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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A Message from the Program Director

To the Aviation Community

The FAA Human Factors Research and Engineering Division ended its year on a high note with many notable achievements valued by our customers. Our successes not only built upon an already solid foundation of research established in previous years, they also represented breakthrough results that will continue the momentum well into the future. Outstanding examples abound - we continued our efforts toward establishing vision standards for aviation maintenance technicians, updated and expanded the rapidly reconfigurable event set for line oriented evaluations used by air carriers, and developed additional tools to identify training needs before pilots transition to automated aircraft. In addition, Version 4.0 of the human factors certification job aid was delivered. The acquisition arena remained a key focus area as we filled targeted positions in the Air Traffic Management/Communications, Navigation, and Surveillance (ATM/CNS) acquisition and development organizations with human factors professionals.

Key activities in air traffic control human factors included the integration of three free flight technologies into one test bed, used in the first simulation study of its kind. Our researchers also developed a flexible, powerful future en route simulation platform that supports many of the capabilities anticipated in future aviation operational concepts. The aeromedical research team enhanced its position as a major player in aircraft accident investigations and postmortem analysis, and expanded its study of solar radiation exposure, biological and chemical threats, and other cabin environmental conditions. Cabin safety is being improved as a result of biodynamic research addressing aircraft seat certification, and studies of emergency evacuation into water and flight attendant preparation for turbulence.

We have assembled a world-class team, and they are leading the way with top human factors research. Many were recognized by management, professional organizations, and by their peers during the year. We are extremely proud of their outstanding achievements. Together, we are working to achieve substantial and sustainable results that will improve aviation safety and capacity. If you take only one message from this annual report, it should be that we are up to this challenge, and we intend to deliver.

Mark D. Rodgers
Program Director
Human Factors Research & Engineering Division

Recent Accomplishments

Rapidly Reconfigurable Event Sets for Line Oriented Evaluations

Model AQP Software

Automation Assessment Tool

Certification Job Aid

Human Factors Considerations in Design/Evaluation of Electronic Flight Bags

Human Factors Acquisition Reviews

Access-To-Egress Evaluation of Type III Over Wing Exits

Analysis of Automatic External Defibrillators

JANUS - Improved Taxonomy of Operational Error Causal Factors

Human Factors Design Standard

Objective Measures to Classify Severity of Runway Incursions

Full-Mission Simulation to Investigate the Interoperability of Three Independently Developed ATC Decision Support Tools

Provided guidance to reduce the likelihood of loss of control following a loss of vacuum or failure of the vacuum-powered attitude indicators

Demonstrated that simplified English improves aircraft maintenance non-native English speaking technicians' comprehension for aircraft maintenance workcards

Completed detailed general aviation fatal accident human error analysis

Provided guidance on the effectiveness and reliability of a Personal Computer Aviation Training Device (PCATD) and a Flight Training Device (FTD) in conducting an instrument proficiency check

Developed method to measure night vision goggle cockpit lighting compatibility

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 pacesetting 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 Sub-Committee.

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

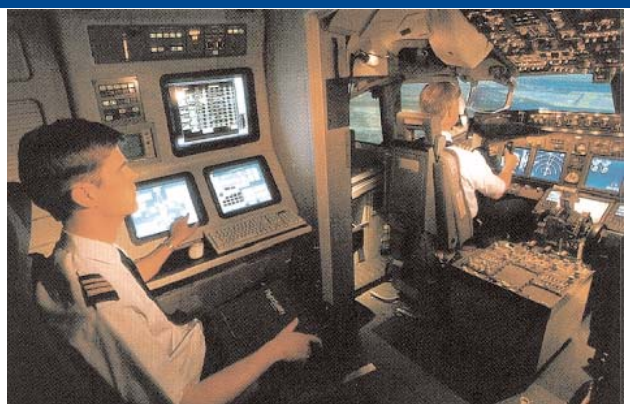
Purpose and Rationale: Flight simulator qualification standards, which may soon become regulatory, need to be sufficient and effective, yet affordable. Current research is examining the requirement for platform motion in the context of continuing qualification of airline pilots, which could greatly impact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

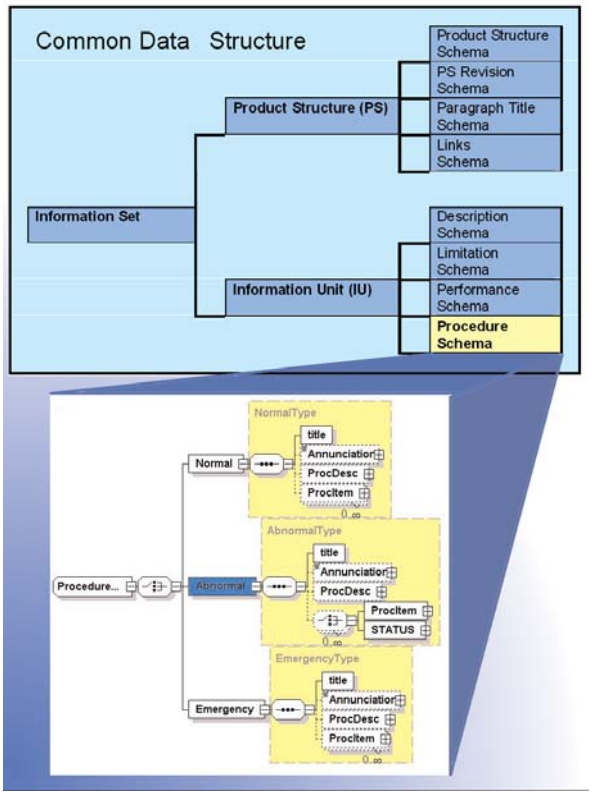
At the end of FY 2003, the simulator and grade data archive contained 1,698 simulator sessions. The simulator sessions averaged about 3.5 hours, and researchers collected 792 parameter values for every second of those sessions. This is about 5,943 hours of simulator sessions, and the resulting archive 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

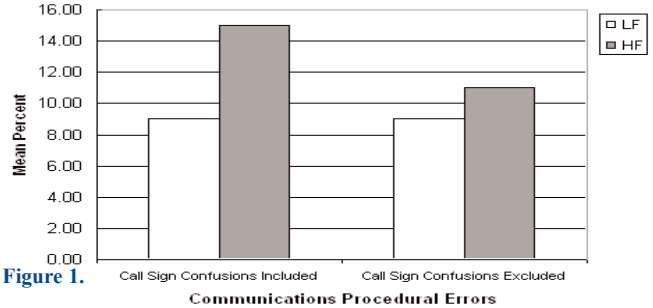


Figure 1.

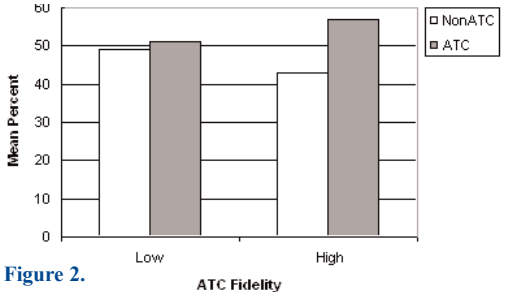


Figure 2.

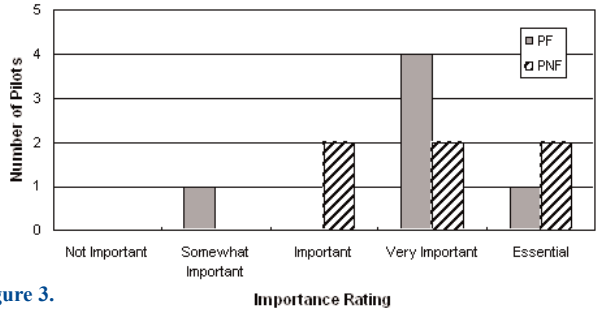


Figure 3.

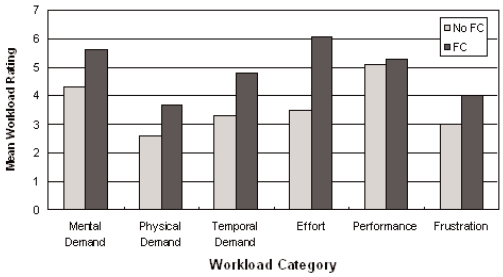


Figure 4.

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

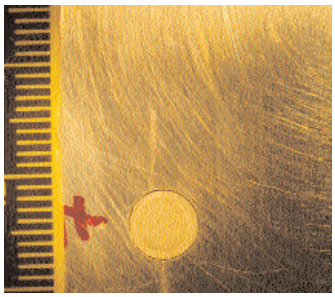
Building on the Legacy

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

General Aviation Maintenance-related Accidents in Alaska: A Comparison to the Rest of the United States

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: The factors that make general aviation flying a necessity in some parts of Alaska also create unique challenges in maintaining aircraft. For example, access to resources, such as parts, training, and tools, may contribute to a higher-risk aviation maintenance environment. Additionally, the remote nature of many communities in Alaska also may contribute to a relaxed attitude toward required maintenance schedules or maintainer credentials. This study seeks to identify any discernable differences between Alaska and the rest of the United States when looking at the effects of maintenance error.

Methodology: Researchers obtained general aviation accident report data from the National Transportation Safety Board and the FAA's National Aviation Safety Data Analysis Center databases for the calendar years of 1990 to 1999. Subject matter experts read each report and categorized the accidents as pilot error, maintenance error, or catastrophic failure. Only accidents that involved at least one maintenance-related factor where included in the sample. Catastrophic part failures were not included. The final sample contained 1532 accident reports, 49 from Alaska and 1483 from the rest of the U.S. Finally, to identify the type of human error and frequency involved in maintenance accidents, researchers used the Human Factors Analysis and Classification System.

Results: Overall, the differences between general aviation maintenance accidents in Alaska and the rest of the U.S. were small. The top National Transportation Safety Board casual factors for both Alaska and the rest of the U.S. were very similar with two exceptions. Major repair and replacement occurred much more frequently in Alaska. Additionally, 40% of the major repair accidents in Alaska were associated with a maintenance violation. Skill-based errors represented the most common form of error and installation the most common maintenance task in both samples. This corroborates previous findings from other maintenance studies. However, the Human Factors Analysis and Classification System analysis provided an additional new perspective about what types of human error are underlying the maintenance casual factors. For instance, well over two-thirds of the installation errors in Alaska and the rest of the U.S. were skill-based. Fifty percent of the inspection reports were decision errors in Alaska but only 11% were decision errors in the rest of the U.S. One third of the annual inspection errors in both samples were violations. Twice as many installation errors were violations in Alaska.

