grading; (b) investigated whether Crew Resource Management (CRM) sub-skills can be graded in terms of performance on discrete observed behaviors (OBs); (c) investigated whether IE grading of critical maneuvers is based on flight parameters; (d) determined whether calibration training influences subsequent grading in the simulator; and (e) studied the rate at which critical skills decay over time.

Methodology: Given the wide range of research topics addressed, it was necessary to employ a variety of statistical methodologies. All analyses used actual pilot training data provided by various air carriers. Analyses were done to determine if it is possible to predict a grade given by an instructor to a simulator performance; to determine whether CRM grades could be differentiated among different sub-skills; to assess what are the effects of calibration on grading; and to answer the question “Do pilot skills decay over time?”

Results: Researchers obtained the following results: (a) OB grades do not discriminate among CRM sub-skills; (b) simulator grades on critical maneuvers cannot be predicted on the basis of flight parameter information; (c) calibration training does not affect subsequent IE grading; (d) critical skills, and in particular those that are not regularly practiced on the line, show significant decay from six- to twelve-months after training. Additionally, researchers successfully developed the IE training and calibration (IETC) software that is currently being used by several major carriers.

Recent Accomplishment: Continuing work on the IETC system directly enhances airline safety since it is absolutely critical that IE judgments of pilot performance be of the highest quality. These judgments determine if pilots are qualified to fly the line, and play an important role in evaluating the effectiveness of training programs and in guiding the future direction of training. To ensure the high quality of IE evaluations of pilot performance, airlines must develop and maintain programs to train, calibrate, and assess their evaluators, and the IETC system helps airlines accomplish this goal. Future efforts include revising the software to meet individual airline needs, advising airlines how to set up and run training and calibration sessions both at individual and group levels, and aiding in the statistical analysis of calibration data. Several major carriers report that these efforts have greatly aided them in training and calibrating their IEs.

Primary Investigator: Timothy E. Goldsmith, University of New Mexico, Albuquerque, New Mexico

Notices to Airmen (NOTAM) Survey Research

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Notices to Airmen (NOTAMs) are temporary notices that contain important time-critical information that pilots need in order to make informed decisions when planning flights. These notices provide information such as airport closures, airspace restrictions, and closed runways. This NOTAM project analyzes the human factors aspects of the NOTAM system to determine how pilots can obtain the most useful information from the system, and assesses whether changes might lead to substantial performance improvements.

Methodology: Researchers at the University of Central Florida distributed a survey to 79 pilots, who revealed that it is easy to make mistakes using the NOTAM system, and that NOTAMs can be easily misinterpreted. Furthermore, pilots suggested that ways to improve the system include the use of plain language, creating a single source from which all NOTAMs can be obtained, and better organization of the NOTAMs.

Results: This project resulted in an interim technical report highlighting the issues of concern with the current NOTAM system and providing suggestions for possible improvements to the system, locally, nationally, and internationally.

Recent Accomplishment: Researchers completed the human factors analysis of NOTAMs and provided the results to the FAA, the Air Transport Association Flight Safety, Training, and Human Factors Committees, and the International Civil Aviation Organization Flight Safety and Human Factors Subcommittee.

Primary Investigator: Clint Bowers, University of Central Florida, Orlando, Florida

Pilot Training for Unexpected Events

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Current research seeks to identify the global, underlying skills needed by pilots to best respond to the myriad unexpected events. They are investigating alternatives and modifications to traditional training approaches, targeting these skills, and developing ways to augment the pilots' ability to respond to an unexpected event and any resultant consequences of that event.

Methodology: In a collaborative effort, researchers at the FAA and the University of Central Florida are investigating the factors influencing pilots' reactions to unexpected events. They developed a theoretical framework, identifying key concepts related to the occurrence of and training for unexpected events.

Results: As a result of their work, researchers have recommended development of training interventions to manage unexpected events, such as scenario-based training, meta-cognitive training, and adaptive expertise training.

Recent Accomplishment: In cooperation with two air carriers, research is underway to understand how preparatory information provided in pre-flight briefings may affect pilot performance when faced with an unexpected event in flight. Researchers also provided training recommendations to the Air Transport Association Automation Subcommittee with respect to what air carriers should focus on in automation training. They provided test bed air carriers with prototype tools for the assessment of pilots before and after initial and recurrent automation training. In addition, they completed an analysis of FAA's Notices to Airmen and provided results to national and international human factors groups.

Primary Investigator: Clint Bowers, University of Central Florida, Orlando, Florida

Scenario Generation with the RRLOE/RRLOS Tool

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: The Team Performance Laboratory at the University of Central Florida developed the Rapidly Reconfigurable Line Operational Simulation/Evaluation (RRLOS/RRLOE) computerized scenario generation system for the FAA's Voluntary Safety Program Office. RRLOS allows training developers to combine training event sets and create training materials. It also generates scenario scripts in real time.

Methodology: Researchers are developing and testing software that will accurately, efficiently, and quickly evaluate pilot performance and training needs using a realistic set of events.

Results: Using the software, a two-hour training scenario can be generated in five to twenty-five minutes versus two to six weeks previously. The software can target specific skill areas, thereby allowing the quick generation of scenarios that are customized to the trainee and his/her training needs, and include customized training materials such as scenario scripts and supporting materials.

Recent Accomplishment: The tool has been delivered to over 50 air carriers and other aviation organizations. In FY 2003, researchers updated RRLOE/RRLOS, increasing its functionality and provided training to multiple airline staff and crew.

Primary Investigator: Clint Bowers, University of Central Florida, Orlando, Florida

Radio Communications Simulation (RCS) Project

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: In collaboration with the FAA, researchers from NASA-Ames and Beta Research, Inc., are investigating the effects of high fidelity air traffic control communications simulation on aircrew performance during line-oriented flight training and line-oriented evaluations. The current approach to this vital element of the flight simulation environment is to have the instructor/evaluator provide air traffic communications to the simulated aircraft. However, background radio frequency chatter, so common in airline operations, is difficult to simulate in this manner.

Methodology: Researchers studied the effects of air traffic control radio frequency chatter in an actual training simulation environment and collected feedback from airline instructor/evaluators. Two matched groups of five airline crews each participated in the study.

Results: Results revealed a significant increase in crew-initiated communications with air traffic controllers as well as call sign confusions as a result of the high level of chatter during the simulation. The crews also agreed that this type of simulation created a more realistic training environment. Additionally, crewmembers experienced significantly higher mental workload and effort with high radio frequency chatter as measured by the NASA-TLX task load index, which allows users to perform subjective workload assessments. Chatter, however, did not create communication and instrument flight procedural errors. Post-session rating data revealed that most of the test pilots considered high ATC fidelity to be very important or essential to pilot training, and that high ATC fidelity should be provided in all flight simulations once basic instrument flight skills are obtained.

Recent Accomplishment: Researchers will present their findings at the Royal Aeronautical Society meeting in late 2003. Their findings provide evidence, from systematic and objective tests, of the importance of high fidelity communications simulations in training.

Principal Investigator: Barbara G. Kanki, NASA Ames Research Center, Moffett Field, California

Co-Primary Investigator: Alfred T. Lee, Beta Research, Inc., Los Gatos, California

Platform Motion Requirements

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Flight simulator qualification standards, which may soon become regulatory, need to be sufficient and effective, yet affordable. Current research is examining the requirement for platform motion in the context of continuing qualification of airline pilots, which could greatly impact simulator acquisition and maintenance costs.

Methodology: Researchers from the Volpe National Transportation Systems Center worked with the FAA and NASA to reconfigure the FAA-NASA Boeing 747-400 Level D simulator to examine the effect of enhanced motion on pilot performance and behavior. Researchers evaluated and trained 20 current airline pilots in the simulator with and without motion. They then calculated pilot-vehicle performance and pilot control inputs in all axes from simulator variables. The pilots also compared the simulator to the airplane or their company simulator on extensive questionnaires, covering control feel, handling qualities, general cues, progress achieved, and acceptability. NASA researchers observed the pilots, recording their observations.

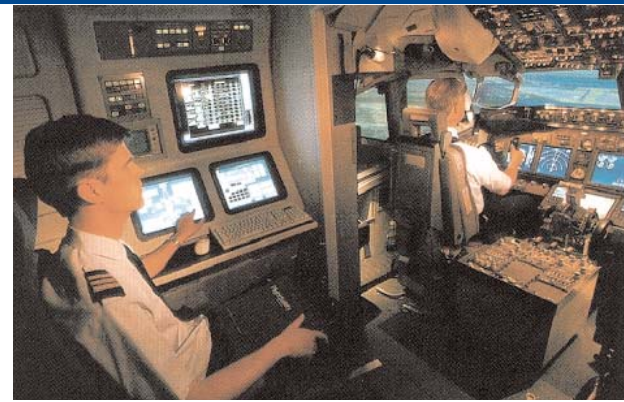
Results: Researchers discovered many effects of hexapod motion that have never been shown in an airline pilot context. Specifically, they found that enhanced hexapod platform motion does affect the accuracy of recurrent evaluation on continuing qualification of airline pilots, provided that it is configured for the specific tasks based on the guidelines in the literature. The reaction-time advantage of the motion group during evaluation and training for an engine failure with continued takeoff confirmed that motion cues alert to disturbances faster than visual cues, but disappeared when both groups transferred to motion. Increased control inputs of the motion group for an engine-out precision instrument approach transferred, but reduced control precision throughout. The motion group landed slightly softer than the no-motion group.

Recent Accomplishment: This research has provided the scientific data necessary for the FAA's effort to develop motion requirements that will allow cost-effective equipment solutions for pilot continuing qualification.

Primary Investigator: Judith Bürki-Cohen, U.S. Department of Transportation, Volpe National Transportation System Center, Cambridge, Massachusetts

Environment Simulation Fidelity Requirements; Realistic Radio Communications Simulation; Automated Realistic Radio Simulation Promotion

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division



Purpose and Rationale: The purpose of this work is to encourage industry interest in developing procedures and technologies for realistic radio communications simulation (RCS) during training and checking of airline pilots. Most training/evaluation occurs entirely in the simulator, followed by supervised Initial Operating Experience (IOE) with passengers. Earlier work revealed that RCS is almost exclusively left to role playing by the already overloaded instructor/evaluator (I/E). This increases I/E workload and reduces the opportunity for pilots in training to realistically practice task management skills associated with radio communications. A follow-up study found that 87 percent of adverse safety events occurring during IOE that were submitted by pilots to the Aviation Safety Reporting System (ASRS) involved radio communications issues.

Methodology: As a result of collaboration with industry partners, the International Air Transport Association Flight Simulator Working Group (IATA FSWG) has adopted the issue of realistic radio communications simulations, and has drafted a paper proposing standards for radio simulation systems. As a result of this effort, the Royal Aeronautical Society invited Volpe researchers to present their work at its 2003 conference on Simulation of the Environment. For this purpose, Volpe conducted new industry and literature reviews.

Results: Despite increased interest from industry, the research shows that the economic climate of the airline industry has not been beneficial for realistic radio communications simulations. Instructors and evaluators indicated that imitating real-life operations is now "considered a luxury," with emphasis shifting toward training in basic techniques and procedures. Moreover, although their perception of the importance of realistic radio communications simulations is high, they believe that the current training sessions already include so much material they do not know how radio communications could be integrated into the course. Newer simulators, however, provide improved data-link simulation and time-saving interfaces. One air carrier developed a low-tech solution that appears to provide higher radio communications simulation realism and to reduce instructor and evaluator workload. One obstacle for a truly interactive simulation system remains-lack of effective automatic speech recognition.

Recent Accomplishment: Researcher publications and outreach continue to document the benefits to scenario-based training achieved by improved realism in radio communications. This will fuel industry interest in developing cost-effective solutions for radio-communications simulation as a means to enhance aviation safety.

Primary Investigator: Judith Bürki-Cohen, U.S. Department of Transportation, Volpe National Transportation System Center, Cambridge, Massachusetts

Analyzing Simulator and Flight Data to Improve Pilot Training

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Researchers on this project are developing the methods, tools, and procedures for analyzing Flight Operational Quality Assurance (FOQA) data (both flight data and simulator data) to provide feedback for inclusion in Advanced Qualification Program (AQP) training. A large part of this project involves collecting, processing, and archiving sizable amounts of simulator and evaluator data that will be used to build and test predictor models. Researchers are also assessing inter-rater reliability training, which assists pilot instructor/evaluators in determining strengths and weaknesses as assessors of pilot and crew performance.

Methodology: Working with a major carrier, researchers modified a simulator to enable the collection of data for analysis. Pilot instructor/evaluators graded the simulator events and then researchers developed models to attempt to “predict” what grades would have been given when applied to actual flight data and to provide feedback to the AQP program.

Results: The models have evolved through application of increasingly sophisticated tools over the past three years, and have been based on increasingly large sample sizes of simulator and grade data. In this process, it has become clear that predictor models are limited by issues involving grading procedures of instructors. Nonetheless, a connection between FOQA and AQP has been made, and the carrier is now committed to developing its FY 2004 line oriented flight training using FOQA and line operations safety audit data.

Recent Accomplishment: As a result of research work with the carrier, the airline is increasingly using advanced data visualization and training technologies, such as data animation and Internet Web-sites, in their FOQA and AQP programs. The carrier has committed to support additional research focused on inter-rate reliability methodologies, effectiveness, and grading issues in FY 2004.

At the end of FY 2003, the simulator and grade data archive contained 1,698 simulator sessions. The simulator sessions averaged about 3.5 hours, and researchers collected 792 parameter values for every second of those sessions. This is about 5,943 hours of simulator sessions, and the resulting archive is over 33 gigabytes. Associated with that archive is the related instructor grade archive, which now stands at 230,589 grades. This archive has been made available to, and is being used by, several researchers, under the appropriate non-disclosure agreements with the carrier.