Recent Accomplishment: Using the Human Factors Analysis and Classification System, researchers discovered that one third of the annual inspection errors in both samples violated certified maintenance tasks.

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

Do Language Barriers Result in Aviation Maintenance Errors?

FAA Sponsor Organization: Flight Standards Service, Aircraft Maintenance Division

Purpose and Rationale: Outsourcing is a preferred corporate strategy for reducing nonessential costs and focusing an organization on its core business (Cant and Jeynes, 1998). In aviation maintenance, outsourcing has been advocated and widely used, as it avoids tying up capital in maintenance facilities and can reduce costs by opening the airline's maintenance operation to outside competition. There is concern that language barriers among maintenance and inspection personnel whose native language is not English may be causing performance errors. This project examines whether such errors exist, what patterns characterize these errors, what contributing factors exacerbate the errors, and how the FAA can mitigate the errors.

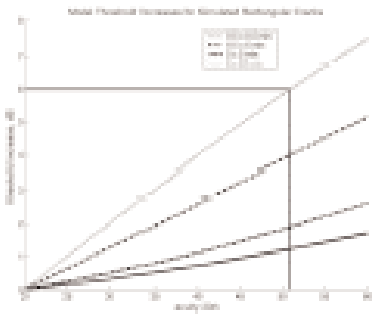
Methodology: Any language errors would be communication errors by definition, so first we reviewed models of communication to search for characteristic error patterns. We identified two primary communication types relevant to aviation maintenance: synchronous communications (largely verbal and informal) and asynchronous communication (largely written and formal). We then analyzed several error databases (e.g., ASRS) and found that both the contributing factors and the use of recovery mechanisms were different for the two error types. Next, we analyzed data from another study that surveyed a large number of airlines throughout the world concerning their use of English and other languages in flight operations and maintenance operations. The database used was based on a large sample (n=113) of airlines, approximately evenly divided between North America, Europe, Asia and the rest of the world. Next, we conducted a series of focus groups at maintenance organizations to understand what type of errors are being committed and understand what mitigation strategies are used to minimize errors. The focus group comprised of aviation maintenance technicians (AMTs), supervisors, engineers and quality assurance specialists. Each interview lasted about 45 minutes.

Results: From the **survey analysis**, written and spoken communications showed that English is spoken and read in North America, and a large extent (75% or so) in Europe. In contrast, Asia and the other countries have about 50% of users able to work with written English effectively, and about 30-40% able to work with spoken English in the same way. The data from each level of English Speaking/Reading ability were analyzed separately using one way ANOVAs among the four regions. All levels showed significant differences between regions. As of May 2003, the **focus group** study has obtained observational data from three U.S.-based Maintenance/Repair Organization (MROs) and two UK-based MROs. We found the following patterns of error in both verbal (synchronous) and written (asynchronous) communication. Verbal (Synchronous) errors included: (a) AMT unable to communicate verbally to the level required, (b) AMT and colleagues/supervisors have poorly matched models of their own and each other's English ability, (c) Native English speakers with different regional or non-US English accents (e.g., UK, India, Caribbean) prevent adequate communications, and (d) AMTs unable to understand safety announcements over the PA system. Written (Asynchronous) errors included: (e) AMT unable to understand safety placard in English, (f) AMT unaable to understand written English documentation, and (g) Foreign documentation poorly translated into English. While the patterns are still being refined as further data is collected, and may eventually exhibit more of a hierarchical structure, they were reasonably consistent between the focus groups studied.

Recent Accomplishment: This project enabled researchers to develop classified lists of contributing and mitigating communication factors, which will be used in subsequent stages to quantify error incidence and test the effectiveness of mitigation strategies.

Primary Investigator: Colin G. Drury, University at Buffalo, Amherst, New York

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 Symbology

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: This project seeks to understand symbology 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 symbology 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 symbology 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 symbology.

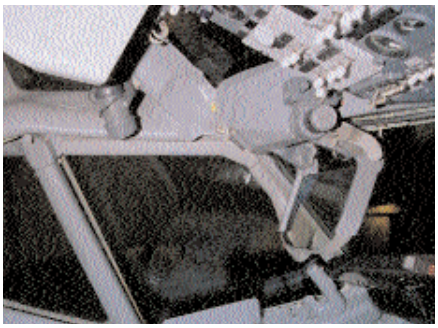
Results: The industry review clearly shows the large variety of systems that support moving map or electronic chart displays. These functions appear on panel-mounted systems, electronic flight bags, and hand-held GPS displays. The physical form and capabilities of these platforms vary widely. From a symbology 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 symbology 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; symbology 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 symbology in use today. This work reveals that the potential for confusing and misleading symbology 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

Profile Situation Awareness and Required Navigation Performance Information Displays

FAA Sponsor Organization: Aircraft Certification Service, Avionics System Branch

Purpose and Rationale: Many avionics vendors are enhancing the traditional horizontal situation awareness displays and navigation displays by incorporating new types of information. Researchers are supporting the development of minimum certification requirements and guidelines for the approval of new moving map displays depicting vertical profile and required navigation performance information.

Researchers seek to provide human factors certification standards and guidelines based on established research and industry developments. They provide these standards and guidelines in four forms: a quick reference checklist of questions certifiers should ask for profile displays; a certification bank of anticipated issues in profile displays up for certification; requirements expressed in RTCA minimum operational performance standards documents; and a report on issues concerning map displays used in a required navigation performance environment.

Methodology: Researchers derived the information for the quick reference checklist and the issues bank from the report *Issues and Design Tendencies in Profile Situation Awareness Displays* drafted the previous year. In the report, they summarized each issue as quick reference item, and used them to generate a set of entries for the issues data bank. Each entry is written as a ready-to-copy certification issue report action item for potential issues in profile displays. Researchers also continue to participate with industry committees charged with drafting and publishing standards for profile and required navigation performance map displays.

Results: Profile displays are being developed to address a number of dimensions of situation awareness, most notably terrain, energy, and stability. Laboratory research suggests that profile displays can improve vertical navigation mode awareness and understanding. However, proper design of the profile displays present a number of human factors trade-offs and certifiers need to evaluate the rationale used by manufacturers in selecting display location, size, scale factor ratio ("aspect ratio"), ownship movement, orientation, and swath shape and behavior.

Researchers found that required navigation performance has relatively little impact on the human factors of map displays, and established map standards and guidelines are largely applicable and sufficient. However, certifiers should be especially aware of the difficulties of adequately designing such a map display to provide fine course guidance.

Recent Accomplishment: Researchers completed: (1) the Required Navigation Performance issues report *Human Factors Design Issues of Electronic Map Displays Used in an RNP RNAV Environment;* (2) a quick reference checklist as an appendix to the report *Issues and Design Tendencies in Profile Situation Awareness Displays,* titled "*Evaluation Considerations for Certification of PSADs*; and (3) an appendix to the RTCA *Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation,* titled *Map Display Minimum Performance Standards*.

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

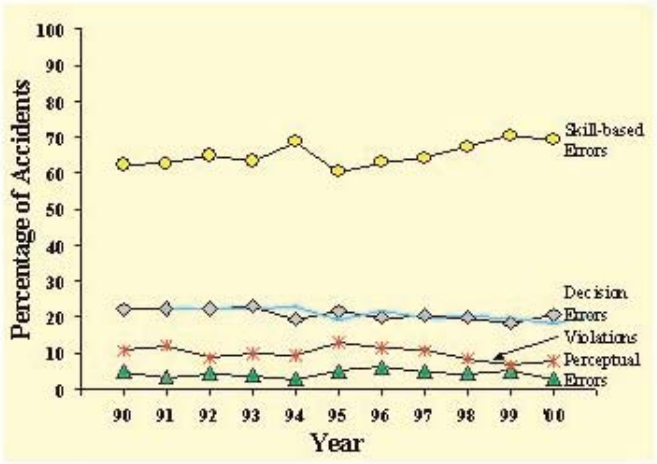


Figure 1. Seminal HFACS Analysis of General Aviation Accidents

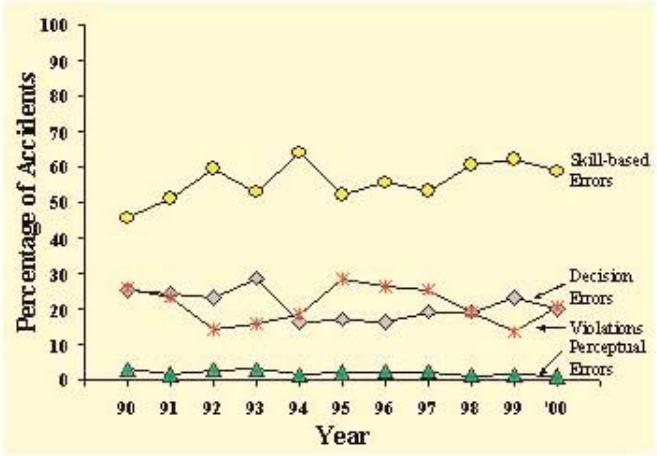


Figure 2. Seminal HFACS Analysis of Fatal General Aviation Accidents

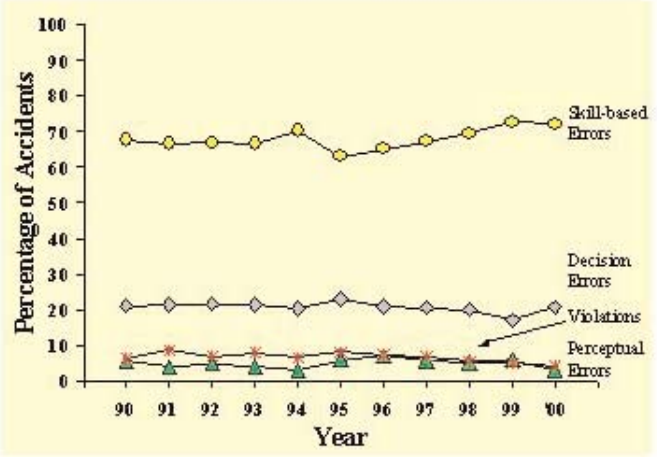


Figure 3. Seminal HFACS Analysis of Non-Fatal General Aviation Accidents

Credit for Instrument Rating in a Flight Training Device or Personal Computer

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

Purpose and Rationale: Current FAA policy allows pilots to complete 10 hours of instrument training in an approved personal computer aviation training device. The intent of this research effort is to determine how effective flight training devices and Personal Computer Aviation Training Devices (PCATD) are on an hour-by-hour basis when compared with training and performance in an aircraft. To evaluate transfer of training effectiveness of a flight training device (FTD), the performance of subjects trained on instrument tasks in an FTD and later trained to criterion in an airplane must be compared to the performance of subjects trained to criterion only in the airplane. This study used an incremental transfer of training research design to measure the effectiveness of an FTD and a PCATD to determine the point at which additional training in an FTD or a PCATD was no longer effective. The collected data will enable certification personnel to determine what credit to award for different classes of flight training devices within an instrument training curriculum.

Methodology: Researchers assigned 180 private pilot students, enrolled in the instrument training program at the University of Illinois, to 1 of 6 groups: 4 flight training device groups, 1 personal computer aviation training device group and a control group. The first group received 5, 10, 15, or 20 hours of flight training device training, the second group received 5 hours in the approved personal computer aviation training device, and the control group received all its training in an airplane. Researchers recorded the trials and time it took each participant to reach criterion performance in the airplane for selected instrument tasks during a stage check and an instrument proficiency check. Researchers evaluated the results to determine how to optimize the value of training time in the flight training device or personal computer aviation training device.

Results: As of September 2003, 65 students had completed and taken the final check ride in the basic instruments course. Preliminary inspection indicates that mean completion times for the airplane-only group are greater (22.89 hours), on average, than for any of the five experimental groups (average of 18.72 hours). A similar pattern is emerging for the advanced instruments students; the airplane group required an average of 27.42 hours, while the experimental groups required an average of 23.42 hours to completion. The amount of data collected to date is insufficient to conduct meaningful statistical analyses. However, preliminary examination suggests that the first 5 hours may be the most effective (consistent with other results) for the specific tasks examined.

Recent Accomplishment: Preliminary results suggest that flight training devices and personal computer aviation training devices are effective, however definitive statements cannot be made until the sample has been completed.

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

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 devised 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.

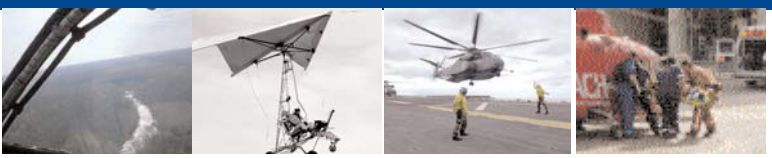
Methodology: The researcher's literature review focused on empirical human factors results relevant to cockpit displays of traffic information, existing standards, requirements and guidelines related to false alerts and alerting criteria, comparison of the existing alerting algorithms, analysis of aviation 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.

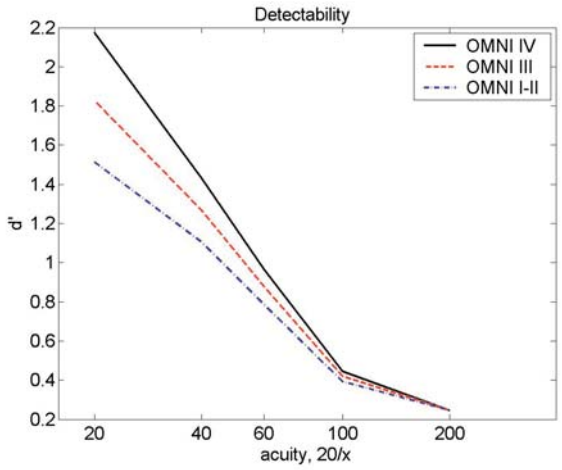
Results: Results from the alternate visual acuity assessment study clearly show that night vision goggle cockpit lighting compatibility assessment can be accomplished using inexpensive equipment. It is also evident that the visual acuity assessment procedure is prone to errors, because of the relatively 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

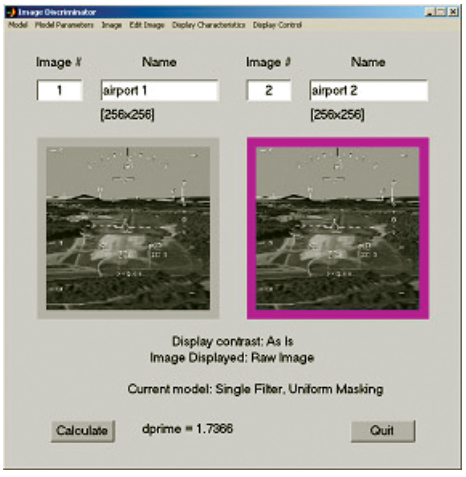


FAA Sponsor Organization: Flight Standards Service, Flight Technologies & Procedures Division

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, tthe 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 theses 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 form 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 Reykjavík 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 l996-2002 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

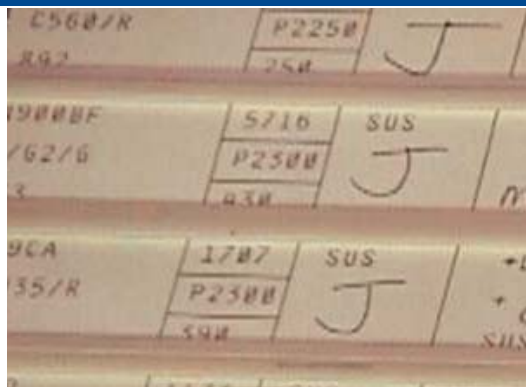
Purpose and Rationale: In 1984, the FAA began administering the Employee Attitude Survey (EAS) to its employees. The survey gathers information about employee attitudes, perceptions, and opinions covering a broad range of organizational issues that affect workforce performance and quality of work life. 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

Optimizing Human Performance to Reduce Air Traffic Control Operational Errors

FAA Sponsor Organization: Air Traffic Service

Purpose and Rationale: In April of 2003, the Department of Transportation, Office of the Inspector General conducted an audit of the FAA's air traffic control operational error reduction plan and reported to the FAA Administrator that while research in this area is resulting in the reduction of operational errors, more can and should be done. As a result, researchers developed and tested a new human factors technique, called JANUS, to identify causal factors related to operational errors.

Methodology: Through a series of activities, researchers harmonized and tested two existing human error taxonomies (U.S. and EUROCONTROL) originally developed for retrospective analysis of aviation accident/incident data. They compared the models' similarities and differences and evaluated their strengths and weaknesses. As a result, they developed JANUS, a new incident investigation technique incorporating the best of both models. Air traffic control subject matter experts in both Europe and the U.S. participated in testing the tool and adapting it to meet each user group's distinct investigation needs.

Results: For the FAA model, specific to the U.S. air traffic environment, researchers conducted 215 interviews of 79 operational errors. Results showed that initial analysis of both objective data from interviews and subjective data from the feedback and expert forums support using this approach. Taken together, the EUROCONTROL and FAA results provided converging evidence that the new technique appears to be more sensitive, useful, comprehensive, and practical than the current processes to identify operational error causal factors. Some scientific issues remain to be more fully answered through further research before operational implementation. These include (a) identifying improvements to increase agreement and reliability between users, (b) using this information to develop appropriate training for users, (c) refining the taxonomy, (d) further standardizing the methodology, (e) making design changes to the computer-based interface, (f) relating causal factors to objective temporal markers in incidents, and (g) linking outputs with ATC error mitigation strategies.

Recent Accomplishment: Through work jointly conducted by EUROCONTROL and the FAA, researchers quickly developed and tested the FAA JANUS technique for operational error causal factors identification. Crucial to the success of this project was the joint work and collaborative participation of FAA air traffic control management and facility managers, controllers, and European incident investigators with researchers.

Primary Investigator: Julia Pounds, 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

Relationships Between Perceived Workload, Taskload, and Physiological Responses of Controllers

FAA Sponsor Organization: Air Traffic Planning and Procedures Program

Purpose and Rationale: As air traffic increases and new technology is deployed, researchers are working to understand the physiological relationship between changing taskload, perceived workload, and air traffic controller performance. What is lacking in the literature is an approach that combines assessment of taskload, mental workload, and subjective appraisals with physiological responses among controllers.

Methodology: Controllers in this study used the Air Traffic Control Advanced Research Simulator, which allowed researchers to control simulated air traffic control operations. Researchers used impedance cardiography to assess both hemodynamic and systolic time intervals while the participants rest and during work. Researchers also collected salivary cortisol to assess task-related neuroendocrine changes. Variable taskload conditions were inserted. Finally, they interviewed the subjects to test the relationship between changing taskload and physiological measures.

Results: The results of this initial investigation produced promising results. One key result is the ability to use respiratory sinus arrhythmia to track physiological changes in controllers. Preliminary results suggest that the simulation can produce reliable results, with the simulated scenarios producing similar physiological reactions as real operations. Respiratory sinus arrhythmia, which can be obtained unobtrusively both in the laboratory and the field, may be a promising measure of air traffic control specialist workload.

Recent Accomplishment: Researchers found that preliminary results supported use of the Air Traffic Control Advanced Research Simulator as an effective research tool in the study of air traffic control specialists' workload. The ability to provide realistic simulations in a controlled laboratory setting will greatly enhance the development of metrics, which can be applied to a wide range of air traffic control specialists operations. Furthermore, the results of the initial study indicate that the ability of respiratory sinus arrhythmia to track changes in subjective workload will allow for an unobtrusive and cost-effective measure of air traffic control specialist workload both in laboratory and field investigations.

Primary Investigator: Albert Boquet, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Shiftwork Countermeasure Assessment

FAA Sponsor Organization: Air Traffic Planning and Procedures Program

Purpose and Rationale: Because air traffic control is a 24-hour per day operation, many air traffic controllers work rapidly rotating shift schedules. While most of these schedules limit midnight shifts to no more than one or two per work week, research has shown that even limited exposure to these shifts can result in significant problems related to sleep duration, sleepiness, alertness, vigilance, and complex task performance. Countermeasures such as napping, exercise, bright light exposure, and pharmacological interventions have been suggested to maintain and/or improve performance while working at night. This study identified effective and operationally feasible countermeasures for fatigue on the midnight shift, with two 20-minute naps, and two 20-minute periods of mild exercise compared to a control condition.