Primary Investigator: Fred O’Neal, CSSI/Island MultiMedia, Freeland, Washington

NASA/FAA Operating Documents Project

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

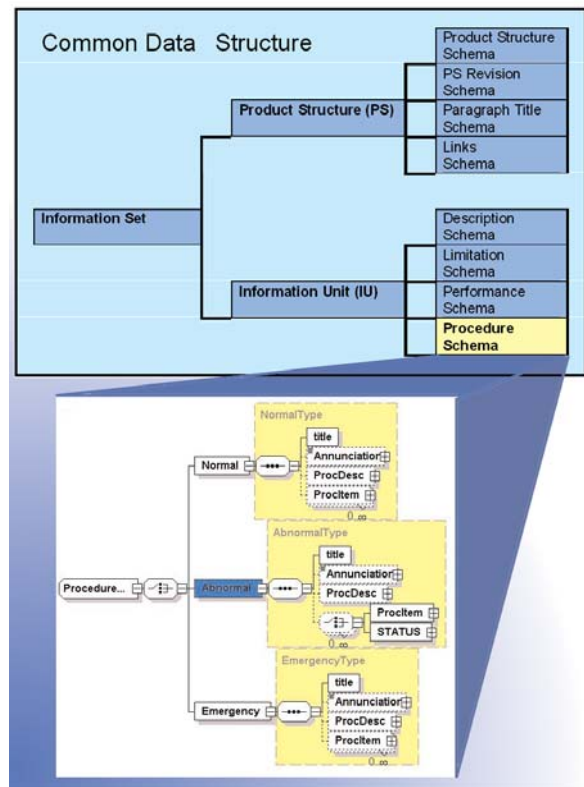
Purpose and Rationale: Aviation operations information management is transitioning from document-based models and processes to digital data. Researchers are currently identifying new ways to manage and use operational information with an emphasis on the near-term need for standardized data presentation and management. The challenge lies in translating complex data into usable and comprehensive operational data for airline use.

Methodology: The NASA/FAA Operating Documents Project brings together major air carriers, regional and cargo operators, manufacturers, and the FAA to work on a human-centered approach to the development and implementation of document systems within flight operations and on the flight deck. The Operational Testing Group, formed under the Air Transport Association Flight Operations Working Group, is evaluating how to create a common data structure, which can be used to exchange usable and timely data with the airlines.

Results: Focus group results are being used to refine the common data structure and improve information interchange. Researchers are currently developing new ways for users to make incremental revisions to the data in an open electronic environment. This will allow for efficient access to operational information independent of specific proprietary applications.

Recent Accomplishment: Researchers developed a prototype data framework as well as a means of testing its ability to store and retrieve data. When fully operational, this database has tremendous implications for flight operations and flight training, and is uniquely positioned to help ensure the development of a usable operational data exchange standard across the aviation industry.

Primary Investigator: Barbara G. Kanki, NASA Ames Research Center, Moffett Field, California



Aircraft Simulator Data and Pilot Automation Skills

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Researchers focused on the use of aircraft simulator data for identifying and measuring pilot automation skills. Their objectives included: (a) evaluating information from available full-flight simulators; (b) establishing the efficacy of using the data, scenarios, and performance measures to identify and assess pilot skill in the use of automation; (c) determining methods and strategies to develop an automated research database to facilitate the collaborative work of a geographically distributed research team; and (d) developing and testing tools to identify the safety issues associated with mixed-fleet flying of automated aircraft.

Methodology: The research team assessed the possibility of developing methods to identify and assess pilot automation skills using simulator data. The team also defined functional and technical requirements of a database and Web site, and developed a database and Web site infrastructure. They tested functionality, usability, and interactivity of a database and Web site, and updated and refined research-centered automation literature for a database and Web site. Researchers identified pilot tasks to be used in a mixed-fleet analysis, analyzed task situations and actions required to each airplane to identify any vulnerabilities that were clearly identified in the analysis. Finally, the team identified safety vulnerabilities that must be verified through a longitudinal study, and provided recommendations for conducting verification studies.

Results: Researchers determined that automation skills cannot be identified or measured effectively using digital simulator data with available technology. They also developed and tested a database and Website (<http://www.flightdeckautomation.com>), that provides a comprehensive list of automation human factors issues as well as research data and other objective evidence related to those issues. The changes made to this Website include restructuring the site to enhance ease of access, and incorporating new scripting technology to facilitate database queries and advanced search options.

Recent Accomplishment: Researchers redesigned the Flight Deck Automation Issues Website, which is now being used by many industry representatives for research and program development purposes. Website users, surveyed for input, stated that the functionality and design have been greatly improved.

Primary Investigator: Elizabeth Lyall, Research Integrations, Inc., Tempe, Arizona

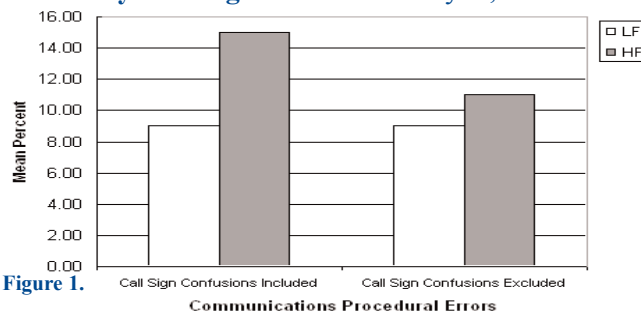


Figure 1.

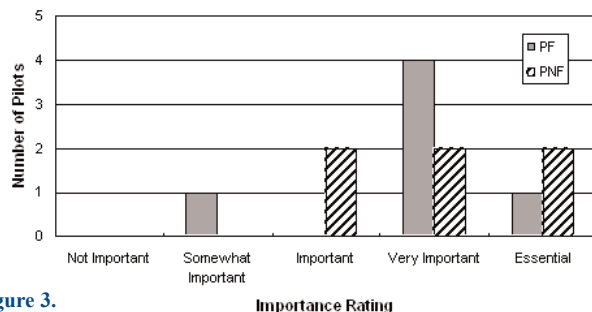


Figure 3.

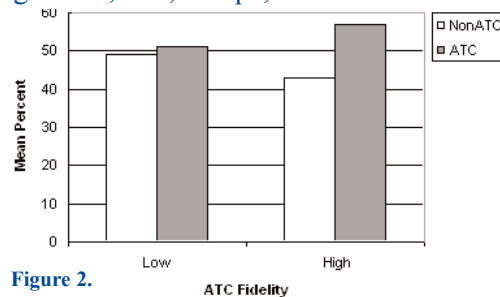


Figure 2.

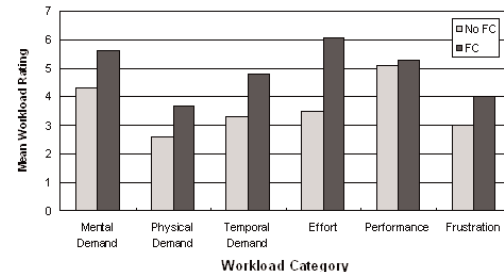


Figure 4.

Figure 1. Communications procedural errors a function of ATC fidelity.

Figure 2. Mean percent Pilot-initiated External Communications as a function of ATC communications fidelity.

Figure 3. Pilot ratings of the importance of adding realistic ATC communication simulation to pilot simulator training. (n=12 pilots)

Figure 4. Mean workload ratings as a function of Frequency Chatter (FC) and No Frequency Chatter (No FC) conditions (n = 12 pilots).

Threat and Error Management Model

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: This project investigates the relationships among flight crew error, operational complexity, and crew performance as it occurs in normal flight operations. Knowledge gained will help support proactive safety efforts through early identification of incident and accident precursors before they become consequential. Researchers are currently involved in the development and refinement of two proactive data collection programs: the Line Operations Safety Audit (LOSA) and the Aviation Safety Action Program (ASAP).

Methodology: This project uses two methodologies to examine threat and error management performance in normal operations: non-jeopardy, confidential cockpit observations, and crew incident reports. In response to the needs identified by a review of ASAP, researchers developed a set of online tools to aid carriers in the categorization and analysis of crew incident reports. This set of tools: (1) enables pilots to submit reports online using threat and error management taxonomies, and (2) aids event review committee members in making data driven decisions by enabling them to assign risk level assessments and behavioral marker ratings to each event.

Results: Researchers empirically identified 10 operating characteristics that are essential to a successful LOSA. The International Civil Aviation Organization, International Air Transport Association, and Boeing formally endorsed these characteristics with approvals pending by the national and international pilots' associations, Airline Pilots Association, and the International Federation of Airline Pilots' Association. For ASAP, researchers developed and tested the first set of ASAP Threat and Error Management Tools with Continental Airlines. Based on initial findings, they are developing a shorter form using an advanced programming language.

Recent Accomplishment: Current research resulted in an ICAO LOSA handbook and articles featured in an ICAO Journal Special Edition on LOSA. In addition, the IATA Safety Advisory Committee formally endorsed use of the Threat and Error Management Model for accident analysis framework. Researchers developed a Web-based ASAP Pilot Reporting Form and ERC Review Form built upon the Threat and Error Management framework. In addition, Continental Airlines initiated the first ASAP Threat and Error Management Program.

Primary Investigator: Robert L. Helmreich, University of Texas, Austin, Texas

Aviation Safety Reporting Program (ASAP) Classification System

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: This project seeks to develop a system for classifying human factors issues identified in Aviation Safety Action Program (ASAP) incident reports. The resulting taxonomy will be used to categorize and quantify the causes of incidents, and later will be embedded within an electronic data collection and reporting tool that will provide sophisticated query and analysis capabilities. With this information, users can develop data-driven interventions and then empirically assess the effectiveness of these interventions.

Methodology: Researchers initially conducted a comprehensive review of existing human factors taxonomies, accident/incident reporting systems, and data collection tools to identify best practices in taxonomic research, and to suggest specific content areas for inclusion in the proposed taxonomy. They described the results in a detailed technical report, a journal article, and presented them at a meeting of the International Symposium on Aviation Psychology. Most recently, researchers completed a series of card-sorting exercises to identify how pilots mentally organize human factors issues. To date, they have collected data from 10 pilot instructor/evaluators and 26 line-qualified pilots, and are currently analyzing the data using hierarchical cluster analysis to identify trends.

Results: Preliminary results from the card-sorting exercise suggest that expert and novice pilots mentally organize human factors issues in qualitatively different ways. Researchers are now conducting follow-up tests with other analytical techniques to verify the existence of these differences. Once they have identified a final set of “core human factors themes,” an independent group of 15-25 line pilots will independently sort the cards into these themes. Researchers will retain only those cards that can be reliably classified. The end result will be a two-tiered taxonomy. The first tier will consist of a small number of overarching human factors themes. The second tier will consist of a variable number of issues/examples within each theme. Each issue/example will appear in only one theme. The review of existing human factors taxonomies, accident/incident reporting systems, and data collection tools suggests that the taxonomy should be kept as simple as possible. This will ensure that the taxonomy can be applied to both ASAP reports and other forms of safety-related data, such as performance ratings in the Advanced Qualification Program

Recent Accomplishment: Researchers organized an extremely well received panel on error reporting, classification, and analysis at the 2003 International Symposium on Aviation Psychology. The panel brought together several well-known authors on human error reporting/analysis, and stimulated a great deal of interest in the topic. Over 100 people attended this panel session.

Primary Investigator: David P. Baker, American Institutes for Research, Washington, D.C.

Pilot Perception and Management of Risk in Dynamic Flight Situations

FAA Sponsor Organization: Flight Standards Service, Air Transportation Division

Purpose and Rationale: Threat and error management is an important part of many Crew Resource Management programs. However, to manage and prevent threats from leading to unsafe situations, pilots must first recognize and assess the risks associated with unsafe situations. Theories about risk and decision-making emphasize the subjective nature of risk assessment. To better understand risk, researchers are examining which risks are most salient to commercial pilots, which risks are most often encountered, which threats are actually experienced, and how risks influence decision difficulty. This year, researchers conducted two studies to examine the role of experience level in pilot conceptualizations of risk and the relation between risk perception and decision-making. Specifically, they compared novice general aviation pilots to those working for a major and a national carrier.

Study One: General Aviation and Commercial Pilots' Risk Concepts

Methodology: Researchers sorted materials concerning 22 incidents from the Aviation Safety Reporting System that involved general aviation and commercial carrier decisions at various phases of flight to assess risk conceptualizations. They asked participants to judge the risk in a situation described in each scenario and to group together those that were similar in risk levels. Researchers then ordered this input from least to most risky. Through multidimensional scaling and clustering analyses, researchers determined the dimensions underlying pilot understanding of aviation risk, and whether general aviation pilot conceptions of risk differed from commercial pilots.

Results: Analyses revealed that general aviation pilots use a single dimension in their risk judgments, while commercial pilots generally use two dimensions. General aviation pilots saw risks as one-dimensional, characterized by the magnitude of potential loss. Commercial pilots base risk judgments on the perceived timeline of a threat and its controllability.

Study Two: The Relation between Risk Assessment and Decision Making

Methodology: To examine the relation between pilot risk perceptions and evaluations and subsequent decision-making, researchers compared pilots from a major carrier and a national carrier using a “think-aloud” procedure. They developed two dynamic scenarios that included features identified in the earlier risk survey as contributing to decision difficulty: ambiguous conditions; goal conflicts and outcome uncertainty. As the scenarios evolved, pilots described their concerns, asked for information, and made decisions. Researchers used statistical models to predict decision choices (more or less risky) based on expressed concerns and evaluation of the situations.

Results: In the takeoff scenario, 73 percent of pilots opted for the riskier scenario, while in the approach scenario, 57 percent chose the safer option and decided to divert. Research revealed that if pilots evaluated weather conditions more positively, they would choose the higher-risk option. On the other hand, if they evaluated conditions negatively, they chose the safer option. Hierarchical log-linear analyses found no differences between airlines or crew positions in decisions. However, pilots from the national carrier more consistently chose either risky or risk averse decisions than pilots from the major carrier. In addition, pilots from the major carrier more often adopted precautionary or mitigating strategies when accepting the riskier option.

Recent Accomplishment:

Study One: Research identified knowledge gaps that should be addressed by training and by increasing awareness of risk trade-offs. Gaps were also identified between safety, schedule, passenger satisfaction, costs, career, and social goals.

Study Two: Researchers briefed training and human factors managers at several carriers on their findings and discussed ways to incorporate new products into training programs. Several of the carriers have invited the researchers to conduct further research with them in the coming year. ICAO invited the researchers to participate in a regional safety seminar in Mexico City, and the Flight Safety Foundation invited them to prepare an article for their flight safety journal.