Methodology: Researchers performed two experiments to assess the effectiveness of brief naps and mild exercise during the midnight shift. Both required 23 participants to work three "quick-turn" rotations, consisting of an 8-hour morning shift, followed by an 8-hour midnight shift for each experimental condition (exercise, napping, control break). Twenty three "ATC equivalents" wore monitors and completed logbooks for the two week protocol.

Results: Subject performance measurements on the Bakan Vigilance Text declined across the midnight shift. Subjects reported feeling more sleepy during the midnight shift, but reduced sleepiness five minutes after they exercised. Experiment two found evidence that grogginess after sleeping adversely affected performance immediately following the nap; however, this appeared to dissipate when measured 40 minutes later. Sleep onset, duration, and EEG data supported evidence of a high biological need for sleep during both treatment sessions. There was also evidence of alertness benefit with a reduced frequency of micro-sleep episodes during task performance following the napping condition.

Recent Accomplishment: This study determined that naps, as short as twenty minutes, on the midnight shift provide a benefit to task performance. However, evidence of grogginess following napping, indicates that further critical investigation is needed before this countermeasure can be recommended.

Primary Investigator: Thomas E. Nesthus, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Assess Existing Supervisory and Managerial Selection Processes in Critical Air Traffic Services Occupations

FAA Sponsor Organization: Air Traffic Resource Management Program

Purpose and Rationale: This research task seeks to establish the framework and technical approach to revitalize and enhance the FAA's supervisory and managerial selection processes such as those outlined in the Air Traffic National Selection Program.

Methodology: Researchers developed a baseline description of existing supervisory and managerial selection processes. Those processes were then evaluated with respect to compliance with the Uniform Guidelines on Employee Selection Procedures, relevant professional standards and principles, and state-of-the-art supervisory selection in the private and public sectors. They also assessed the feasibility of developing computerized application processing under the Merit Promotion Program.

Results: Based on their review, researchers developed a framework and technical approach to the modernization of supervisory and managerial selection processes in critical Air Traffic Services occupations.

Recent Accomplishment: This research has been incorporated into an agency-wide supervisory/managerial competencies model and mandated selection criteria developed by the FAA's Office of Human Resources Management.

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

Complete Workforce Baseline Job/Task Analyses for Selected Airway Facilities Occupations

FAA Sponsor Organization: Air Traffic Resource Management Program

Purpose and Rationale: Researchers found that job analyses for the Airways Transportation Systems Specialist occupation were incomplete and not in compliance with accepted professional and legal standards for job/task analysis in the development and validation of employee selection procedures. FAA's Airway Facilities organization requested researchers to conduct a selection-oriented baseline job/task analysis for their occupations. The results would provide a basis for validating the content of current entry-level selection procedures, and help in identifying changes in the occupation resulting from NAS modernization and new technology.

Methodology: The FAA contracted with North American Business and Management Company (NAM-BCO) to conducted the job/task analysis. They completed the analysis in three phrases: (a) worked with a series of subject-matter expert (SME) panels to develop lists of job tasks/duties and knowledge, skills, and abilities (KSAs); (b) conducted a structured job analysis survey on all incumbent systems specialists in the Airway Facilities organization based on those lists; and (c) used the SME panels to helped link the necessary knowledge, skills, and abilities to clusters of critical and/or important job tasks/duties.

Results: The analysis identified a core set of job tasks/duties across the five systems specialist "specialties," specifically, communications, navigation, radar, automation, and environmental. The analysis also identified the knowledge, skills, and abilities required to perform those core, critical tasks/duties at the time of hire.

Recent Accomplishment: Identification of the core critical job tasks/duties across the occupation, and identification of the KSAs required at entry. The results of this study provided the scientific and legal, foundation for validating the content of the current systems specialist entry-level hiring criteria.

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

Develop a Prototype Human Factors Tutorial for Air Traffic Controllers on CD

FAA Sponsor Organization: Runway Safety Office

Purpose and Rationale: The FAA developed and distributed a booklet, *Runway Safety: It's Everybody's Business,* to inform pilots and controllers about runway incursion prevention. Based on the findings of FAA-sponsored human factors research, the booklet provides helpful "tips" on how controllers and pilots can optimize their performance and minimize the chances of a runway incursion. The booklet contains chapters on: controller-pilot voice communications, attention and memory, and fatigue and other threats to performance. Because of the success of this pamphlet, the FAA determined that an interactive tutorial for controllers, based on the booklet, would be useful to tower controllers.

Methodology: Researchers developed a human factors tutorial for tower air traffic controllers that contains a variety of "hands-on" demonstrations of phenomena such as the effects of expectations on perception, selective attention, the effects of distraction on short-term memory, and others.

Results: Researchers developed a prototype interactive training CD-ROM. Researchers collaborated with specialists in the FAA's Office of Runway Safety (ARI) to refine course content. This computer-based course seeks to educate controllers about the factors that limit attention and memory, and provide tips to safeguard their performance and the performance of their colleagues.

Recent Accomplishment: ARI further refined the product into a computer-based instruction that will be distributed to controllers. ARI also plans to distribute "Runway Safety: It's Everybody's Business" to all pilots in FY04. The FAA's Runway Safety Office now plans to distribute this interactive CD training program to all controllers.

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

A Model to Assess the Severity of Runway Incursions

FAA Sponsor Organization: Runway Safety Office

Purpose and Rationale: The Office of Runway Safety classifies the severity of runway incursions into four categories: A, B, C, and D. An "A" represents an accident or an accident that was narrowly averted. A "D" represents an incident that meets the definition of a runway incursion, but where no potential for collision existed. Currently, these categorizations are made by a group of subject matter experts. Researchers are developing a model that provides a more structured and objective method for determining the severity rating. The DOT Inspector General issued a report in 2003 assessing the runway incursion severity index.

Methodology: Researchers detailed scenarios that could result in runway incursions and their relevant factors (visibility, pilot response time, and aircraft performance characteristics). They collected data on pilot response time and other factors relevant to runway incursions.

Results: Initial research is complete, and development of the model is now underway.

Recent Accomplishment: Based on their scenario development work, researchers worked with the FAA's Office of Runway Safety to review the needs for the runway incursion severity model. At a preliminary meeting, the Office of Runway Safety reviewed fundamentals of the presented model and discussed the preliminary results of the analysis of several incursions.

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

Forecasting Integration Issues in the Air Route Traffic Control Center

FAA Sponsor Organization: En Route Integrated Product Team

Purpose and Rationale: As planned enhancements to improve the information and tools available to controllers are developed to address specific operational needs, their development is independent of development of the legacy system. This means that human factors issues surrounding system integration are usually not identified until the first attempt at implementation. Previous research identified high-level integration issues surrounding the air traffic controller workstations in en route, terminal radar approach control (TRACON), and oceanic environments. In addition, the TRACON environment possesses specific human factors integration challenges. The focus of this study is to forecast future human factors integration challenges to improve the information and tools available to control the en route environment.

Methodology: Researchers consolidated information gathered from research reports, documentation on future system requirements, operational evaluations, and interviews with specialists. They compared this information to current controller information requirements, operational requirements for programmatic success, and potential integration issues across environments. System integration issues included: information requirements, source(s) of information and possible conflicts, and ways new information/tools may affect controllers.

Results: Researchers identified critical integration issues and future research requirements that will need to be addressed for the successful implementation of future systems. Research requirements include the investigation of the effects of: color-coded data blocks on conflict detection; changes to controller displays on operational errors; and implementation of new systems on operational errors. Integration issues include: benefits of ARTCC tools realized beyond center boundaries; how the use of new tools can be optimized; and, suggestions for future implementation strategies. Research requirements include investigation of the effects of: color-coded data blocks on conflict detection; changes to controller displays on operational errors; and, implementation of new systems on operational errors – with particular emphasis on the effect of new tasks or new systems on controller-controller coordination. Integration issues are discussed within the context of the potential of new and proposed en route systems to meet future requirements of the NAS for increased flexibility and efficiency.

Recent Accomplishment: The researchers have proposed updated requirements for new en route systems that address integration issues and meet the future requirements of the NAS for increased flexibility and efficiency.

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

Building on the Legacy

The Aeromedical research program addresses improved health, safety, and survivability of aircraft passengers and aircrews. There are two major program areas: (1) Toxicology and Accident Research which evaluates medical findings gleaned from aircraft accidents to improve the safe operation of aircraft; and (2) Protection and Survival which develops injury reducing materials and structures, and also evaluates survival equipment and procedures to protect aircraft occupants. Program outcomes include:

- Human failure modes (physiological, psychological, clinical) both in uneventful flight and during civil aircraft incidents and accidents are identified and formal recommendations for counteracting measures are provided.
- The FAA is able to develop bioaeronautical guidelines, standards and models for aircraft cabin equipment, procedures, and environments as a base for regulatory action to enhance appropriate human performance.
- Pilot medical and flight histories and information from accidents and incidents are reviewed to develop new medical criteria, standards, and assessment/certification procedures to ensure full performance capability.
- Assessments of flight attendant and passenger work, behavior, and disease issues are used to propose guidelines for actions to improve the health and safety of cabin occupants.

Solar Alert System

Purpose and Rationale: One of the potential hazards of air travel is exposure to excessive amounts of ionizing radiation from the sun during a solar particle event. The FAA's Radiobiology Research Team in collaboration with the Space Environment Center of the National Oceanic and Atmospheric Administration (NOAA) could not predict such events reliably before the development of the Solar Radiation Alert system.

Methodology: The Solar Radiation Alert system uses solar proton measurements, made by instruments aboard satellites, to estimate radiation levels at specified high-latitude locations at altitudes from 20,000 ft. to 80,000 ft. in 10,000 ft intervals. If the radiation level at any of these altitudes equals or exceeds 20 microsieverts per hour, an alert is transmitted worldwide to subscribers of NOAA's Weather Wire Service. The entire process, from measurements by satellite instruments to issuance of a Solar Radiation Alert (if appropriate), takes 5-10 minutes. For air-carrier aircraft, the recommended response to an alert is to minimize flight time at altitudes where the radiation level equals or exceeds 20 microsieverts per hour. A "recommended maximum flight altitude" in the alert message is the maximum altitude, at the specified high-latitude locations, where the radiation level is below 20 microsieverts per hour.

Results: Air travelers can be protected from exposure to excessive amounts of ionizing radiation from the sun.