Primary Investigator: Judith Orasanu, NASA Ames Research Center, Moffett Field, California

Co-Primary Investigator: Ute Fischer, Georgia Institute of Technology, Atlanta, Georgia



Building on the Legacy

Aviation Maintenance research focuses on identifying human factors issues that affect aircraft maintenance and inspection personnel. This research program maintains a focused research approach in four major components - skill development, organizational influences, human error, and maintainer proficiency.

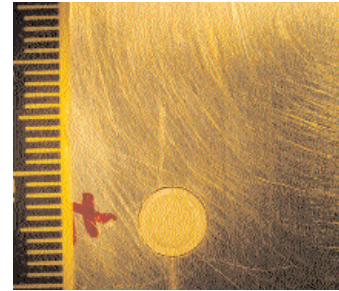
Skill development addresses issues of improved primary training, on-the-job training, and recurring training. Organizational issues include maintenance resource management, environmental stressors, and cultural implications. Human error research attempts to identify sources of human error in the maintenance environment and to develop countermeasures to reduce the risk of these errors contributing to aviation mishaps. Maintainer proficiency research focuses on maintaining skill sets, as well as interventions to maintain a safe level of proficiency in all critical job skills.

To obtain a detailed description of current aviation maintenance human factors projects, projects completed, accomplishments, and products delivered, please point to

<http://www.hf.faa.gov/maintenance.htm>.

Impact of Vision Testing Requirements on Non-Destructive Inspection (NDI) / Non-Destructive Testing (NDT) and Visual Inspection Personnel

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division



Purpose and Rationale: Visual inspection is an important component of aircraft maintenance. The National Transportation Safety Board cited the failure to identify visually detectable corrosion, cracks, or inclusions as the probable cause of several aviation accidents. In addition, visual inspection is an important component of Non-Destructive Inspection (NDI) and Non-Destructive Testing (NDT) procedures. NDI/NDT personnel must use their vision, with or without various aids, to make gross judgments, as well as when inspecting aircraft using highly sophisticated imaging and scanning devices (e.g., borescopes, ultrasonic scans, eddy current imaging, X-ray). While guidelines exist for vision standards for NDI/NDT personnel, no such guidelines exist for visual inspectors. Because of the intimacy between the two inspection classifications (i.e., visual vs. NDI/NDT), most facilities use similar testing requirements for the two types of inspectors. This project seeks to determine acceptable vision standards and procedures for personnel involved in nondestructive inspection and testing and visual inspection of aircraft and aircraft components.

Methodology: Researchers observed inspectors at two aircraft maintenance facilities as they performed visual inspection duties on various types of commercial aircraft. They recorded various measures of the visual tasks and recorded the specific auxiliary materials used during inspection procedures. In addition, they collected demographic data to classify the inspector workforce, the type and frequency of procedures performed, and vision screening practices.

Results: Researchers observed over 900 inspections, finding that 60% of the time, inspectors worked at distances of 50 cm or less and intermediate distances approximately 28% of the time. Since the primary duty of visual inspectors is the identification of defects in aircraft when viewed at near and intermediate distances, data from this study supports the need for nearpoint visual acuity requirements. A demographic study of 889 NDI/NDT personnel revealed that 99% were male, with a median age of 45 years old, and ethnic diversity that included 73% Caucasians, 13% Asian, 7% Hispanic, 6% African-Americans, and 1% others. The NDI/NDT personnel performed eddy-current inspection most often, and radiographic inspection least. Preliminary analysis suggests that the visual capabilities and ophthalmic conditions related to males over 40 years of age should be given special consideration in the implementation of a vision-screening program.

Recent Accomplishment: Researchers conducted facility and personnel surveys and a detailed visual task analysis at five aircraft maintenance facilities.

Primary Investigator: Van B. Nakagawara, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Co-Primary Investigator: Gregory W. Good, The Ohio State University, College of Optometry, Columbus, Ohio

An Evaluation of Broadband Applications to Aircraft Maintenance Safety

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: As aircraft maintenance organizations recognize the potential cost-savings offered by technologies that store and communicate information in a digital format, technology companies are rushing to the marketplace to meet the demand. However, before the FAA can fully support the use of such technologies, researchers must assess human performance in the aircraft maintenance workplace. Specifically, researchers need to: (a) understand how and why the technology is used, (b) identify maintenance facilities that currently use the technology, and (c) receive feedback from both managers and maintenance technicians about their experiences with the technology.

Methodology: Researchers identified and reviewed the computer and broadband technologies now offered to aircraft maintenance facilities. Through a series of site visits and telephone interviews, they also documented the use of these technologies at eighteen aircraft maintenance facilities.

Results: For the most part, managers and maintenance technicians at eighteen aircraft maintenance facilities liked the new technology, with one exception. That is, whereas managers were enthusiastic about portable and wearable computer systems because they represented a cost savings to the airlines, maintenance workers were concerned with the practical usability of the computers. Interestingly, neither managers nor technicians discussed the potential safety aspects of using computer and broadband technologies. In no case did a maintenance technician make reference to any technology helping them find or resolve a maintenance problem that they would not have found or resolved otherwise. Rather, they viewed the technology as an aid to more efficiently and economically using their existing maintenance resources. The aviation maintenance human factors computer technology and broadband, human error, training, and fatigue literature search results can be found at <http://automation.arc.nasa.gov/mx>.

Recent Accomplishment: Researchers developed a survey to assess the employees' attitudes and perceptions of the broadband technologies they currently use. They then administered that survey to managers and maintenance technicians at eighteen aircraft maintenance facilities.

Primary Investigator: Steve Casner, NASA Ames Research Center, Moffett Field, California

Co-Primary Investigator: Antonio Puentes, San Jose State University Foundation, San Jose, California

Review of Amateur-Built Aircraft Accidents/Incidents

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Goldman, Fiedler, and King (2002) revealed that approximately 7% of the 1983-2001 National Transportation Safety Board (NTSB) general aviation (GA) accident investigation reports listed at least one maintenance-related error as the primary cause or factor. Amateur-built (A-B) aircraft accounted for an average of 14% of the general aviation maintenance-related accidents, even though amateur-built aircraft account for less than 3% of the general aviation hours flown. Using the 1983-2001 National Transportation Safety Board GA accident investigation reports, this study compares maintenance-related accidents for amateur-built and all other GA aircraft by type of maintenance procedure, airframe hours, phase of operation, and time since last inspection.

Methodology: Researchers used the 1983-2001 NTSB general aviation accident investigation reports to generate a human factors taxonomy of maintenance-related causal factors. They classified the data by type of maintenance procedure, airframe hours, phase of operation, and time since last inspection. For this 19-year sample of maintenance related accidents, 413 involved amateur built aircraft, and 3,262 involved all other types of general aviation aircraft. They compared the incidence of causal factors for amateur built aircraft accidents with those for all other general aviation maintenance-related accidents.

Results: From 1983 to 2001, there were 3,572 built aircraft accidents, with 1,082 fatalities or 30%. The total number of all other general aviation aircraft accidents was 34,482, with 6,582 fatalities or 19%. Of the 3,572 amateur built aircraft, 395 or 11% were maintenance related accidents. Of the 34,482 all other GA accidents, 2,327 or 7% were maintenance related accidents. There were 151 fatalities in the 395 maintenance related accidents for A-B, or 14% of the 1,082 fatalities for A-B aircraft. There were 810 fatalities in the 2,327 maintenance related accidents for all other GA aircraft, or 12% of the 6,582 fatalities. For amateur built aircraft, 59% of fatalities and 64% of maintenance related injuries occurred during the first 15 hours after last inspection. Installation of aircraft parts was identified as the leading cause for maintenance related accidents in amateur built and GA aircraft, 127 (32%) and 397 (17%) respectively.

Recent Accomplishment: Results will assist Flight Standards to identify mitigation strategies to minimize amateur built aircraft maintenance-related errors.

Primary Investigator: Nicole Nelson, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Co-Primary Investigator: Scott Goldman, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Use of Advanced Technology to Support Inspection Training in the General Aviation Industry

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: A sound aircraft inspection and maintenance system is vital in providing the public with a continuing safe, reliable air transportation system. This is true for both general as well as commercial aviation. Since it is difficult to eliminate errors altogether, continuing emphasis must be placed on developing interventions to make the inspection/maintenance system more reliable and/or more error tolerant. Training is a primary intervention strategy to improve the quality and reliability of aircraft inspection and reduce errors. This research seeks to demonstrate how advanced technology and computer software applications can be used for inspection training and reducing inspector errors within the general aviation industry.

Methodology: The research will utilize an integrated task analytic (Gramopadhye and Thaker, 1998) and iterative software development methodology (Gould et al, 1997). The motivation is to improve inspection performance via the development of training programs based upon task analyses of the existing environment. The first step will be to use task analysis to identify factors affecting aircraft inspection performance and, subsequently, using those factors to develop a framework to understand inspection performance. Based upon this framework, intervention strategies will be identified that reduce their drawbacks. Later, the investigative team will identify which of these can be most impacted by training. Following this step, a training program will be developed using the classic iterative development methodology.

Results: As a first step, a detailed literature review was conducted. The literature is available online and can be accessed through the following website (http://www.ces.clemson.edu/~agramop/cur_act.htm). Following this step, the study analyzed the inspection process at representative general aviation aircraft maintenance sites, including the norms, information transfer procedures, guidelines and FAA-mandated procedures. Next, a detailed error taxonomy was developed to help classify the typical inspection errors. These errors were then analyzed and interventions identified to develop a standardized inspection process to minimize them. During this phase of the study, the researchers focused on the mechanic/inspectors, their respective supervisors, and the various entities with whom they interact. Following this step, recommendations were developed to support improved inspection performance.

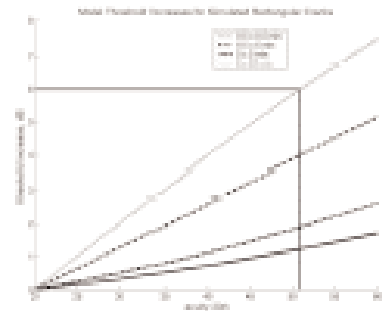
Recent Accomplishment: This is the first time an effort has been made to extend computer based technology to inspection training in the general aviation environment to enhance inspector performance and standardize the inspection training process. When development is complete, this computerized training tool will not only enhance technician skills, but also improve safety.

Primary Investigator: Anand K. Gramopadhye, Clemson University, Clemson, South Carolina

Vision Testing Requirements for Certain Persons Maintaining and Inspecting Aircraft and Aircraft Components

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Good eyesight is a vital qualification for aircraft maintenance inspectors. However, no general standards for visual acuity currently exist for this position. Beard et al. (2002) found that the majority of occupational vision standards are not empirically substantiated, and appear to be arbitrarily decided. This project seeks to define an empirically based visual acuity standard for aircraft maintenance personnel who perform non-destructive inspection (NDI), non-destructive testing (NDT) and visual inspection. In this paper, we apply a novel methodology toward defining an empirically based visual acuity standard for a representative task performed by aircraft maintenance personnel who do NDI/NDT and visual inspection.



Methodology: To obtain an estimate of a visual acuity standard using an image discrimination model (Ahumada, 1996), we follow a multi-step process. First, we calibrate the model for stimuli representative of airframe and powerplant cracks that are clear and blurred. We use a subset of the standard Modelfest images, whose contrast thresholds have been measured in a number of laboratories to calibrate the model. Second, we use the calibrated model to predict the visibility of simulated cracks of different lengths and widths as a function of blur, simulating reduced visual acuity in the image, rather than with blurring lenses, so that the image characteristics are exactly known. This provides an estimate of how much contrast sensitivity is lost by blur, so that if the tolerable loss in contrast sensitivity can be specified, the corresponding visual acuity is then specified.

Results: The first aim of this research was to describe a methodology that may be used to generate empirically based occupational vision standards. It does not provide a standard, but it converts the problem to specifying a desired physical limitation in performance. Here we use this technique to help define the spatial vision requirements for aircraft NDI/NDT personnel using simulated crack images. These modeling results will help define the parameters tested in the human psychophysical experiments. We next need to validate that line detection predicts actual aircraft crack detection. Vision is a fundamental component of effective aircraft maintenance inspection. All the same, so too are other cognitive factors such as attention, memory, and experience. Inspectors are knowledgeable about individual components as well as the overall aircraft being inspected, thus they possess the background to properly locate, identify, and evaluate aircraft defects. Therefore, although vision is a critical component in inspection, other factors weigh in heavily on the naturalistic task.

Recent Accomplishment: Researchers devised a methodology that can be used to generate empirically based occupational vision standards. Researchers summarized research relevant to setting an occupational vision standard for NDI/NDT personnel. See: <http://www.hf.faa.gov/docs/508/docs/maint/FY02/VisionNASAinterimRpt.pdf>.

Primary Investigator: Bettina L. Beard, NASA Ames Research Center, Moffet Field, California

Co-Primary Investigator: Albert J. Ahumada, Jr., NASA Ames Research Center, Moffet Field, California



Building on the Legacy

Flight Technologies & Procedures research addresses human factors considerations in the design, certification, and approval of new technologies, procedures, or capabilities that cut across several operational environments, such as major and regional airlines, and general aviation. Examples of research include:

- Development of a job aid for use by certification personnel and aircraft designers to identify and address human factors issues with flight deck technologies and systems during the certification process.
- Development of human factors considerations in the design and evaluation of electronic flight bags.
- Assessment of human factors issues and design characteristics of profile situation displays.
- Assessment of human factors issues in the design and certification of multi-function displays and controls.
- Assessment of human factors issues associated with depicting weather on flight deck displays

Airport Surface Information Displays

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: Many avionics vendors are enhancing the traditional situation awareness displays to present airport surface information, depicting information pertinent to takeoff, landing, and taxiing operations. The surface map display assists flight crew orientation by enhancing the pilot's awareness of the position of the aircraft on the airport surface and improves pilot position awareness with respect to taxi operations. Such enhancements present potential human factors certification issues for the FAA. This project seeks to produce guidance to facilitate the identification and resolution of flight deck human factors issues on airport surface information displays.

Methodology: Researchers created a comprehensive reference document capturing human factors issues relevant to the design of airport surface information displays from: discussions with engineers studying or developing these displays; participation in industry groups; reviews of specifications and research reports describing a display's features and intended usage; and a review of FAA regulations. The highly detailed reference document also contains a checklist to be used as an additional guidance tool aimed at assisting evaluations of surface map displays; and an industry review of surface moving map displays.

Results: The document provides guidance to facilitate the identification and resolution of flight deck human factors issues regarding surface map displays. The topics addressed range from general user interface, to the integration of the surface map application into the flight deck, to specific topics addressing the design and layout of surface maps. Researchers used the associated checklist to evaluate the usability of the guidance document. The evaluation provided input regarding the comprehensiveness of the guidance and helped to identify strengths and weaknesses of the checklist design.

Recent Accomplishment: Researchers completed the draft *Human Factors Considerations in the Design of Surface Map Displays* and submitted it to the FAA for acceptance. An updated review of industry surface map products was included as a chapter in the report.

Primary Investigator: Michelle Yeh, U.S. Department of Transportation, Volpe National Transportation Systems Center, Cambridge, Massachusetts

Error Management and Mitigation

FAA Sponsor Organization: Aircraft Certification Service, National Resource Specialist Flight Deck Human Factors

Purpose and Rationale: Human error is considered a contributing factor in 70-80 % of all aviation accidents. Efforts to reduce or eliminate errors through training have had only limited success. Therefore, it is critical to determine how best to mitigate the negative consequences of error, including the detection, explanation, and recovery from errors. To date, research in this area has focused on error detection. This project uses a converging operations approach to identify process and strategies involved in error explanation and recovery, particularly in flight deck errors.

Methodology: To identify and analyze the processes and strategies involved in both successful and poor management of automation-related errors on modern flight decks, researchers used a combination of methods in a converging operations approach. To accomplish this, they completed an extensive review of the existing error management literature, conducted jumpseat and simulator training observations, surveyed glass cockpit flight instructors, and reviewed 935 Aviation Safety Reporting System reports that involve the management of automation-related errors on a variety of modern flight decks. The final activity in this line of research - a controlled simulation study of error management on the Boeing 747-400 – is currently under way.

Results: Researchers found that once an error is detected, pilots rarely attempt to explain the reason for its occurrence but rather tend to proceed directly to some form of recovery action. If error detection is delayed, error recovery is more likely to require collaboration with air traffic control. The observed strategies and difficulties with error management suggest the need for improved feedback and the need for new training approaches that support the formation of accurate mental models and assist in error explanation.

Recent Accomplishment: Researchers produced a technical report summarizing results of the error management on modern flight decks analysis. Early this year, they finalized a cooperative agreement with Boeing Commercial Airplanes that will permit the use of their B-747-400 simulator to conduct the first experimental study of error management on modern flight decks.

Primary Investigator: Nadine B. Sarter, The Ohio State University, Columbus, Ohio

FAA Aircraft Certification Job Aid for Flight Deck Human Factors

FAA Sponsor Organization: Northwest Mountain Region Transport Airplane Directorate

Purpose and Rationale: Aircraft certification requires judgments about whether new aircraft designs will be safe to be flown in the global airspace by current and future pilots. Although experience has shown that design-induced human performance errors have contributed to many aviation incidents and accidents, there is a lack of guidance describing what human performance areas should be evaluated and, until now, there have been only a few methods available to help certification personnel predict the future occurrence of such errors based on analysis of the flight deck design. The FAA Aircraft Certification Job Aid is a computerized decision-support tool designed to help aircraft certification personnel ensure aircraft flight deck technologies are user friendly.

Methodology: This PC-based software has three major databases addressing regulatory information, flight deck components, and human factors considerations. The current version is focused on air transport category aircraft. During this year, researchers reviewed FAA regulatory information, industry standards, and other human factors literature for human factors control-related information to update the databases.

Results: During this year, researchers developed a hierarchy of 20 human factors considerations to address topics related to the design of flight deck controls. They tested the hierarchy of human factors considerations and confirmed that these included all the issues pertinent to the design and certification of flight deck controls. They also expanded the information in all three data bases to address control-related human factors as well as the previous display-related information.

Recent Accomplishment: This year a limited number of certification personnel were trained on the initial fielded version of the Job Aid, are using it in their workplace, and providing feedback for future version enhancements. This decision support tool is assisting them in identifying, assessing, and resolving potential design-induced human performance errors that could contribute to aviation incidents and accidents. In addition, it is enhancing the speed, accuracy, and repeatability with which they can access relevant regulatory and human factors information to make their decisions.

Primary Investigator: Elizabeth Lyall, Research Integrations, Inc., Tempe, Arizona

Electronic Flight Bags

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: Electronic flight bags, which are electronic information management devices used by pilots in performing flight tasks, present many human factors challenges. Researchers have identified and prioritized these challenges in collaboration with vendors and operators, to help designers and evaluators make informed choices. Because of its breadth and depth, the report documenting this research is difficult to use in the field, so researchers are now developing and testing a tool, based on the report, which can be used for short periodic structured assessments of electronic flight bag usability by FAA field inspectors.



Methodology: Aviation human factors experts evaluated several electronic flight bags using the full-length document. In a second test, researchers used two different paper assessment tools, a checklist based on the full document and a short high-level list of usability topics, to conduct expert reviews and team evaluations. As a result, researchers refined these tools and integrated them into a single tool, which is waiting further testing. In addition, researchers updated, expanded, and released a second version of the full electronic flight bag human factors document.

Results: Initial tests of a prototype electronic flight bag usability assessment tool uncovered areas for improvement, such as the need for more intuitive terminology. Once it is refined, the new tool will be a useful and usable aid, helping inspectors to conduct more structured, thorough, and predictable regulatory evaluations. For industry designers, the tool will allow them to anticipate and resolve human factors issues before going through a formal regulatory evaluation.

Recent Accomplishment: Electronic flight bag systems are now being designed in accordance with the guidance contained in the second draft document and industry interest in the tool development is significant.

Primary Investigator: Divya Chandra, U.S. Department of Transportation, Volpe National Transportation Systems Center, Cambridge, Massachusetts

Flight Symbolology

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: This project seeks to understand symbolology issues for electronic map and chart displays that present navigation information. The issue is complex because display technology varies widely, from inexpensive small hand-held displays for general aviation, to high-end avionics for transport operations. Manufacturers use a variety of symbols, which may be confusing and potentially misleading. Therefore, researchers need to understand what display technologies are in use, what symbolology is in use, and how the recommended symbols could be improved and standardized.

Methodology: Researchers conducted a comprehensive industry review, using a web search and a review of published product literature to identify the range and quality of moving map and chart displays on the market. They created a compact spreadsheet of the range of functions, display characteristics, and other pertinent information for each system. In addition, researchers compiled a list of symbolology being used by manufacturers to determine the degree of inconsistency in the symbols, and documented a list of research issues related to electronic moving map display symbolology.

Results: The industry review clearly shows the large variety of systems that support moving map or electronic chart displays. These functions appear on panel-mounted systems, electronic flight bags, and hand-held GPS displays. The physical form and capabilities of these platforms vary widely. From a symbolology point of view, the biggest difference between “low-end” and “high-end” displays is display resolution.

Researchers completed a paper listing topics that should be considered in the design of electronic flight symbolology and proposing research experiments that may be used to address the issues described. The issues can be categorized into four areas: display technology characteristics, e.g., display resolution, display size, contrast ratio; symbolology characteristics, such as symbol size, symbol salience, and level of detail; consistency in the presentation of symbols across low-end and high-end displays; and new capabilities offered by database-driven displays, e.g., automated de-cluttering.

Recent Accomplishment: Researchers prepared a comprehensive industry review of moving map technology that clearly documented the broad range of display technology and symbolology in use today. This work reveals that the potential for confusing and misleading symbolology clearly exists and should be addressed through further research.

Primary Investigator: Divya Chandra, U.S. Department of Transportation, Volpe National Transportation Systems Center, Cambridge, Massachusetts

Guidelines for Certification of Head-Up Displays (HUDs)

FAA Sponsor Organization: Northwest Mountain Region
Transport Airplane Directorate

Purpose and Rationale: Manufacturers are meeting an increased demand for head-up displays by marketing new models with various innovative features. These HUDs present human factors issues with regard to accessibility to the information displayed, since head-up display elements need to show critical information without interfering with the out-the-window view or with other nearby information. FAA certification personnel need guidelines for certifying head-up displays.



Methodology: This project seeks to provide FAA certification guidelines for head-up displays through direct experimental evaluation of design alternatives in a simulator and the development of a computational tool that predicts clutter effects on human performance.

Results: The development of a means to identify and understand the cognitive tasks associated with instrument flight (e.g., maintaining desired vertical flight path) is a key element when evaluating head-up display design alternatives. For example, a less detailed display design alternative, such as instruments that lack gradation marks, could require greater attention to the task they support. During fiscal year 2003, researchers combined a visual scanning model with pilot eye-tracking data during an instrument approach conducted in a simulator and were better able to predict pilot cognitive task performance.

Recent Accomplishment: Researchers found that the structure of the model provides insight into demands placed on the pilot. For example, more experienced pilots exhibited simpler models than pilots with less experience.

Primary Investigator: Michael Zuschlag, U.S. Department of Transportation, Volpe National Transportation Systems Center, Cambridge, Massachusetts

Weather Displays

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: Graphical weather displays can play an integral role in supporting strategic and tactical flight. However, if important considerations are not made for human factors issues regarding the display of weather, the presence of weather displays in the cockpit also has the potential to be detrimental to flight. Thus, flight certification standards should reflect the important human factors issues and guidelines for resolving them.

The objective of this project was to create a usability tool for use by both FAA certification officials and also by avionics vendors prior to starting the certification process. This tool could be used to evaluate candidate weather displays regarding conformance to established FAA guidelines (minima) for presenting weather information in the cockpit. The deliverable for this task will be a relatively quick and easy tool to aid FAA certification officials in evaluating to what extent candidate weather avionics displays conform to these significant human factors guidelines.

Methodology: Based on the 2002 usability assessment, a methodology for weather avionics certification was proposed. Also, based on the 2002 human factors literature review and usability assessment, a draft checklist of recommended and required guidelines was created upon which the candidate avionics will be evaluated. This master list of display guidelines was comprised of basic human factors design guidelines as well as general usability issues and issues specific to the depiction of weather. We have solicited feedback on the checklist content and terminology as well as the feasibility of the methodology from potential end-users. The next step is to perform a preliminary evaluation of the checklist and proposed certification protocol in terms of time and personnel constraints. After the preliminary evaluation, a “mock” certification session will be conducted in which the checklist and certification protocol will be employed, using actual certification personnel as end-users.

Results: Based on favorable feedback from our FAA supervisors and ACO personnel, the checklist and certification protocol have been being finalized. The next phase of the project will provide validation of the checklist and protocol by performing a “mock” certification on two avionics displays using actual certification personnel as end-users.

Recent Accomplishment: This task led to the development of a more behavioral-based approach to the avionics certification process. Through implementation of benchmark tasks and user-testing paradigm, this behavioral approach allows certification personnel to systematically but efficiently evaluate avionics with regard to real-world tasks. Also, the approach provides more behaviorally-based usability criteria on which to evaluate the avionics. Initial ACO feedback for this approach has been extremely favorable.

Primary Investigator: John Uhlarik, Kansas State University, Manhattan, Kansas



Building on the Legacy

General Aviation (GA) focuses on reducing fatalities, accidents, and incidents within the General Aviation flight environment. This environment is defined as all flights that are conducted under FAR Part 91 as well as the general aviation maintenance community. The research addresses better methods for the detection, classification, and reporting of human factors accidents; developing certification and flight standards and guidelines based on human factors research; and identifying and implementing intervention strategies to impact general aviation accidents.

Research objectives concern reduction of weather related and maneuvering flight accidents, controlled-flight-into terrain, and pilot field-of-vision capabilities and limitations. Other objectives include loss of primary flight instrumentation during IMC conditions, future technology implications, and improving general aviation training.

To obtain a detailed description of current general aviation human factors projects, projects completed, accomplishments, and products delivered, please point to

<http://www.hf.faa.gov/ga.htm>.

Human Error and General Aviation Accidents: A Comprehensive, Fine-Grained Analysis Using the Human Factors Analysis and Classification System

FAA Sponsor: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: The Human Factors Analysis and Classification System (HFACS) is a theoretically based tool for investigating and analyzing human error associated with aviation accidents and incidents. Previous HFACS research has shown that this system can be reliably used to analyze the underlying human factors causes of both commercial and general aviation accidents. Furthermore, these analyses have helped identify general trends in the types of human factors issues and aircrew errors that have contributed to civil aviation accidents. For this project, researchers used HFACS to answer specific questions about the exact nature of the human errors identified within the context of general aviation to assist in the generation of possible intervention programs.

Methodology: Using records maintained by the National Transportation Safety Board and the FAA, researchers used HFACS to determine the global human error categories associated with aviation accidents. (Note that researchers have already analyzed and coded more than 32,000 human causal factors associated with over 15,000 general aviation accidents occurring between 1990 and 2000.) Researchers are developing a detailed analysis of each of the different error forms, decision, violations, skill-based, and perceptual errors, to determine the exact nature of their genesis and relative importance in the causal sequence of events.

Results: Unlike previous studies focused on the percentage of accidents associated with at least one instance of a given unsafe act, this project is identifying the seminal (precipitating) aircrew unsafe act. That is, what percentage of the time are skill-based errors, decision errors, perceptual errors, and violations the *first* unsafe act committed by the aircrew in the chain of events leading to an accident. As in previous studies, using HFACS analysis, (Figure 1) researchers found skill-based errors as the most frequent unsafe act by an almost 3 to 1 margin, followed by decision errors, violations, and perceptual errors. Note that unlike the data from the previous studies, the percentages here do add up to 100% since there is only one seminal (precipitating) error per accident. When the researchers analyzed separately for fatal (Figure 2) and non-fatal GA accidents (Figure 3), the pattern of errors remained essentially unchanged. That is, skill-based errors were the most frequently cited seminal unsafe act. The only notable difference was that considerably more violations were seminal in the chain of events leading up to a fatal accident when compared to non-fatal accidents.

Recent Accomplishment: It would appear from our fine-grained analyses that it doesn't matter whether one examines the percentage of accidents associated with at least one instance of a given unsafe act or the seminal unsafe act, the pattern of human error observed among GA accidents remains essentially the same. That is, skill-based errors are consistently the most common error leading to a GA accident and in most cases represent the seminal error form as well. Furthermore, when violations are associated with general aviation accidents, they are more likely to result in a fatality. It is also noteworthy that efforts to inform pilots of the hazards of spatial disorientation and visual illusions appear to be successful since perceptual errors are the least common among all four categories of unsafe acts.