Recent Accomplishment: Dr. Friedberg received the 2003 Office of Aviation Medicine Outstanding Innovator award for the project.

Primary Investigators: Wallace Friedberg & Kyle Copeland, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Biodynamic Research

Purpose and Rationale: FAA's Biodynamic Research Team evaluates the injury potential of new materials and structures by utilizing advanced computational and impact test techniques under simulated crash environments and supports other FAA elements in conducting dynamic tests. These researchers develop new methods, techniques, and equipment for evaluating injury potential and provide research products to support FAA aircraft certification and rule-making organizations.

Methodology: The team uses the impact test sled, static test procedures, mathematical dynamic models, instrumented anthropometric test dummies, high-speed digital video recording, and other research tools to evaluate aircraft occupant restraint systems and seats. Results are often of a sensitive nature and are provided directly to FAA sponsors. Open literature publication is accomplished when the subject is appropriate for that venue.

Results: Seat Certification Streamlining: Current aircraft seat certification rules often require that full scale testing be conducted for relatively minor changes to the seat. In response to a congressional mandate addressing this issue, the FAA Air Transport Directorate and the Aircraft Engineering Division of Aircraft Certification Service initiated a program to develop improved/simplified methods to conduct aircraft seat certification testing. As part of the certification-streamlining program, the FAA funded the National Institute for Aviation Research, Wichita State University, to develop a test device, called the Head-impact-criteria Component Tester, that could simulate the motion and forces that result from occupant head impact on an aircraft structure or seat. To support this effort, the Biodynamics Research Team conducted an evaluation of the tester to develop design enhancements and validate the effectiveness of the device. A series of biodynamic tests comparing the tester to full-scale impact sled tests with instrumented crash dummies was conducted. The test program identified a number of design improvements for the tester. Analysis of the data is ongoing; however, a preliminary review indicates that the tester may duplicate full-scale sled testing in some areas. This could significantly reduce the complexity and time required by the manufacturing industry to certify aircraft seats, thereby streamlining the certification process.

Recent Accomplishments: The Head-impact-criteria Component Tester study shows that the tester will realistically duplicate the results of sled testing in some conditions. The results are comparable when the impacted medium is an aircraft seat back or object with equivalent impact absorbing capability. When the impacted object is not shock absorbing (for example- a rigid aircraft divider), the tester does not duplicate sled test results.

Primary Investigator: Roy Van Gowdy, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Bioinformatics Research

Purpose and Rationale: Bioinformatics is an integration of data analysis and imagery staff to meet the unique research needs of the FAA's research community. In addition to conducting its own research, the team collaborates and provides support to many other research projects. Bioinformatics research is creating the Scientific Information Systems (SIS) and Laboratory Information Management Systems (LIMS) computer database systems to aid researchers and regulatory authorities in accessing and sharing key safety data.

Methodology:

- Scientific Information Systems (SIS): A government information factory using scientific and innovative methods of data visualization and analysis is available for use in researching safety trends. This is unique in the world in that no other country has a data warehouse containing relational aviation safety information that spans pilot medical information and aviation outcomes.

- Laboratory Information Management Systems (LIMS): Bioinformatics is collaborating very closely with the FAA's Functional Genomics Research Team. The Genomics team is conducting several gene expression experiments using microarray laboratory techniques to determine differential human gene expression in the presence of certain aviation stressors. Bioinformatics is providing analysis and data mining of the anticipated very large datasets. To conduct the analysis and provide for collaboration between the teams, a LIMS is being developed to deal with data needs for differential gene expression experiments in FY 2004.

Results: Data is now more routinely available to support safety recommendations, rulemaking, and other research projects. All data used for regulation (as opposed to research) is required to be reviewed and made available to persons requesting it in order to examine notices of proposed rulemaking.

Recent Accomplishment: This project provides data mining of large aviation safety dataset capabilities for aviation researchers. The growing number of published research reports citing the bioinformatics databases supports active international cooperation.

Primary Investigators: Stephen Veronneau & Nicole Vu, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Cabin Safety Research

Purpose and Rationale: Cabin safety researchers monitor aircraft cabin safety problems and conduct research studies and tests pertaining to the emergency evacuation of aircraft and subsequent survival situations. The team conducts evaluations of emergency situations to determine adequacy of survival equipment and procedures based on human factors requirements.

Methodology: The researchers evaluate various aspects of cabin evacuation and cabin safety through literature reviews, mathematical models, and research evaluations using human subjects. Unique laboratory equipment used to conduct this research includes a large survival tank, a narrow body aircraft simulator, a wide body aircraft simulator, and other laboratory facilities that may be required to support processing and care for large numbers of research subjects.

Results: Passenger Safety Awareness Research: Questionnaire data from subjects participating in a study of emergency egress through cabin emergency exits has been obtained to support a replication of a 1979 FAA study of passenger safety awareness. Analysis of the data will reveal the degree to which current airline passengers make themselves aware of the safety information available on board commercial transport airplanes, illuminating the extent to which such passengers are in need of additional information, alternate safety information presentation methods, etc. The results will be presented initially at the 2004 Annual Scientific Meeting of the Aerospace Medical Association.

Evacuation Into Water: Certification procedures for new transport category aircraft require manufacturers to show the aircraft can meet certification criteria for passengers evacuated onto land. Evacuation criteria for ditching scenarios, in which passengers must evacuate into life rafts or into the water, are not included in those requirements. Instead, certification requirements for ditching have generally been demonstrated via the use of a flotation-time analysis for each new airplane type. The differences in the proposed design and operation of new very large transport airplanes, e.g., the Airbus A-380, which will conduct many extended over-water operations, raises questions regarding some of the assumptions in the flotation-time analyses. In a successful A-380 ditching, the height above water level for emergency exits has been predicted to range from just a few inches to about 6 feet. This may create significant deviations from the historically assumed passenger flow rates into the water. Additionally it was recognized that differences in personal flotation devices and their modes of operation could add to the variance of evacuation rates. At the request of the FAA's Transport Airplane Directorate, the Cabin Safety Research Team conducted a series of tests to evaluate water evacuation flow rates with test subjects entering the water from Type A (42" wide) and Type 1 (24" wide) exits. The tests evaluated exit heights of 6", 2', 4' and 6' above water level with the subjects using three different types of flotation equipment (seat cushions, life preserver inflated prior to water entry, and life preserver inflated after water entry). Findings indicate that the exit flow rate decreased with higher over water exit heights and that evacuation rates for subjects using seat cushions for flotation was slower than evacuations with subjects wearing life vests.

Recent Accomplishment: Under Memorandum of Agreement FNA 08-00-01, the FAA and NASA developed a cooperative program for Weather Accident Prevention R&D activities. A task under this agreement included turbulence detection and mitigation efforts for atmospheric clear-air turbulence (CAT). NASA research in this area has developed airborne sensor technology that may detect CAT and provide the flight crew with a turbulence warning. To determine the potential application of the CAT detection system and provide NASA developers with test data on the time required to secure an aircraft cabin in preparation for CAT, NASA requested the support of the Civil Aerospace Medical Institute (CAMI) to conduct a live subject study. The NASA led and funded experiment used the CAMI Boeing 747 Aircraft Environmental Research Facility (747AERF) as a wide body test facility. The research team

for the study consisted of personnel from six airlines, two flight attendant labor unions, NASA (Dryden) and CAMI. CAMI provided subject, logistic and data analysis support. The study placed subjects in test start positions that might be expected from three different cabin scenarios (after movies, after snack service, and during full meal service) and evaluated the time required to secure the cabin using standard and expedited passenger handling/clean-up procedures. Results indicate that seating times were consistent throughout all trial conditions. Overall, 95% of subjects were seated in 95 seconds. Flight attendant seating times were more variable, with an overall time to seating and strap-in of 188 seconds.

Primary Investigator: G.A. "Mac" McLean, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Environmental Physiology Research

Purpose and Rationale: FAA's environmental physiology researchers study environmental factors, including biological/chemical threat environments that detrimentally influence human functioning, physiology and safety in aerospace environments. The team evaluates emergency situations to determine adequacy of aircrew protective systems for altitude and toxic environments. The team is directly involved in the development of improved test methodology and procedures to identify environmental hazards and quantify preventive measures.

Methodology: The Environmental Physiology Research Team conducts extensive literature reviews and coordinates with industry to maintain cognizance of the state-of-the-art in aircrew protective systems. The team uses the full range of physiological test devices, the FAA's research altitude chamber, the flight deck environment simulator, and the Boeing 747 Aircraft Environment Research Facility to conduct evaluations of aircraft environment and aircrew protection systems.

Results: Computational Fluid Dynamic Modeling of Cabin Air Flow. In 2000, the Environmental Physiology Research Team collaborated with the University of Tennessee to initiate a project to develop and validate a computational fluid dynamics (CFD) model of cabin airflow in transport aircraft. At that time, it was recognized that an airflow model could be important to track the distribution of potential contaminants that could be intentionally or unintentionally released in an aircraft cabin. University of Tennessee researchers developed the mathematical model while FAA's researchers conducted airflow measurements in the Boeing 747 Aircraft Environment Research Facility to validate the model. After the tragic events of September 11, 2001, interest in the program increased and the FAA began sharing information with Boeing, Kansas State University, and other government agencies. In July 2002, the Aerospace Medical Research Division hosted an Aircraft Cabin Airflow Computational Fluid Dynamics Modeling Colloquium, bringing together modeling experts from industry, academia, and government. A report on the colloquium is currently being published as an Office of Aerospace Medicine report. Based on collaborative efforts developed during the colloquium, FAA researchers worked with Kansas State University and Boeing to conduct a comparative evaluation of airflow measurement instrumentation and flew on a Boeing test aircraft to measure cabin airflow during actual flight conditions. The CFD model will be used in an evaluation of aircraft cabin decontamination that is planned as a cooperative research and development agreement project to be conducted with the Steris Corporation. The research is aimed at being able to ensure that an aircraft could be decontaminated and safely returned to service.

Recent Accomplishment: The cooperative agreement between the researchers at the FAA's Environmental Physiology Research Laboratory and the Steris Corporation will provide a unique opportunity to evaluate the potential for a full aircraft biological and chemical decontamination system and to add data to the validation process for the University of Tennessee CFD airflow model. This evaluation will clearly define the validity of the CFD model and will represent the first application of the model in a chemical/biological scenario.