Primary Investigator: Scott Shappell, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Co-Primary Investigator Douglas Wiegmann, Institute of Aviation, University of Illinois, Savoy, Illinois

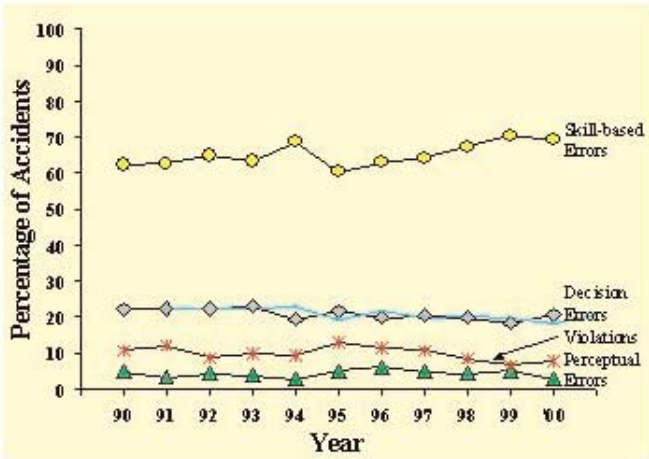


Figure 1. Seminal HEACS Analysis of General Aviation Accidents

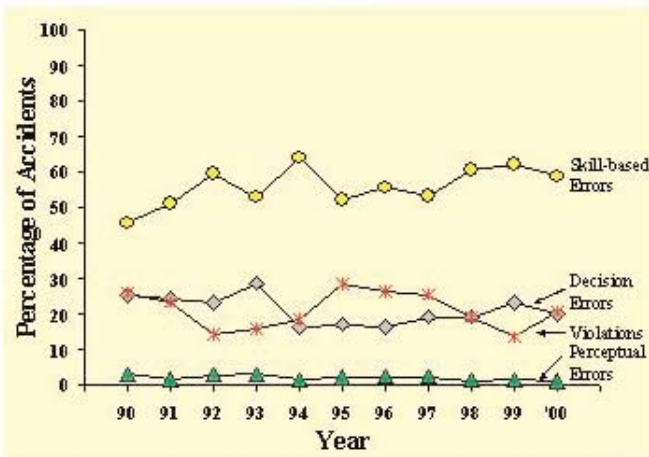


Figure 2. Seminal HEACS Analysis of Fatal General Aviation Accidents

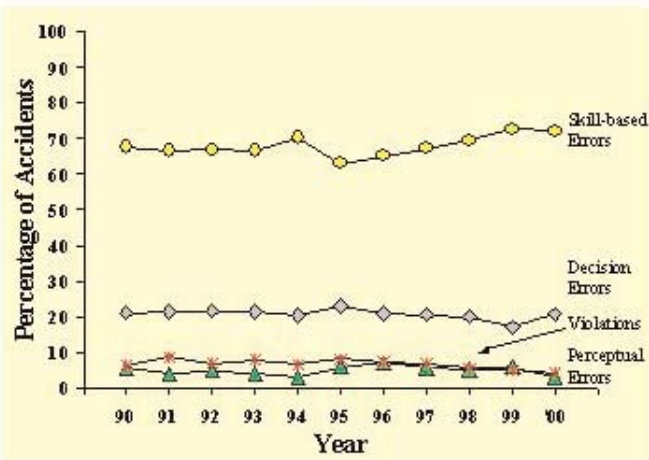


Figure 3. Seminal HEACS Analysis of Non-Fatal General Aviation Accidents

Comparison of the Effectiveness of a Personal Computer Aviation Training Device (PCATD), a Flight Training Device (FTD) and an Airplane in Conducting Instrument Proficiency Checks

FAA Sponsor: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Under one Federal Aviation Requirement, pilots must maintain instrument currency through activities conducted in an airplane or in an approved FTD. If pilots fail to meet this requirement within a 12-month period, they must undergo an instrument proficiency check with a certified flight instructor instrument. However, there is some question as to whether PC-based FTDs are effective in administering the instrument proficiency check. This project compares the performance of pilots receiving an instrument proficiency check in a PCATD, not currently approved to administer these checks, an approved FTD, or an airplane. These comparisons will help determine the effectiveness of the PCATD to administer an instrument proficiency check and the appropriateness of the current rule regulating instrument proficiency checks in an FTD.

Methodology: Researchers separated 75 pilots (25 subjects in each group; FTD, PCATD and airplane) into one of four categories: (1) instrument current; (2) within one year of currency; (3) outside one but within two years of currency; and (4) outside 2 but within 5 years of currency. All participants received a familiarization flight and a review of the systems and instrumentation in the FTD, the PCATD and the airplane prior to being assigned to an experimental group. Following the familiarization flights, all 75 pilots receive a baseline IPC flight either in the FTD, PCATD or an airplane (IPC #1) according to the group they are assigned. IPC #1 is flown with a certified flight instructor, instrument (CFII) who acts both as a flight instructor and as an experimental observer. Then all subjects are given a second IPC in the airplane (IPC #2) with a second CFII. The participants are required to refrain from instrument flight following IPC #1 until IPC #2 is completed.

Results: As of September 2003, 54 of 75 of intended pilots (72%) have completed IPC #1 and 51 of the 75 pilots (68%) have completed the study. A total of 42 of 54 pilots failed IPC #1 (78%) and a total of 26 of 51 pilots failed IPC #2 (51%). The percentages of pilots in each of the three groups who failed IPC #1 are as follows: for the Airplane group, 78%, for the FTD group 74% and for the PCATD group 82%. The pass/fail rates for IPC #2 in the airplane show fewer failures for each group and for the total when compared to the pass/fail rates for IPC #1. Of the 51 pilots who have taken IPC #2, twenty-five passed (49%) and 26 failed (51%). The failure rate by group was 53% for the Airplane group, 59% for the FTD group and 41% for the PCATD group. Of the pilots who took IPC #1 eight passed (22%) and 29 failed (78%), while 15 passed (43%) and 20 failed (57%) the IPC #2.

Recent Accomplishment: Researchers will continue to collect data to help determine the certification of safety requirements aimed at ensuring pilot instrument proficiency using various training devices.

Primary Investigator: Henry L. Taylor, Institute of Aviation, University of Illinois at Urbana-Champaign, Savoy, Illinois

How Training Devices are Actually Being Used by General Aviation Flight Training Organizations

FAA Sponsor: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: The use of flight training devices in general aviation is increasing rapidly and is now recognized as an important innovation in flight training. Benefits from the use of these devices range from the ability to train in less time, train in situations normally considered hazardous in actual flight, to lowering costs. Unfortunately, there is little information available regarding the use of these devices in particular tasks and types of training. While guidance exists regarding the certification requirements of these devices (FAA, 1992, FAA 1997), it is not fully known if the devices in use are being used in accordance with these guidelines. The purpose of this study was to reveal the types of training devices in use, how they are being used to enhance skill and proficiency, which tasks are being taught in these devices, whether or not the devices are appropriately certified and being used in accordance with National Simulator Program (NSP) guidelines, and if they are being used to augment training outside of approved training curricula.

Methodology: Researchers surveyed 184 schools that owned or used some sort of flight training device, had a minimum enrollment of 25 students or more, and some percentage of their students used these devices in their training programs. Researchers included all Part 61 schools, regardless of enrollment data since the number of these schools using training devices was low. Of the 184 schools targeted, 70 (38%) responded: 35 universities, 22 Part 141 schools, and 13 Part 61 schools.

Results: In general, the results indicated that flight training devices are more prevalent in FAA approved flight schools than other schools. Researchers found that most of the schools adapted their flight training devices to tasks focused on instrument pilot certification, training time does not appear to be correlated with the use of these devices, and some schools appear to be using training devices for non-instrument tasks. However, the results also indicate a poor level of understanding regarding the certification requirements and regulations surrounding the use of flight training devices. The final report can be found at <http://www.hf.faa.gov/docs/508/docs/FTDphaseII.pdf>.

Recent Accomplishment: Through this study, researchers identified the tasks being taught in flight training devices and developed a database showing the different types of devices and programs currently being used by flight schools. This information collected may provide a basis for changes to current regulations, for example, changing credit earned from an hourly basis to a task basis. This study also highlighted that many schools may not fully understand the correct methods of certification of their devices and indicated a need for better instructions for both operators and inspectors. As a result of their work, Flight Standards may seek to streamline, simplify, and educate flight schools regarding the certification and regulations pertaining to flight training devices.

Primary Investigator: Michael Wiggins, Embry-Riddle Aeronautical University, Daytona Beach, Florida

Co-Primary Investigator: Michael Crognale, University of Nevada at Reno, Reno, Nevada

Developing and Validating Criteria for Constraining False and Nuisance Alerts for Cockpit Display of Traffic Information Avionics

FAA Sponsor: Flight Standards Service, General Aviation & Commercial Division

Purpose and Rationale: Aviation safety improvements are dependent on developing a national aviation system that is not only technically sophisticated, but also human performance-based and human-centered. Technology and human factors simply cannot be separated from one another if safety and efficiency are to improve. There have been numerous human factors issues documented when new technology is inserted into the airspace system, e.g., the number of false and late alerts in the airborne collision avoidance system. This research project is concerned with the potential human factors issues that might come from the introduction of technologically advanced automated systems into the national airspace system. Specifically, researchers are developing a framework and scenarios for evaluating cockpit displays of traffic information. They reviewed cockpit alerting systems to understand the human performance issues associated with these systems so as to develop and validate criteria for constraining false and nuisance alerts.

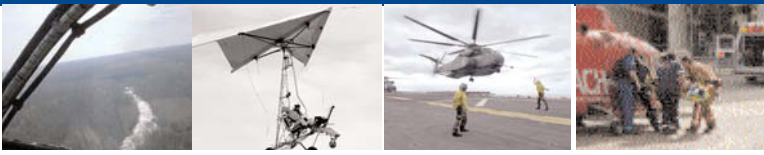
Methodology: The researcher's literature review focused on empirical human factors results relevant to cockpit displays of traffic information, existing standards, requirements and guidelines related to false alerts and alerting criteria, comparison of the existing alerting algorithms, analysis of aviation safety reporting system reports on traffic alert and collision avoidance system related incidents, and literature on human factors guidelines for the development of evaluation criteria for cockpit display of traffic information systems. Through a review of relevant literature, researchers sought to identify the features of conflict geometry that proved particularly challenging for pilots in unaided conflict detection and to establish a methodology for assessing pilots' understanding of the conflicts spatial/temporal properties. They felt this information would provide an objective basis for the design of scenarios to be used in evaluation of cockpit displays of traffic information. In a second experiment, they established the nature of pilot response to alerts with long look-ahead time, which reflected the trade-off between false alerts and late alerts.

Results: Researchers developed a taxonomy of variables relevant to human factors evaluation of cockpit displays of traffic information and arranged the relevant literature into a matrix showing known relationships between these variables. This research showed that pilot estimates seemed more accurate for traffic passing in front than behind and that estimates of horizontal miss distance grew more inaccurate as the true miss distance increased. Relative bearing estimate accuracy decreased with increasing miss distance. Pilots underestimated the time to closest passage, particularly with high relative speeds. Pilots overestimated time-to-conflict at long distances and fast speeds, relative to conditions of short distances and slower speeds.

Recent Accomplishment: Researchers mapped the relevant literature and empirical results to the evaluation requirements of new technologies, developed a taxonomy of conflict geometries, and identified those algorithm variables that were most influential in determining the trade-off between false alerts and late alerts. This information will ultimately help to direct further research and develop cockpit displays of traffic information evaluation scenarios.

Primary Investigator: Esa M. Rantanen, Institute of Aviation, University of Illinois at Urbana-Champaign, Savoy, Illinois

Co- Primary Investigator: Christopher Wickens, Institute of Aviation, University of Illinois at Urbana-Champaign, Savoy, Illinois



Building on the Legacy

Vertical flight human factors is a relatively new research domain. Research in this area is meant to identify specific human factors associated with helicopter flight regimes within the National Airspace System. Such issues include certification and regulation of civilian flights with night-vision-goggle devices, simultaneous non-interfering operations, and implications of tilt rotor controls. Other current research requirements include head-up displays for general aviation rotorcraft, low speed helicopter/power lift displays, and vertical flight IFR approach lighting requirements.

To obtain a detailed description of current vertical flight human factors projects, projects completed, accomplishments, and products delivered, please point to <http://www.hf.faa.gov/vertical.htm>.

Quantify Precision Visual Flight Rules and Simultaneous Non-Interfering Routes for Rotorcraft Operations

FAA Sponsor Organization: Flight Standards Service, Flight Technologies & Procedures Division



Purpose and Rationale: The purpose of this project is to examine the Precision Visual Flight Rules (PVFR) and Simultaneous Non-Interfering (SNI) routes for rotorcraft. PVFR routing is based on the hypothesis that rotorcraft with Global Positioning System (GPS) navigation capabilities can stay within narrow, defined horizontal airspace limits while operating under visual flight rules. If the pilot maintains the aircraft within the confines of a PVFR route, and if these routes can be designed to keep rotorcraft separated from fixed-wing traffic, then PVFR routes offer rotorcraft the possibility of operating in congested airspace simultaneously with fixed-wing aircraft on a non-interfering basis, hence the term SNI operation. Researchers are evaluating the ability of GPS to provide lateral guidance for helicopters flying on PVFR routes, while using barometric altitude for vertical guidance. A secondary research objective is to develop and demonstrate PVFR routes and ATC procedures that use GPS to enhance the helicopter pilot's ability to navigate more efficiently in the National Airspace System.

Methodology: The assessment of PVFR human factors and route widths is being performed by a combination of flight test and simulation methods. The flight PVFR/SNI tests, performed in the airspace around Tullahoma, Tennessee Regional Airport using an Army OH-58A test GPS-equipped helicopter operated by the University of Tennessee Space Institute, will assess human factors, flight technical error, navigation system error, and total system error. A key element of the overall test methodology is to provide a means to correlate the results of the flight tests and the simulation. This will allow simulation to support areas that cannot be adequately addressed by flight tests and vice versa. A virtual simulation will be used to replicate the same task and environment used in the in-flight data collection. Human factors data (visual scan patterns, performance, and workload) will determine if the simulation approximates actual flight and is therefore suitable for further investigation.

Results: The flight test plan, which can be viewed online at <http://www.hf.faa.gov/docs/508/docs/SNItestplan.pdf>, is complete. Flight tests began October 2003 and simulation tests will begin in January 2004. Researchers also completed two successful system integration flights to test data collection instruments and the head and eye tracking system.

Recent Accomplishment: FAA will use these assessments to develop policy, criteria, and guidance to support implementation of PVFR/SNI operations. Specific operations that may be enhanced by PVFR routes include helicopter transitions through control zones and congested airspace, and flights through areas with natural or manmade obstacles, such as mountain passes and valleys.

Primary Investigator: Stephen M. Hickok, Satellite Technology Implementation, LLC, Orange Beach, Alabama

Co-Primary Investigators: Rudolph P. Darken, Joseph A. Sullivan, and Jeffrey Mulligan (Naval Postgraduate School, Monterey, CA, NASA Ames Research Center, Moffet Field, California)

Night Vision Imaging System Lighting Compatibility Assessment Methodology

FAA Sponsor Organization: Flight Standards Service, Flight Technologies & Procedures Division

Purpose and Rationale: Aircraft cockpit lighting can interfere with the proper operation of night vision goggles (NVGs). The accepted military practice to determine whether a lighting system is NVG compatible is to compare visual acuity through the NVGs with and without the cockpit lighting activated. This military procedure requires expensive illumination sources and radiometric measurement equipment that costs in excess of \$100,000. An inexpensive alternative method to assess compatibility, that provides the same quality of results as the military method, is needed for civilian applications. The purpose of the project was to review methods and procedures that will allow a non-night vision goggle user to measure night vision goggle compatibility of a modified cockpit at low cost and to have a reasonable assurance that the measurement was accurate.

Methodology: To develop an alternative lighting method for the visual acuity-based approach, researchers investigated alternative night vision image system compatibility test methodologies that do not depend on any type of measurement equipment and investigated methods that require a bare minimum of inexpensive or easily fabricated equipment. In order to develop an alternative method for the visual acuity-based approach, it was necessary to identify the specific elements of the method and produce inexpensive alternatives. The specific elements identified for devising alternatives were: (a) the visual acuity chart, (b) the calibrated illuminator, and (c) a means of verifying the chart radiance, and (d) a means of determining that the test facility is sufficiently dark to conduct the test. In addition, theoretically workable methodologies were developed for determining: (a) that the light environment for the testing is sufficiently dark to achieve valid test results, (b) that the resolution target radiance is appropriate to provide optimum NVG operation and (c) that visual acuity assessment can be made as reliably as the military method.

Results: Results from the alternate visual acuity assessment study clearly show that night vision goggle cockpit lighting compatibility assessment can be accomplished using inexpensive equipment. It is also evident that the visual acuity assessment procedure is prone to errors, because of the relatively broad nature of the curve. Furthermore, it is apparent that the night vision imaging system radiance-based criteria, currently used by the military, does not adequately address the difference in visual impact of a reflected light source versus a non-reflected light source. Night vision goggle model 103 provided much better results than the visual acuity assessment, although it did not differentiate between reflected and non-reflected light sources. The NVG light output measurement is a possible objective method of verifying NVG compatible cockpit lighting. Issues that still need to be addressed, using this device, are calibration procedures and the establishment of a criterion level.

Recent Accomplishment: Researchers discovered an alternative evaluation method that makes use of the light output of the night vision goggles. This new method provides a more precise acceptance/rejection criteria than the visual acuity method.

Primary Investigator: Alan Pinkus, Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio

Co-Primary Investigator: Lee Task, Task Consulting, Dayton, Ohio

Discrimination Model To Predict Night Vision Goggle Target Detection

FAA Sponsor Organization: Flight Standards Service, Flight Technologies & Procedures Division

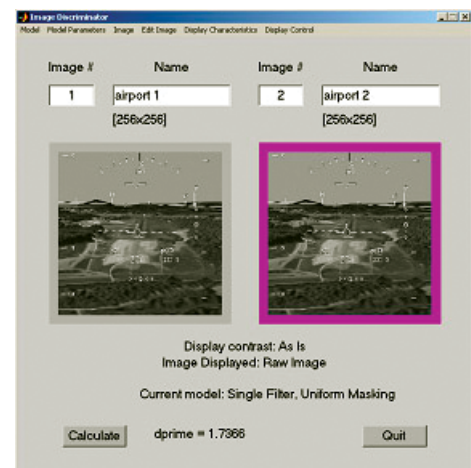
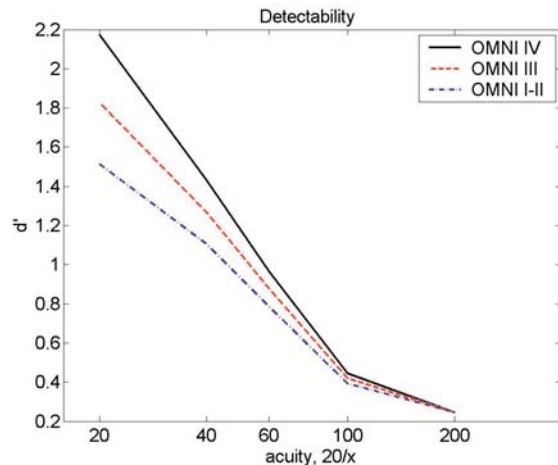
Purpose and Rationale: The purpose of this project is to develop an image discrimination model that can predict the detectability of targets for different image-intensifier tubes. Pilots flying under FAR Part 91 only require a Class 3 flight physical. This allows the pilot to have uncorrected or corrected 20/40 vision and still be qualified to fly at night. Night vision goggles (NVGs) have only been tested with pilots that have vision correctable to 20/20. The effect of allowing pilots with vision less than 20/20 to fly with NVGs is currently unknown.

Methodology: Researchers used a MATLAB image discrimination model to analyze observers' detectability of targets as seen through different types of night vision goggles. The MATLAB tool can model both the human observer as well as the sensor and display system used to detect and display image materials (e.g., night vision equipment). The MATLAB model parameters include noise, blur, spatial frequency, and luminance to determine how these effects influence pilots' detectability and readability of a target. The model predicts an observer's detectability by comparing two scenes – one scene with a target and the other scene without the target. The MATLAB model allows the user to compare the two images to determine the effects of night vision goggle tube quality by observer visual acuity. The user will be able to compare values between given resolutions for a particular goggle tube.

Results: The figure below shows the main window of the model, which provides a number of capabilities through menus, and through pop-up sub-windows. The user builds a library of input images that are either read in from files or constructed using various built-in image manipulation primitives. On the main window, two of these images can be displayed (here, two slightly different airport images are shown). The currently active image is distinguished by its magenta outline. A button below the images allows the user to request that the model calculate the two images currently displayed, using the current parameters that govern the display and observer models.

Recent Accomplishment: An easy to use application to investigate image discriminability between display systems.

Primary Investigator: Albert J. Ahumada, Jr., NASA Ames Research Center, Moffet Field, California





Building on the Legacy

To enhance safety in the national aerospace system, the FAA's human factors researchers are working to better understand human performance considerations and human factors issues in the acquisition of air traffic control systems. Their study of the collocation of various decision support tools has provided valuable data needed for the development of the next generation air traffic control workstation. Taxonomic analysis of operational errors is identifying improvements in how errors are investigated and reported, which in turn is leading to more effective interventions.

Human factors research is also providing: critical guidelines and other information for the design and development of new air traffic control systems and product improvements; development of workload, performance, and decision-making measures and models for existing systems and new technologies; tests and criteria for selecting operational personnel; guidelines and recommendations for minimizing sources of error and fatigue; and other research that helps increase understanding of human factors of emerging technologies, changing human roles and responsibilities, and evolving procedures, to help optimize human performance.

The air traffic control/airways facilities human factors research program is the product of continued cooperation and collaboration between the Human Factors Research and Engineering program and its customer base, the air traffic operations and systems development community.

Optimizing Human Performance to Reduce Runway Incursions

FAA Sponsor Organization: Air Traffic Service

Purpose and Rationale: This project addresses the need to develop a technique to identify causal factors related to runway incursions. CAMI researchers adapted the FAA’s JANUS technique for identifying operational error causal factors, to including vehicle-pedestrian deviations related to runway incursions. The JANUS approach encourages a thorough examination of incidents using a structured interview process. This process encourages the analyst to think both broadly and specifically about factors that may influence the event to avoid potential bias due to tunnel vision or overlooked factors.

Methodology: Researchers recruited subject matter experts to observe ground and surface operations at Will Rogers Airport in Oklahoma City, Oklahoma. They reviewed and revised the JANUS causal factor taxonomy to include factors relevant to vehicle operations. They reviewed factors such as attention, memory, decision-making, response execution, violations of procedures, and fourteen additional contextual factors. Using this revised taxonomy, researchers analyzed archival vehicle and pedestrian incident reports and noted three areas that appear to influence a vehicle operator’s choice of actions: ground traffic; ground and approach operations; and ground equipment.

Results: The analysis of vehicle deviations illustrated that existing reports capture “what” happened, but provide only limited information regarding “why”. There is very little information about the thinking of the vehicle operator or the circumstances that led to the deviation. Researchers found that most reports focused on the lack of communication with air traffic controllers and that many authorized movements were executed poorly because of read-back and hear-back problems. The researchers also found inadequate information about the type of vehicle being relayed to controllers. There is a need for a reporting system to identify the human factors in vehicle operator and pedestrian incidents.

Recent Accomplishment: Researchers worked with the airport manager to obtain subject matter experts who volunteered their time over several months in support of this project. Researchers revised the existing FAA JANUS taxonomy to accommodate causal factors related to airport surface operations.

Primary Investigator: Julia Pounds, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Support For Development of a Research Framework For Controller En Route Evolution Procedures

FAA Sponsor Organization: Air Traffic Planning and Procedures Program

Purpose and Rationale: The aim of the proposed research is to provide a bridge between the abstract, general principles of cognition that have been learned through Human Factors research during the past few decades and a specific operational context for application of the proposed technologies for NAS modernization. This would provide a pragmatic mechanism for anticipating the effects of the introduction of new technology into a work setting. We will develop new methods, or augment existing ones, that explicitly consider the impact of technology on a work effect zone. The focus of these methods will be cognitive and will take into consideration information availability and perceivability, mechanisms for coordination, support for decision-making, and the flexibility of a system to detect and adapt to unexpected circumstance. The methods will then be applied to present and proposed FAA research initiatives.

Methodology: What is needed is a framework that can be used to support the sources of research requirement reviewed above, and also supports insight into the system wide implications of the technology or operational concept, or service modification. We intend to conduct the analysis, descriptions of service provider tasking, technologies and assumed concepts of operation and to determine objectives for research and evaluation. Since this effort involves both re-evaluating some earlier decisions as well as evaluating projected future changes, operational improvements across the timeframe from 1993 to 2015 are to be included. These operational improvements will be organized using a framework and use-case methodology. The framework method identifies required and exchange, brief scenarios.

Results: Built use cases in the NAS from 1993 to present. Extracted use cases from RTCA Conops/FAA-ATS Strategic Vision. Conducted site visits and interviews with technology development teams.

Recent Accomplishment: Conducted a two-day organizational meeting to: (a) Assure cooperation from all stakeholders, (b) Review existing products and concepts, (c) Identify existing and future uses cases, and (d) Assign tasking and products.

Primary Investigator: Kevin Corker, San Jose State University, San Jose, California

Auditory Alarms in Airway Facilities (AF)

FAA Sponsor Organization: National Air Space Operations

Purpose and Rationale: The FAA's AF specialists rely on auditory alarms to provide information on systems and equipment that are in need of their attention. Unfortunately, the alarms on maintenance systems lack standardization, and as a result, many of the alarms are difficult to hear or are distracting, or simply very annoying.

Methodology: FAA researchers measured ambient sound levels, recorded previously unrecorded alarms, captured equipment layout, and collected data on frequency of occurrence and criticality of alarms at a number of field sites. They also asked the maintenance specialists to rank the severity of 15 potential auditory alarm issues and expanded on these issues in subsequent structured interviews.

Results: AF specialists rated the top problems they encountered with respect to audio alarms. Although the lists were very similar, there were slight differences depending on the operational environment. The top five issues for AF TRACON personnel were: no alarm, alarms sound alike, alarms difficult to hear, false alarms, difficulty locating the source of the alarm. For AF en route, additional concerns were: visual alarms should be auditory, or auditory alarms should be visual, and, simply put, too many alarms. In general, Airways Facilities specialist concerns included: the need for audio alarms in some situations; alarm confusion; alarms that are difficult to hear; the frequency of false alarms; difficulty in locating the source of alarms; too many simultaneous alarms; and too many different alarms. These data will allow designers to use alarms better matched to the operational environment.

Recent Accomplishment: Researchers identified critical auditory alarm issues in field settings. The resulting data will provide human factors guidance that will help to address issues with the alarms.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

Communication and Coordination Lessons Learned in Operations Control Centers

FAA Sponsor Organization: National Air Space Operations

Purpose and Rationale: Recently, the FAA consolidated its Airways Facilities communication and coordination operations such that they will now be performed in three newly created Operations Control Centers (OCCs). While streamlining much of the duplicative work, anecdotal reports indicate that communication and coordination within these centers needs improvement. Through comparison with prior communication and coordination efforts, this study identified problematic issues with these newly formed centers to develop human factors best practices. This study compares and contrasts current communication and coordination at the OCCs with studies from Maintenance Control Centers that existed prior to the OCCs and human factors best practices.

Methodology: Researchers visited the three OCCs to collect observational data and conduct structured interviews. The structured interview consisted of a series of statements in which specialists were asked to indicate their level of agreement with a statement by selecting a response in a range from strongly disagree to strongly agree. Each question had room for the specialist to provide comments or further explain their rating. The structured interview also contained open-ended questions that allowed the specialists to address issues not covered in earlier questions.