Primary Investigator: Robert Garner, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Ethanol Origin in Postmortem Urine: A LC/MS Determination of Serotonin Metabolites

Purpose and Rationale: Specimens from fatal aviation accident victims are submitted to the FAA's Civil Aerospace Medical Institute (CAMI) for toxicological analysis. During toxicological evaluations, ethanol analysis is performed on all cases. Due to microbial contamination of postmortem specimens, care must be taken when interpreting a positive ethanol result due to the potential for postmortem ethanol formation. Several indicators of postmortem ethanol formation exist, however, none are completely reliable. The consumption of ethanol has been shown to alter the concentration of two major serotonin metabolites, 5-hydroxytryptophol (5-HTOL) and 5-hydroxyindole-3-acetic acid (5-HIAA). While the 5-HTOL/5-HIAA ratio is normally very low, previous studies using live subjects have demonstrated that the urinary 5-HTOL/5-HIAA ratio is significantly elevated for 11-19 hours after acute ethanol ingestion. The 5-HTOL/5-HIAA ratio is not affected by the postmortem microbial formation of ethanol or the consumption of serotonin rich foods. This methodology has not been routinely used for the determination of ethanol origin in forensic samples because of the difficulty of the analysis of these two compounds. Until now two, researchers had to use two different analytical techniques to perform this analysis.

Methodology: In this study, researchers investigated the 5-HTOL/5-HIAA ratio as a potential indicator of ethanol origin in postmortem urine specimens. They developed and subsequently validated a novel method for the simultaneous determination of 5-HTOL and 5-HIAA in forensic urine specimens using a simple liquid/liquid extraction in combination with LC/MS. The liquid/liquid extraction involved buffering the urine specimens to pH 6.00, followed by the addition of a saturated sodium chloride solution. Researchers added ethyl acetate to isolate the compounds of interest, which they then derivitized with BSTFA-1% TMS. The LC was operated in an isocratic mode using a mobile phase composed of 80:20 methanol:50.0 mM formate buffer pH 5.00. The APCI-MS was operated in the PCI mode. This procedure resulted in a rapid and sensitive method for the simultaneous quantification of both 5-HTOL and 5-HIAA by LC/MS.

Results: The extraction employed provided an average recovery of approximately 80% for both compounds. The LC/MS method proved highly selective and sensitive, having an LOD of 0.1 ng/mL for both compounds. The accuracy and precision was also very good. Using the LC/MS method, researchers examined the 5-HTOL/5-HIAA ratio in 21 ethanol-negative and 23 true ethanol-positive postmortem urine specimens. They found that all ethanol-negative specimens had 5-HTOL/5-HIAA ratios significantly below 15 pmol/nmol, a previously established antemortem urine cutoff for recent ethanol ingestion. All ethanol-positive urine samples had 5-HTOL/5-HIAA ratios above 15 pmol/nmol. The data obtained statistically validated the 15 pmol/nmol antemortem cutoff for use with postmortem urine specimens. This method is currently being used to examine cases that contain ethanol from an unknown origin, but are suspected of containing ethanol formed postmortem.

Recent Accomplishment: Until recently, toxicologists had difficulty determining if the ethanol present in the body was the result of alcoholic beverages (ethanol is the main component of all alcoholic drinks), or the result of normal postmortem ethanol formation in the body as a natural fermentation process. Researchers have now discovered the key to more accurately determining the origin of ethanol and can predict pre-death alcohol consumption.

Primary Investigators: Russell Lewis, Robert Johnson & Dennis Canfield, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Flight Crew Exposure to Ionizing Radiation

Purpose and Rationale: One of the potential hazards of air travel is accumulated exposure to ionizing radiation over the course of a career of flying. Damage from the radiation leads to an increased risk of cancer in the individual and an increased risk of genetic defects in future generations. Flight personnel are generally unaware of these risks.

Methodology: To help frequent flyers determine their exposure to ionizing radiation, researchers developed computer programs to estimate radiation dosage on flights. These user-friendly programs are available free at http://www.cami.jccbi.gov/radiation.html. The programs calculate the effective dosage rate of galactic radiation received on an aircraft flying a great circle route or on a user-defined route. In addition to these computer programs, researchers have developed educational materials for the flying public, explaining the potential risks of frequently flying at high altitudes.

Results: This work improved awareness in the aviation community of the health risks of exposure to ionizing radiation.

Recent Accomplishment: An Office Of Aviation Medicine report entitled "What Aircrews Should Know About Their Occupational Exposure to Ionizing Radiation," by Dr. Friedberg and Mr. Copeland has been approved for release. Dr. Friedberg and Mr. Copeland have given invited talks to commercial and FAA aircrews on the subject of occupation exposure of aircrews to ionizing radiation. An invited article "Perspectives: Ionizing Radiation Safety" by Dr. Friedberg and Mr. Copeland was published in *Avionics Magazine* in May 2003.

Primary Investigator: Wallace Friedberg & Kyle Copeland, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

Functional Genomics Research

Purpose and Rationale: Human factors have been implicated in 70-80% of civil aviation accidents. The Functional Genomics Research Program seeks to understand the genesis of human error through application of genomics, proteomics, and bioinformatics for ensuring aerospace safety. Studies conducted by the Functional Genomics Team will assist the FAA as well as the National Transportation safety Board in post-crash accident investigations, enhance the drug abatement objectives by the Office of Aerospace Medicine, and fine-tune the existing knowledge base for various human conditions of particular concerns in pilot certification. The team objectives are: (1) develop new analytical techniques, investigative methods, and databases for data collection, and, (2) develop effective tools for predicting and preventing human error before the occurrence of incidents/accidents.

The focus of current investigation includes: Acute Alcohol Effect on Human Performance and Gene Expression: Identification of Alcohol Responsive Genes for Molecular Diagnostic Application. This study is performed in collaboration with the University of Utah and its affiliate, the Center for Human Toxicology (Salt Lake City, Utah). The goal is to define measurable parameters that are indicative of alcohol induced functional impairment. The first phase of this project, which is scheduled to completed in 2003, will identify alcohol responsive genes in blood cellular element for further investigations.

Circadian Desynchronosis and Gene Expression Pattern: A Clinical Model of Fatigue. In this research, physiological stress due to circadian desynchronosis is studied as a model of fatigue, since fatigue is an invariable consequence of a sleep-deprived condition that leads to performance deficits and accidents. The results from this study will provide insight for analyzing the human factor of accidents, whether fatigue is the consequence of jet lag, rotating shifts, working overtime, or other stress conditions. Thus, understanding the molecular basis of fatigue is important for implementing rational interventions to overcome the effects of fatigue. High Altitude Hypoxia: A Molecular Basis for Adaptation in Cardiovascular Compromised Model. Cardiovascular diseases remain the leading cause of death in the US, and are major concerns in pilot certification. Results from this study will provide a knowledge base for regulatory decisions in certification of pilots, and a strategy for prevention of in-flight catastrophic events at high altitude.

Methodology: High-throughput technologies are in use and include cDNA Microarray, Real-Time Quantitative Polymerase Chain Reaction (RT-QPCR), Two-Dimensional Gel Electrophoresis (2-D GE), Luminex xMAP Protein Array, as well as computational tools. This approach combines information from messenger RNA (mRNA) and protein expressions with computational methods to examine networks of responsive genes and how these networks can signal malfunction due to drugs, chemicals, hypoxia, cosmic radiation, gravity, jet lag and fatigue.

Results: Researchers established procedures for instrument, apparatus, reagents, and supplies to ensure a productive research operation that is applied toward addressing pertinent aerospace safety issues.

Recent Accomplishments:

- Validated methods for sample collection, preservation, and isolation of RNA for gene expression analysis. The validated protocol was used to isolate RNA from samples collected in the alcohol and performance studies conducted at the University of Utah.

- Researchers: developed a method for synthesizing cDNA probes from a limited amount of RNA for gene expression profiling. This method is employed in generating cDNA probes for high throughput screening of alcohol responsive genes using a microarray technique. Developed a method for quantification and validation of differentially expressed genes identified in microarray experiment. A fluorescent-based real-time reverse transcription quantitative PCR (RT-QPCR) is developed for sensitive detection of rare gene transcripts.

- This method will be used in identifying specific gene transcripts and verifying microarray expression profiles of alcohol responsive genes.

- Plasma cytokine assay validation using Luminex technology. This method will be used to determine alcohol responsive cytokines identified in microarray and RT-PCR assays. These cytokines could be used as molecular diagnostic markers in peripheral blood for alcohol intoxication and performance impairment.

- Software evaluation. Microarray analyzers in S-Plus and ArrayStat are evaluated for collaborative research in gene expression analysis. The analyzers are used for collection of experimental data into a database that supports comprehensive statistical analysis, data visualization, and connection to the available knowledge about the structure and function of the individual genes. This research is in collaboration with Bioinformatics, Insightful, and Imaging Research teams.

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

Prevalence of Selective Serotonin Reuptake Inhibitors in Pilot Fatalities of Civil Aviation Accidents, 1990-2001

Purpose and Rationale:. Selective serotonin reuptake inhibitors (SSRIs)—fluoxetine (Prozac®), sertraline (Zoloft®), paroxetine (Paxil®), and citalopram (Celexa®)—are effective medications for the treatment of depression. These drugs have preferentially been prescribed because of low incidences of untoward adverse effects associated with their use, allowing these 4 SSRIs to remain in the top 200 of the most dispensed prescriptions in the United States' pharmaceutical industry. Aviators have the potential for the need-based use of SSRIs, but United States aeromedical regulatory authorities have not approved these psychotropic medications for use. SSRIs have been linked to adverse effects primarily associated with the serotonin syndrome and drug metabolism inhibition. Since patients with depression are frequently treated with multiple drugs, inhibition of the metabolism of these drugs by SSRIs can lead to drug-drug interactions, toxicity, and even death. Little is known about the postmortem aviation forensic toxicology of SSRIs. Findings on the prevalence of SSRIs in aviation accident pilot fatalities with the concentrations of SSRIs in the associated postmortem biosamples will be useful in the investigations of SSRI-associated aviation accidents. Such information will also be important to aeromedical regulatory authorities for making a possible future decision on the use of SSRIs by aviators.

Methodology: Researchers searched the Civil Aerospace Medical Institute's (CAMI) Toxicology Database, the FAA's National Aviation Safety Data Analysis Center Database, and the National Transportation Safety Board's (NTSB) Aviation Accident Database to obtain the applicable information.