Results: While still preliminary, the report written in September provided a quick look at the data collected during the site visits. Researchers found that OCCs neither did not function as planned nor did they followed staffing levels and procedures outlined in initial planning documents. In addition, researchers found differences between the three OCCs in such areas as terms of training, workload, communication between supervisor and specialists, perceived relationships with external customers, and understanding of individual roles and responsibilities. They also recommended improvements to the tools used to communicate information to the specialists, such as the telephone system and the large screen displays.

Recent Accomplishment: Although this effort is still in progress, researchers have already collected critical data that will ultimately result in improved operations.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

Core Commands Across Airway Facilities

FAA Sponsor Organization: National Air Space Operations

Purpose and Rationale: Airways Facilities (AF) specialists are required to use over 25 different systems to monitor and control complex software programs and network hardware. Consistency in interaction, and standardization in the systems have many benefits including transfer of learning, decreased potential for errors, and decreased training time. Problems occur due to lack of standardization in how they are operated. Standards have been developed to help improve standardization and interaction when developing a new system.

Methodology: Researchers analyzed current commercial software standards. They reviewed computer-based instruction and software technical manuals to collect data on how the different AF systems use and display core commands, menu terms and structures, and shortcut keys.

Results: Researchers found little consistency in the assignment of functions to the function keys and shortcut keys, use of menus and mnemonics, and recommended standardizing the key use across systems. In addition, because home computers use the function (F) keys for commands, researchers recommended that F keys on the AF systems should not be assigned certain actions to alleviate confusion, and also recommended a list of core commands. To meet human factors recommendations for menu structure, terminology, options, and organization, researchers created a catalog of menu and mnemonic use for the AF systems.

Recent Accomplishment: This research effort resulted in three different reports: the first focused on core commands used across different systems; the second focused on function keys and shortcut keys; and the third focused on menus and mnemonics. This work will be used to reassess acquisition standards for AF systems to determine the feasibility of standardizing the systems. It will also be used to help resolve inconsistencies with human factors guidelines and industry standards.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

Status Coding in Airway Facilities

FAA Sponsor Organization: National Air Space Operations

Purpose and Rationale: It is critical that Airway Facilities AF specialists know the operational status of their systems and equipment. Lack of consistency of status codes and of items that are coded across complex AF systems can reduce situation awareness and result in confusion in the action required of the specialist. The effects of inconsistency are compounded by the complexity of AF systems. It is important that we identify salient items to code and determine what is currently coded in order to see where improvements are required.

Methodology: Researchers collected data on 97 different items that are coded and defined for each system. The researchers identified the primary status screen, what information is conveyed to the user on the primary status screen, and what action the user must take to address changes to the primary status screen. The researchers are using this information to create a preliminary prioritization scheme for the coded items. This scheme will help the researchers in collection of data on information requirements in a structured manner. The next step is to identify user functional requirements and provide recommendations on how to use different coding methods, color, shape, flash, highlighting more effectively.

Results: Researchers completed the initial literature search and preparations are underway to collect user functional requirements. They identified the primary status screen for most AF systems, documented how status changes for different systems are coded, and identified discrepancies across systems.

Recent Accomplishment: Researchers identified and defined 97 status codes used by more than 20 AF systems.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

The Human Factors Design Standard

FAA Sponsor Organization: Human Factors Research and Engineering Division

Purpose and Rationale: Initially released in 1996, the Human Factors Design Guide (HFDG) is a primary human factors reference guide in the acquisition and development of systems for the FAA. It takes information from a broad range of sources including government and industry standards and academic research, and presents the information in the form of “should” and “shall” statements. These statements can be easily converted into system-specific requirements documents or checklists. Due to the dynamic nature of the HFDG, it needs to be updated and reorganized periodically, allowing easier access to what systems developers need. Although used by the FAA and related contractors, as well as other federal agencies and industry, the Guide needed to be updated to include new research and procedures.

Methodology: In fiscal year 2003, the FAA released its new *Human Factors Design Standard* (HFDS). This comprehensive human factors reference incorporates best practices and information from a broad range of human factors sources, including government, industry, and academia. It includes the results of collection, review, and analysis of a large volume of documentation including other standards in use and research products from across the human factors domain. The HFDS replaces and expands upon the earlier *Human Factors Design Guide*. It includes both air traffic and airway facilities systems, providing a common source of FAA-specific design requirements. The resulting set of standards can be tailored to meet the needs of any system or program.

With over 100 new rules and guidelines and a reorganization of material based on information from users, the *Human Factors Design Standard* presents information in the form of “should” and “shall” statements. These statements can be easily converted into system-specific requirements documents or checklists.

Results: The *Standard HFDS* is now available for download through the internet at <http://hf.tc.faa.gov/hfds/> or in CD ROM format.

Recent Accomplishment: With over 100 new rules and guidelines and a reorganization of material based on information from users, the updated HFDS provides information in a clear, concise format that will improve usability. The release of the new standard has broad impact both within and beyond the FAA, and is currently being accessed by educational, ergonomic, industry, and aerospace organizations within the United States and in over 40 different countries.

Primary Investigator: Vicki Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

The Future En Route Workstation

FAA Sponsor Organization: Air Traffic Planning and Procedures Program and En Route Integrated Product Team

Purpose and Rationale: Human factors researchers are working to create a future en route workstation that applies good human factors principles and will give controllers quick and efficient access to information and capabilities projected for the future of ATC.

Methodology: Through literature review, prototyping and limited human-in-the-loop simulations, researchers developed the foundation for assessing future workstation concepts. It will serve as a basis for a simulation in FY04.

Results: The researchers found that although many organizations are exploring new air traffic control technologies, little attention is being focused on how the predicted 60-100% increase in air traffic activity will affect controllers. To assess controller needs, researchers are now preparing for a human-in-the-loop study focused on traffic load and workstation design. The prototype platform that will serve as the foundation for the new simulation efforts now receives automation-generated information that will be integrated into new displays.

Recent Accomplishment: Researchers developed a flexible, powerful future en route simulation platform with many of the capabilities anticipated in planning documents.

Primary Investigator: Pan Della Rocco, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

Co-Primary Investigator: Ben Willems, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey

Weather Information Needs in the TRACON Environment

FAA Sponsor Organization: Terminal Business Unit

Purpose and Rationale: In the National Airspace System (NAS), weather reportedly causes over 70% of all delays. For several years, researchers and air traffic control personnel have debated how to best use weather representations on operational air traffic control displays to optimize traffic flow around and through weather. This research program addresses controller weather information needs to determine how the information should be used and displayed.

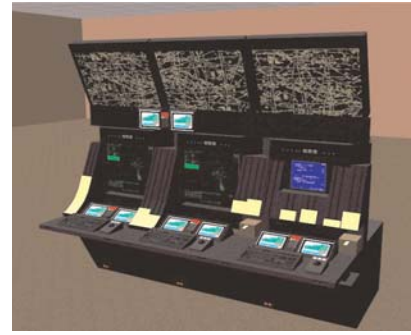
Methodology: Researchers completed a literature review and task analysis designed to define the information needs of terminal radar approach controllers, and studied how to best display that information as well as what procedures will be required to integrate the new information into the air traffic controller workstations. The researchers are working to upgrade the FAA's simulation platform to accommodate a future human-in-the-loop study. In addition, they are developing metrics to assess the benefits of the weather displays.

Results: The literature review revealed that very little research has been conducted on the weather information needs of terminal radar approach control (TRACON) controllers or how the information should be displayed and used. Application of human factors principles suggests that the display of information should minimize the requirement for a controller's mental integration and provide the user with meaningful, effortless information pick-up comprehension. Researchers are now examining weather information needs, important issues related to weather phenomena for pilots and controller operations, and current deficiencies in the display and dissemination of weather information to pilots and controllers.

Recent Accomplishment: A literature review leading to the derivation of human factors principles that were reviewed by a controller-pilot work group and submitted for publication by the Air Traffic Control Association.

Primary Investigator: Pan Della Rocco, FAA William J. Hughes Technical Center, Atlantic City International Airport New Jersey

Co-Primary Investigator: Ulf Ahlstrom, FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey



Human Factors Considerations in Future Oceanic Air Transportation Systems Architectures Which Include Automatic Dependent Surveillance

FAA Sponsor Organization: Air Traffic Planning and Procedures Program

Purpose and Rationale: As air traffic increases, and the emphasis on safety and efficiency rises, there is a greater demand for reduced separation and more efficient routing over the ocean. Therefore, oceanic air traffic control systems and processes are quickly evolving to accomplish these objectives with the integration of new technologies, integrated information systems, and procedures. This new environment will significantly influence the tasks of the controller and the pilot. To provide human factors support to oceanic modernization efforts, collaborative research studies are being done by Iceland and the United States. This collaboration includes Massachusetts Institute of Technology (MIT), FAA, University of Iceland, and Iceland's Civil Aviation Administration.

Methodology: The first step in MIT's study is to complete a human-centered systems analysis of oceanic air traffic control. This includes reviewing operating procedures and job task analysis to formulate a preliminary cognitive model, and then conducting site visits to refine this model and learn more about the oceanic environment. The first site visit, at New York Air Route Traffic Control Center, consisted of one exploratory observation to gather an initial understanding of the oceanic environment. Following this visit, researchers conducted more focused observations at Reykjavik Center in Iceland and New York Center.

Results: Based on the initial site visits, researchers analyzed the air traffic control processes and information flow. They further refined and used a cognitive model to identify key issues in the current oceanic air traffic control system used at Reykjavik Center and oceanic air traffic control in general. Some of the key preliminary issues discovered included the need to overcome automation limitations to support the controllers' cognitive processes, to understand better the mixed equipage issue of transitioning boundaries of different performance, and the need for more consideration into the type of separation requirements given to the controllers in the future. Additional efforts are focused on generating an Air Traffic Service Research Management Plan through collaboration with FAA contacts, developing an annual status report, and presenting initial analysis at the June 2004 FAA/NASA Joint University quarterly review meeting.

The next steps towards MIT's human-centered systems analysis of oceanic air traffic control is to conduct more focused observations in the United States, as well as to look into the key issues that have been identified. Further efforts will also be focused on analyzing the future air traffic control systems and processes.

Recent Accomplishment: Presented preliminary results at the FAA/European ATM 2003 Symposium held in Budapest, Hungary in June, 2003.

Primary Investigator: John Hansman, Massachusetts Institute of Technology, Cambridge Massachusetts

Reroute Advisory Tools, Coded Departure Routes and Enhanced Feedback

FAA Sponsor Organization: Traffic Flow Management Integrated Product Team

Purpose and Rationale: This project focuses on three distinct goals: to provide design input for the implementation of a suite of reroute advisory tools; to provide an assessment of the use of Coded Departure Routes (CDRs), a set of predefined alternative routes for flying between particular city pairs, and recommend methods to enhance the use of CDRs; and to identify ways to enhance feedback to FAA staff and National Aerospace System (NAS) users. The primary focus of this research effort is to provide improved, efficient information access and feedback to both FAA traffic managers and NAS users regarding traffic flow management plans and their outcomes. Such improvements offer the potential to reduce significantly departure delays, improve the planning and implementation of responses to severe weather, to accommodate better the priorities and constraints of NAS users, and to reduce the workload of FAA traffic managers, freeing them up for other tasks.

Methodology: Researchers used four approaches: structured interviews with FAA and airline staff to conduct needs assessments; apply post operations evaluation tool (POET) analyses to provide objective data about scenarios that arise in the NAS and that offer insights into problematic or successful responses to weather and traffic constraints; analytical evaluations of proposed tool designs to assess potential usefulness and usability; and the design and implementation of prototype tools to explore and communicate alternative designs to meet identified needs. POET is an analysis system used by the FAA's Air Traffic Control System Command Center, Air Route Traffic Control Centers, other FAA facilities, and NAS users to identify and analyze air traffic control system-wide problems. Researchers applied these methods to identify opportunities for improving communication about traffic flow management plans, to gain insights into the use of Coded Departure Routes and to recommend ways to improve their effectiveness, and to identify areas where current feedback to operational staff about the impacts of their plans is inadequate, thus making it difficult for them to learn and make improve future performance.

Results: During fiscal year 2003, researchers provided significant input into the design of the suite of Reroute Advisory Tools. They also documented that there is a great need for better coordination in the use of Coded Departure Routes to improve the NAS in terms of both safety and efficiency and, as part of this analysis, they proposed a method for achieving better coordination. Finally, researchers documented the need for better tools to provide feedback to FAA operational staff and to the NAS users, and developed a prototype system to demonstrate how to meet this need.

Recent Accomplishment: This work provided both strategic guidance and detailed input into the design of new operational tools and procedures. For example, researchers recommended the development of Reroute Advisory Tools advisories, and, with industry, identified the necessary mechanisms to initiate use of such advisories. As a result, in May of 2003, Reroute Advisory Tools advisories became operational.

Primary Investigator: Philip J. Smith, The Ohio State University, Columbus, Ohio

Air Traffic Control Information Complexity

FAA Sponsor Organization: Terminal Business Unit

Purpose and Rationale: With the increase in number and complexity of decision support tools for air traffic controllers, it is critical that researchers assess the amount of information that new air traffic control tools provides controllers. This project seeks to develop objective metrics to measure information complexity associated with air traffic controller displays. It is expected that the metrics will be able to predict controller difficulties in future human-system interface integrations.

Methodology: Because of the difficulty involved in determining a single rating number to describe the complexity of an air traffic control display, researchers developed multi-dimensional metrics of information complexity and then validated the metrics through objective and subjective measurements. The initial phase of the project included an extensive literature review of available methods of display evaluation and complexity computation. This provided a list of factors that contribute to information complexity. Once they determine an appropriate way to compute complexity, researchers plan to apply such metrics to a variety of air traffic control tools, such as the proposed weather display on the Standard Terminal Automation Replacement System (STARS), and will compare results with a baseline display. After the results are validated, researchers will apply the methods to current ATC tools and create an information database.

Results: The literature review and analysis demonstrated that information complexity is mediated by three factors: numeric size, variety, and interaction. Knowing this, researchers developed a framework for the evaluation of ATC displays. Based on the memory structure of the human brain, they also proposed four metrics of information complexity, each affecting different cognitive processes: relational complexity that effects working memory, representational complexity that effects the operation span of mental representations, dynamic complexity that affects computation of mental representations, and executive complexity that affects the execution of attention. Currently, researchers are developing methods to measure these metrics and their application to interface design.