Results: The study revealed that out of 4,184 fatal civil aviation accidents from which CAMI received samples, there were 61 accidents in which pilot fatalities had SSRIs. Of these accidents, 56 were of the general aviation category, two were of the air taxi and commuter category, two were of the agricultural category, and one was of the ultra light category. In 39 of the 61 pilots, other drugs—for example, analgesics, antihistaminics, benzodiazepines, narcotic analgesics, and/or sympathomimetics—and/or ethanol were also present. As determined by the NTSB, the use of an SSRI [with or without other drug(s) and/or ethanol] has been a contributory factor in at least nine of the 61 accidents. Numbers of SSRI-involved accidents were low, and blood SSRI concentrations in the associated pilot fatalities ranged from subtherapeutic to toxic levels. However, the interactive effects of other drug(s), ethanol, and/or even altitude hypoxia in producing adverse effects in the fatal-pilots cannot be ruled out.

Recent Accomplishment: Findings from this study will be useful in investigating SSRI- and other substance-involved accidents and in making decisions concerning the use of SSRIs in aviation.

Primary Investigators: A.K. Chaturvedi and Ahmet Akin, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma

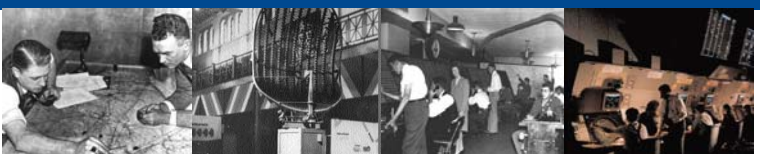
Aviation Medical Research

Purpose and Rationale: FAA's medical researchers conduct medical and laboratory studies of aircraft accident victims, including invited onsite participation in selected cases, to analyze medical, engineering, and human factors findings gained from such accidents. They also conduct appropriate research into the relationships of findings to the safe operation of aircraft. In addition, they develop methods for the better understanding of such factors in aircraft accidents and evaluate performance decrements resulting from disease/physiological processes to determine their effects on aerospace safety.

Methodology/Results: In-flight Medical Incapacitation and Impairment of U.S. Airline Pilots. The Medical Research Team completed a study to evaluate airline pilot incapacitation and impairment during flight. Researchers reviewed National Transportation Safety Board and FAA databases for incapacitation/impairment events. They identified 48 pilot incapacitation/impairment events (39 incapacitation events and nine impairment events) and found that the frequency of incapacitation increased with pilot age, with loss of consciousness being the most frequently reported event. The study suggests that flight safety was seriously impacted in seven of the events, and pilot impairment may have resulted in two non-fatal accidents. This information will assist the Office of Aerospace Medicine in monitoring pilots with specific medical conditions associated with the risk of incapacitation, and in examining the appropriateness of decisions being made concerning airman medical certification.

Recent Accomplishment: Over 4,000 cardiac special issuance medical certificates are granted by the FAA each year. To better understand potential issues surrounding the special issuances, researchers studied the accident experience of cardiac special issuance pilots, 1990 – 1999. This study examined whether the extra scrutiny cardiac special issuance pilots receive might result in a level of safety equal to or greater than other pilots, in spite of the more serious medical conditions that are generally involved. Researchers searched the Civil Aerospace Medical Institute's Aviation Accident Medical Database - Decision Support System for pilots with and without cardiac special issuances from 1990 to 1999. They then compared the accident experience of pilots with cardiac special issuances to that of pilots without cardiac special issuances. Results indicate that cardiac special issuance pilots were not significantly more likely to be involved in an aircraft accident than non-cardiac special issuance pilots. Although pilots with cardiac special issuances generally have more serious medical conditions than other pilots, the likelihood of an accident is no different than with other pilots. This suggests that the extra scrutiny afforded as these pilots appears to be protective, resulting in a level of safety equal to other pilots.

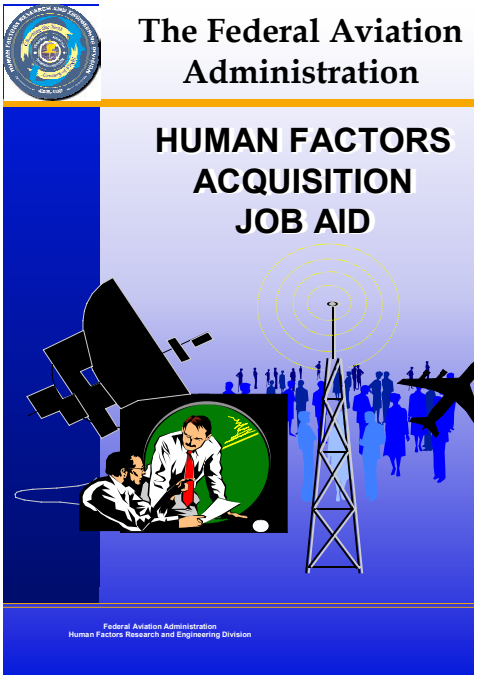
Primary Investigator: Charles DeJohn, Civil Aerospace Medical Institute, Oklahoma City, Oklahoma



Building on the Legacy

This effort focuses on the application and integration of human factors engineering (HFE) in system acquisitions related to the definition, procurement, design, development, testing, and implementation of diverse systems within the National Airspace System (NAS) and supporting the FAA. It conducts activities associated with building a human factors engineering program within the FAA and its systems engineering community. It addresses the application of human factors engineering during mission and requirements analysis and development; investment analysis; product analysis, design, development, and testing; source selection package preparation and evaluation; and post-deployment data collection and analysis.

The objectives associated with this endeavor are to ensure the incorporation of human factors engineering in a manner that is explicit, timely, systematic, efficient, and value-added. The efforts relate to identifying and defining system-specific human factors requirements, assessing human factors risks, providing technical solutions to mitigate risks, advising on policy decisions related to human factors engineering, conducting human factors training, acquiring and supporting human factors tools and technologies, and implementing human factors plans. Technical support to system acquisition programs encompasses areas of study related to human-computer interface, staffing and training, workload, procedures, documentation, communications, and other salient human-system interface issues.



Human Factors Acquisition Job Aid

Purpose and Rationale: Originally developed in 1997, the FAA Human Factors Acquisition Job Aid provides a "How To" manual on integrating human factors in the FAA Acquisition Management System. The job aid accomplishes three primary objectives: 1) provides acquisition practitioners and managers an outline of the human factors tasks to be performed to support their acquisitions; 2) standardizes the general approach and terminology that human factors practitioners use in the performance of their tasks; and 3) serves as a resource of information about applying human factors engineering to acquisition programs. This project seeks to update the current job aid and address additional human factors needs such as requirement development and investment analysis activities.

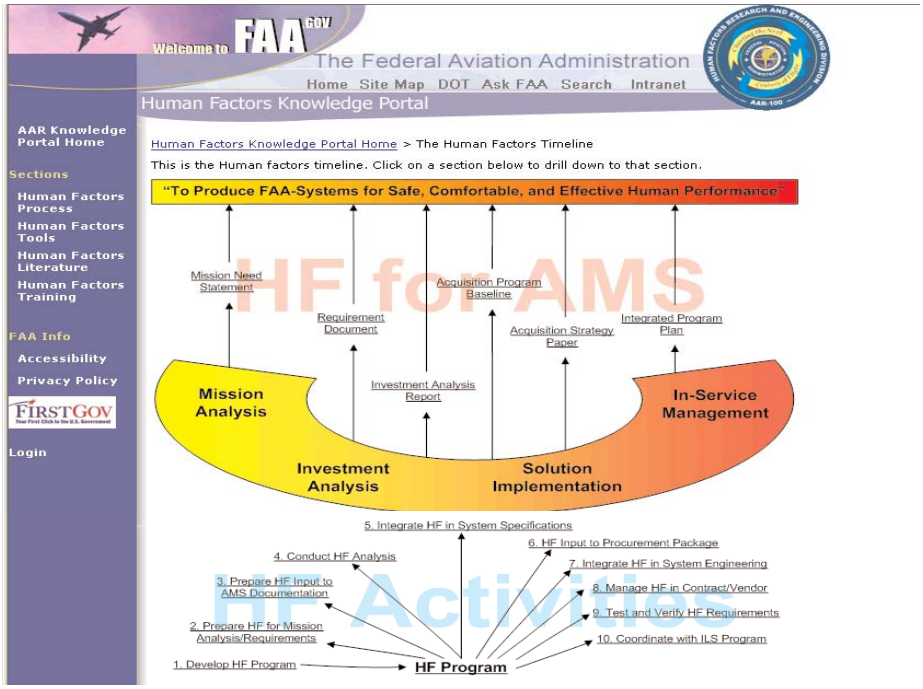
Methodology: Human factors specialists sought to improve the job aid by: updating the appendices; streamlining the data item descriptions; adding a chapter on mission analysis and requirements development, and a chapter on investment analysis; and reviewing and revising other chapters and sections.

Results: Human factors specialists completed the improvements and updates to the Human Factors Acquisition Job Aid. The content of the revised job aid efficiently defines the human factors acquisition program as consisting of 10 key activities, each described in corresponding chapters, and contributing directly to the six essential documents required under the FAA Acquisition Management System.

Recent Accomplishment: The updated job aid is being distributed in hardcopy as well as on the Internet through the Human Factors Knowledge Portal.

Primary Investigator: Glen Hewitt, FAA Human Factors Research and Engineering Division, Washington, D.C.

Co-Primary Investigator: Alan Poston, Office of Communications Navigation, and Surveillance Systems, Washington, DC



Human Factors Awareness Course/Tool

Purpose and Rationale: Researchers and human factors specialists identified a need to provide an efficient means to familiarize the FAA workforce with the general concepts and scope of human factors research and engineering. Although a lecture-based Human Factors Awareness Course exists, established through the Human Factors Research and Engineering Division and University of Central Florida (UCF), the FAA identified a need to offer more information about the human factors discipline to a wider number of people throughout the acquisition community and FAA workforce.