Recent Accomplishment: A draft technical report that identifies one of four metrics of information complexity, based on the ways the human brain works. This information allows researchers to directly correlate the cognitive workload imposed by using new technologies and controllers' cognitive capacity limits. The results will support the development of guidelines for automation interface design and evaluation.

Primary Investigator: Jing Xing, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Air Traffic Control Intra-Team Communication and Coordinated Decision Making

FAA Sponsor Organization: Runway Safety Office

Purpose and Rationale: Researchers are working to reduce the number of runway incursions attributed to a lack of coordination/communication between ground and local control. Since runway incursion report forms do not provide enough details about that coordination/communication during an incident, there is a need to develop better ways to understand this process so improvements can be made.

Methodology: Researchers are identifying the operationally relevant outcomes (e.g., percentage of communication related to runway crossings vs. takeoffs and landings) that are related to ground and local coordination/communication. Other examples of relevant outcomes may include: (a) the determination and frequency of topics discussed between ground and local control; (b) the percentage of ground and local communications that involve take-offs and landings vs. crossing runways; and (c) the influence of the availability of taxiways and access roads on communications.

Results: Researchers completed the first version of the Air Traffic System Research Management Plan.

Recent Accomplishment: Clarification of Air Traffic sponsorship including the coordination of field activities.

Primary Investigator: Larry Bailey, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Color and Visual Factors in Advanced ATC Displays

FAA Sponsor Organization: Air Traffic Planning and Procedures Program

Purpose and Rationale: The project seeks to evaluate the impact of color-coding in air traffic systems and to improve the effectiveness of color use. New air traffic control displays use color extensively, since earlier research found color to be the most effective cue in guiding visual search and segregating information. However, inappropriate use of color can reduce efficiency, reduce the reliability of information perception, and may adversely impact the performance of color-deficient controllers. The FAA has no requirements on the use of color in ATC displays. However, the FAA does have color vision standards in place for controller selection. Given the extensive use of color, it is important to understand the impact of color-coding in air traffic systems and to evaluate the use of color. Previous evaluations have shown advantages of color; the disadvantages have not been adequately addressed.

Methodology: Researchers first examined how color-coding on newly introduced automation air traffic display systems affect controller's job performance. They also conducted vision experiments to establish color specifications for air traffic control and to validate color vision standards for controller selection. Computational models of color vision will allow researchers to compute the perceptual effects of color-coding on air traffic controllers with color vision deficiencies.

Results: Field observation and data analysis demonstrated several aspects of the problematic use of color with new technologies: (a) many displays use colors as the primary cues for critical information, however, the colors were not conspicuous enough for viewing-at-a-glance; (b) some color coded text had low readability, which reduced reading speed and accuracy; and (c) color coding was inconsistent across different displays or different modes of the same display. Additional analyses revealed that air traffic controllers with color deficiencies could not distinguish some color-coded graphical information.

Recent Accomplishment: Through this project, researchers have brought to the attention of manufacturers, industry, and air traffic control organizations the crucial role that color plays when considering new air traffic control technologies. Analysis revealed that some color-coded graphical information associated with new technologies might not be easily distinguishable by ATCSs with color deficiencies.

Primary Investigator: Jing Xing, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Complete Development of the Statistical Retirements and Attrition Model (SCRAM) to Support ATS Occupational Workforce Planning

FAA Sponsor Organization: Air Traffic Resource Management Program

Purpose and Rationale: The FAA hired most of its air traffic control specialists or controllers between 1981 and 1996. A large percentage of them will soon approach mandatory retirement at age 56. This uncertainty complicates workforce planning and management of the air traffic control specialists recruitment and training pipeline. One approach to reduce this uncertainty is to develop a probability-based model of retirements, using eligibility as the starting point and historical separation data. This research task seeks to develop a prototype statistical tool for estimating future retirement and attrition based on historical separation data for critical air traffic control occupations.

Methodology: Researchers obtained agency-wide historical separation data from Fiscal Year 1996-2002 and then developed a method for determining retirement eligibility under a variety of retirement options. They analyzed historical separation data with respect to eligibility to construct probability tables for (a) controllers and (b) non-controllers. Researchers translated the eligibility determination method and probability tables into a dynamic database.

Results: To maintain a stable workforce, researchers created a statistical tool to calculate the average number of employees lost annually through retirement or attrition. This tool, the Statistical Retirements and Attrition Model (SCRAM), will be integrated into an Office 97® compatible desktop application and will standardize historical data concerning retirements, separations, and promotions out of key workforce as well as identify hiring sources and pools.

Recent Accomplishment: This project culminated in two major accomplishments: (a) researchers developed estimates and forecasts of future retirements to use in the Air Traffic Specialist Human Capital Plan; and (b) they created a working prototype database with the flexibility to handle different retirement rules and incorporate separations and on-board data.

Primary Investigator: Dana Broach, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

FAA Employee Attitude Survey

FAA Sponsor Organization: Office of Administrator

Purpose and Rationale: In 1984, the FAA began administering the Employee Attitude Survey (EAS) to its employees. The survey gathers information about employee attitudes, perceptions, and opinions covering a broad range of organizational issues that affect workforce performance and quality of work life. In late Fiscal Year 2003/early 2004, researchers revised and administered the EAS to continue the development of a longitudinal database for evaluating efforts aimed at enhancing job satisfaction and the organizational climate. Many of FAA's lines of business and major organizations use the results of the survey to gauge their progress regarding various action plans established as organizational performance indicators. Measures of organizational effectiveness assist in identifying potential problems associated with implementation of proposed air traffic control system and/or organizational changes.

Methodology: Completing a census survey of employee attitudes for an agency of this size requires the support and involvement of individuals across the agency to reflect accurately issues of interest, throughout the agency, while maintaining core historical items across administrations.

Results: Results of the 2003 EAS will be distributed to Lines of Business and major organization points of contact.

Recent Accomplishment: The FAA's Office of Human Resources, the Civil Aerospace Medical Institute, and the survey points of contact jointly advertised the distribution of the EAS to increase participation. With the assistance of members of the Agency's Virtual Organization for Internal Communications (VOICE) team, survey creators established a web site that featured a descriptive history of the survey program, frequently asked questions about the survey, and an EAS sample report.

Primary Investigator: Carla Hackworth, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Flight Strip Studies

FAA Sponsor Organization: Terminal Business Unit

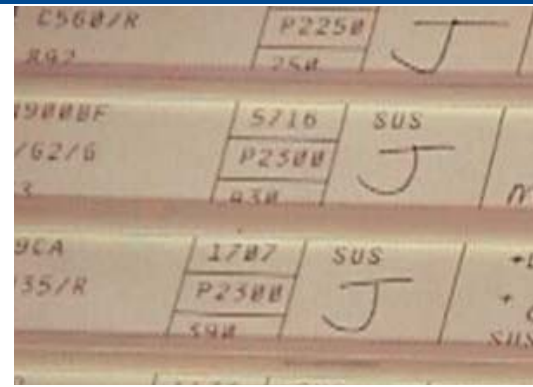
Purpose and Rationale: One step toward increasing tower traffic capacity is to eliminate the use of paper flight strips and substitute less laborious ways to manage flight plans and flight progress. However, before developing a new technology that replaces paper flight strips with an electronic form of flight data, it is first necessary to understand how, why, and when controllers use paper strips. Knowledge of information and operational requirements for flight strips provides a valuable contribution to decisions about the appropriate method for displaying electronic flight data in towers. The information and operational requirements can be used to identify electronic flight data displays that can be compared in a simulation.

Methodology: Expert controllers systematically observed other controllers to determine how they used paper flight progress strips. They counted and reported the number of times the observed controllers marked, moved, or otherwise manipulated strips or other flight progress data as a means of monitoring environmental variables, such as amount of traffic, position, staffing, time of day, etc. Expert controllers also obtained additional information through interviews with the observed controllers.

Results: Initial field research has been completed and a research plan developed for the next phase of this study.

Recent Accomplishment: Researchers developed the research management plan for the tower flight strip project, and are now working to select subject matter experts and facilities to conduct the next phase of this work.

Primary Investigator: Carol Manning, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma



Individualized Assessment Instruments (Cognitive and Personality)

FAA Sponsor Organization: Office of Aviation Medicine

Purpose and Rationale: Under an Institutional Review Board-approved protocol, the FAA administers personality tests to students at the FAA Air Traffic Academy. These tests include the NEO Personality Inventory-Revised (NEO PI-R), a comprehensive and detailed assessment of adult personality based on five factor model and the Armstrong Laboratory Personality Survey, a 15 scale survey that covers personality, psychopathology, and crew interaction styles (ALAPS), and the 16 Personality Factor exam which tests for and describes the sixteen dimensions of a person. Researchers track student progress over time to determine the validity of the test results and the use of these current alternative personality assessment tools.

Results: Researchers compared results from the personality assessments to scores on the FAA developed Air Traffic Selection and Training exam, a 6-1/2 hour computer-based test designed to identify the cognitive skills needed by air traffic controllers. They discovered that the scores were relatively consistent with expectations, which suggests that the FAA scales are reasonably reliable. The current screen-out approach appears to focus primarily on the extent to which the applicant reports symptoms consistent with neurotic, inefficient, and perhaps, argumentative characteristics.

Recent Accomplishment: Researchers wrote and distributed a technical report that revealed the strong performance of FAA developed psychological tests. The ability of these tests to enable the hiring of a highly skilled workforce will lead to improved decisions regarding the future of personality testing in the selection of air traffic controllers.

Primary Investigator: Raymond King, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Longitudinal Assessment of AT-SAT

FAA Sponsor Organization: Air Traffic Resource Management Program

Purpose and Rationale: The Air Traffic Selection and Training (AT-SAT) exam was initially validated using job performance data from incumbent FAA controllers. The test needs to be studied to determine its effectiveness with regard to job applicants. A longitudinal follow-up will then determine the effectiveness of the test at identifying the most successful candidates. Researchers are working with Air Traffic Services to gather job performance data on air traffic controllers, and are also comparing archived AT-SAT data on fully trained controllers to their performance on a computer-based task. The Air Traffic Selection and Training exam, a 6-1/2 hour computer-based test, identifies the cognitive skills needed by potential air traffic controllers. Researchers are comparing the results from the initial test to on-the-job performance. This follow-up validates the effectiveness of this examination to determine the most successful candidates.

Methodology: The work, other than collecting and archiving Air Traffic Selection and Training exam data, will focus on the development of criterion measures of success in the tower cab and terminal radar environments and the comparison of individual exam results to these measures. Research questions include: (a) Is AT-SAT a valid and legally defensible selection tool, and (b) What are the appropriate performance criteria and does AT-SAT predict acceptable performance?

Results: The research focuses on answering questions concerning the use of this exam as a valid and legally defensible selection tool, the determination of the appropriate and measurable job performance criteria for air traffic controllers, and the use of this exam as a means of predicting acceptable performance. Periodic reports evaluate the reliability, fairness, validity, and utility of AT-SAT as part of the ATS selection process.

Recent Accomplishment: This data collected through the archiving of AT-SAT exam results, which will be greatly enhanced by the upgraded software for the AT-SAT operating program. will lead to great enhancements to the current software.

Primary Investigator: Raymond King, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Parallel Form of AT-SAT

FAA Sponsor Organization: Air Traffic Resource Management Program

Purpose and Rationale: The current version of the Air Traffic Selection and Training (AT-SAT) selection battery is based on a single questionnaire for each component sub-test, making them vulnerable to coaching efforts. Applicants are also able to inflate their scores through repeated testing, without increasing their potential to successfully complete training and qualify as Certified Professional Controllers (CPCs). CAMI completed initial development of parallel forms of selected subtests in FY2002 and tested those forms through cooperative research with the Department of Defense in FY2003. This work continues development of the next-generation selection criteria and tools to support long-term hiring requirements with the goal of having two equivalent parallel versions of AT-SAT that operate on a Windows 2000 and Windows XP platform.

Methodology: During the FY 2002 Pilot Study, researchers presented alternate AT-SAT items to voluntary military participants along with items already on the validated AT-SAT. Researchers analyzed these items and eliminated those considered too easy or too difficult. Through a process of over sampling, they specifically examined information from minority members to ensure the best potential for equivalent, and hence, equally valid, forms for members of these groups. Also, in FY 2003, researchers revised the operating platform for AT-SAT.

Results: The military participants provided useful data to the FAA. While minority participation was good, the over sampling was not optimal because of the tendency of some to “jam,” rendering useless data. The AT-SAT subtests are transitioning well to a state-of-the-art software platform. This recent testing pointed out the challenges of administering the existing test in the field as opposed to administering it at the FAA’s Civil Aerospace Medical Institute

Recent Accomplishment: The previous version of AT-SAT, based on a single form for each component sub-test in the battery, operated utilized an obsolete operating system. The FAA is now positioned to field two equivalent forms that run on state-of-the-art operating systems to combat the risk of test compromise, system failure, and score inflation.

Primary Investigator: Raymond King, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

POWER Taskload and Performance Baseline Assessments

FAA Sponsor Organization: Air Traffic Planning and Procedures Program and Office of System Architecture and Investment Analysis

Purpose and Rationale: As new and more complex technologies are introduced into the National Airspace System, it is important to understand the interaction between the air traffic controller and the technology. The FAA's human factors researchers developed the Performance and Objective Workload Evaluation Research (POWER) software to quantify the relationship between air traffic controller activity and taskload.

Methodology: Researchers identified a list of more than 20 POWER measures describing different aspects of air traffic controller activity that are objective, and routinely recorded. The measures encompass controller and aircraft information, such as traffic volume, the average heading, speed, and altitude changes, the number of hand-offs, data entries, route displays, point-outs, data block offsets, conflict alerts, etc. POWER collects actual data from several air traffic control databases and then uses the information to estimate controller task load in a variety of situations.

Results: Researchers conducted critical preliminary work developing objective measures of controller workload. They are now refining a research software tool that will estimate workload measures and system performance, which will, in turn, help determine the effect of new technology on the controller workforce.

Recent Accomplishment: POWER software will enable researchers to develop baseline measures of controller activity and task load for en route air traffic controllers. These baselines will be extremely useful for evaluating the effects of changes in equipment and procedures used by controllers.

Primary Investigator: Carol Manning, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