Methodology: Converting the lecture-based course to a web-based product involved several steps related to identifying major themes for the course as a whole and themes for each module, integrating previously used student interactive components into the web-based presentation, establishing captivating graphics to enhance the interest of the information presented, and devising the web page verbiage to adequately replace the well-informed aural lecturer. The course/tool is designed with emphasis on ease of use where presentation of the information and navigation extensively employ such features as module icons; course outline mapping (left margin); mapping sign post headings (top margin); next, previous, and home buttons (bottom margin). Each module of instruction is initiated with a tailored version of the standardized Human Factors Model, which is first presented in the "Introduction" module. Each module treats topics important to the field of applied human factors engineering (e.g., anthropomorphics, measures of differences, human error), offers basic human factors principles for the topic, and summarizes the topic in a general review.

Results: As a result of intensive design, analysis, and development, the FY03 version of the course consists of 10 modules covering such subject areas as usability, visual displays, non-visual displays, cognition, training, and team performance. This web-based course/tool provides an easily accessible, graphically-enhanced discussion of important human factors topics, thereby increasing the understanding among members of the FAA and contract employee workforce of how human factors can assist them in achieving agency goals.

Recent Accomplishment: The Human Factors Awareness Course/Tool has been recognized for its usability and utility. Members of the FAA training community have identified the course as a model for future FAA web-based training development. It has received wide interest for its presentation of valuable information, has continuously received a high number of "hits" on web site, and has enjoyed requests for use in other arenas such as in air carrier crew resource management training.

Primary Investigator: Glen Hewitt, FAA Human Factors Research and Engineering Division, Washington, D.C.

Co-Primary Investigator: Rebecca Gray, Titan Inc., Washington, D.C.

Human Factors Knowledge Portal

Purpose and Rationale: The purpose of the Human Factors Knowledge Portal is to provide FAA employees, system acquisition developers, and other associated individuals with easy access to human factors information to support aviation related human factors endeavors. The Human Factors Knowledge Portal organizes four categories of information: 1) human factors system acquisition processes; 2) human factors technical tools; 3) human factors definition and scope (awareness training); and 4) human factors literature. It provides a comprehensive treatment of essential information that is easily accessible via the Internet.

Methodology: The Human Factors Knowledge Portal capitalizes upon related efforts to assemble useful information for the human factors community of practice and associated managers. This Internet site ties together information by using: human factors process descriptions used in the updated Human Factors Acquisition Job Aid as a basis for outlining the essential processes and activities conducted during the acquisition management system lifecycle; a taxonomy, description, and enhanced accessibility of more than 50 human factors tools, such as the FAA Human Factors Design Standard; basic training about human factors using the newly created web-based Human Factors Awareness Course/Tool; and publications, studies, and other papers assembled into a relational database that can be easily explored with embedded search tools.

Results: The creation of the Human Factors Knowledge Portal has increased the availability and accessibility of critical information where sharing knowledge about human factors best practices helps inform the human factors community, the acquisition and FAA workforce, and associated participants to accomplish FAA objectives for the NAS.

Recent Accomplishment: One of the essential ways to institutionalize human factors best practices and identify and mitigate human-system performance risks is to share human factors information. To this end, the Human Factors Knowledge Portal promotes the use of important information related to solving human-system performance challenges in the aviation community.

Primary Investigator: Glen Hewitt, FAA Human Factors Research and Engineering Division, Washington, D.C.

Co-Primary Investigators: Dino Piccione, FAA Humanand Engineering Division, Washington, D.C.; Peter Moertl, Tiatan Systems Corporation, Washington, D.C.; and Robert Heckart, CSSI Inc., Washington, D.C.

Human Factors Acquisition Review

Purpose and Rationale: The purpose of this project is to conduct an annual event-based review of human factors issues/risks and mitigation activities in a cooperative manner between the FAA Human Factors Research and Engineering Division and the human factors coordinators in the Associate for Research and Development (ARA) Integrated Product Teams. In accordance with the FY 2003 acquisition program performance goals, selected individuals have conducted assessments of ARA systems and applications during the last three years. As the number and expertise of human factors practitioners in the Integrated Product Teams grew, the FAA sought a new approach to capitalize upon this experience and insight so as to address the acquisition program and systemic human factors engineering and analysis areas.

Methodology: Human factors specialists reviewed all ARA systems and applications to assess the degree to which the acquisition program integrated human factors best practices, identified human factors risks, and implemented activities to mitigate the risks. The Integrated Product Team's human factors practitioner conducted the review using criteria focused on human factors technical best practices (versus program risk decisions). The reviews provided an event-based assessment tailored to the system level of need.

Results: During FY03, FAA human factors specialists conducted 12 reviews across acquisition programs covering 116 systems. As a result of the reviews, they identified 18 findings/observations, suggesting 33 separate actions in response. In the planning stages for research and engineering, reviewers identified 37 activities as candidate tasks for FY04. These 37 activities generally fall within three primary areas: changes to the HF Review process and approach for FY04 so as to place emphasis on key areas not previously given adequate attention (14 items); actions to be addressed by tasks within the scope of the human factors research and engineering program for FY04 and beyond (17 items); and systemic issues for which broad agency organizational strategies need to be devised to resolve persistent and fundamental challenges (six items).

Recent Accomplishment: A primary focus and benefit of this project is the sharing of information during the Human Factors Reviews to help the collective human factors community of practice and the system acquisition community better understand program and systemic human-system performance risks and the means to mitigate them. During the conduct of the FY03 Human Factors Reviews, 103 of 116 (89%) of systems were determined to have integrated human factors best practices into the program.

Primary Investigator: Glen Hewitt, FAA Human Factors Research and Engineering Division, Washington, D.C.

Co-Primary Investigator: Paul Krois, FAA Human Factors Research and Engineering Division, Washington, D.C.

Human Capital Management

Purpose and Rationale: One of the most critical activities of the human factors engineering program is to ensure that the appropriate level of human factors expertise is available within the workforce. The FAA needed a "Human Capital Management Plan for Human Factors" to provide a systematic and comprehensive approach covering staffing, training, and professional development.

Methodology: Human factors specialists developed the Human Capital Management Plan for Human Factors as a component of the annually updated, five-year Acquisition Human Factors Plan, which provides goals, strategies, and tasks to meet human factors objectives including those related to staffing and professional development targets.

The staffing element of the Human Capital Management Plan for Human Factors includes activities related to: identifying "essential" human factors positions that are critical to meeting system acquisition objectives; accounting for the number of personnel resources available to meet all human factors acquisition requirements; devising and supporting a "personnel succession plan" to transition the intellectual capital from NASA to the FAA at the same time the technology development activities transition from NASA to the FAA; and supporting the identification and selection of qualified human factors practitioners to fill FAA and contractor support personnel requirements.

The training and professional development element of the Human Capital Management Plan for Human Factors provides continuous development opportunities to the human factors community of practice and includes the activities related to: human factors awareness instruction to familiarize the workforce with basic human factors concepts and principles; tailored program training that is focused on the specific needs of an Integrated Product Team, acquisition program office, or acquisition system; and professional community developmental and specialized technical training which consists of activities that promote the technical and professional development of the FAA human factors workforce.

Results: The activities conducted under the auspices of the Human Capital Management Plan for Human Factors promote the professional community's cohesiveness, consistency, and cooperation. Results from FY03 included support activities such as: promoting partnerships that strengthen the technical capabilities of the FAA workforce; technical and awareness training events; managing the human factors staffing plan; devising an initial "Orientation" for new FAA and contract support employees; regular publication of an electronic human factors newsletter; meetings of the Human Factors Acquisition Team and Work Group; sharing of information on the human factors web site; and representation of human factors on key committees and advisory groups.

Recent Accomplishment: As part of the professional development of FAA human factors practitioners, the FAA established a program to encourage and support professional certification. Under this program, three FAA employees achieved human factors professional certification during FY03.

Primary Investigator: Glen Hewitt, FAA Human Factors Research and Engineering Division, Washington, D.C.

Requirements Development

Purpose and Rationale: Human factors requirements are often inadequately stated in the flow of documents related to system acquisitions. Human factors input to documentation during and subsequent to a mission analysis must include essential elements of information that will provide the basis upon which to build good requirements; cost, benefit, and risk analyses; and study and analysis plans, specifications, and statements of work. Human factors practitioners participate in Integrated Requirements Team activities to provide essential expert input for the development of requirements documents.

Human factors requirements are intended to ensure that equipment operated or maintained by the FAA is easy to operate, maintain, and train. The FAA Human Factors Design Standard provides broad guidelines and conventions to achieve a human-centered, error resistant, error tolerant, operationally effective, operationally suitable, and usable system. Human factors requirements must address: human-system interfaces that impact on user performance efficiency and effectiveness; system architecture design that impacts on human-system interfaces; and human-systems considerations outside the boundary of the system being acquired.

Methodology: To support the Integrated Product Teams and human factors practitioners, the requirements development project included two activities in FY03: 1) direct support in the development of human factors requirements, and 2) creation of a tool (i.e., guidelines and template) to assist practitioners in the determination of human factors requirements for system acquisitions. To accomplish these activities, human factors specialists received input from a variety of sources of human factors requirements: human factors study areas from the FAA Human Factors Acquisition Job Aid; results of mission analyses and mission need statements; results from functional analyses; Operational and Maintenance Concepts; context of use documentation; predecessor system information; acquisition oriented research, studies, and analyses; and subject matter expertise.

Using the results from the mission analysis and other human factors inputs, human factors specialists identified the human factors risks, standards of design, human-system performance boundaries, and other design constraints and limitations that may affect human-system performance. They developed a human factors requirements document template to construct the initial requirements document (iRD) and to add specificity and detail to the final requirements document (fRD). By modifying, adding, and deleting sections to fit the specific system, human factors specialists tailored the requirements document to fit the specific system.

Results: The requirements development project resulted in several iterations of requirements documents for: Automated Flight Service Station, Asset Supply Chain Management, Juneau Airport Wind System, System Approach for Safety Oversight, NAS Interference Detection, Locating, and Mitigation, Aeronautical Enhancement System, Safety Management System Traffic Flow Management, Thunderstorm Weather, En Route Automation Modernization, Collaborative Tool Set, Medium Intensity Airport Weather System, En Route Automation Modernization,

Recent Accomplishment: The creation and institutionalization of a comprehensive and standardized template for human factors requirements provides a simple and useful tool to aid human factors practitioners in the development of requirements. The tool, available on the Internet, supports the activities of the Integrated Requirements Team and significantly contributes to the quality of initial requirements documents and final requirements documents as the basis upon which product teams design and develop acquisition systems.

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