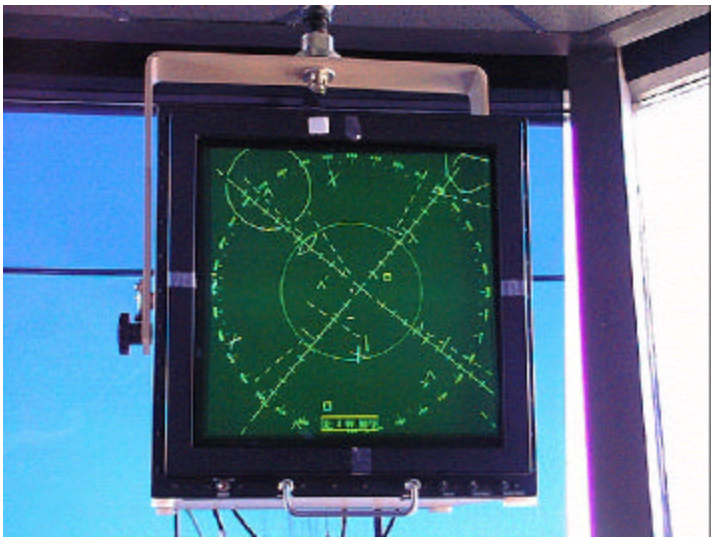


Human Factors Research and Engineering Division

Annual Report 2002

Cover: NASA Simulator (Top Left); DBRITE Display from a Tower Cab (Top Right): CAMI Mathematic Dynamic Model Simulation of Mannequin Action During Accident Impact (Top Left, Lower); B747 take-off (Lower Left)

Table of Contents

FAA Human Factors

A Vision for Today and Tomorrow

2002 was not just another year, and it was not business as usual. It was a year that provided exceptional opportunity for the human factors team to raise the standards of performance and create lasting value in all aspects of our business. From the outset, it was clear that our success would be measured not by getting bigger, but by getting better. We would operate intelligently, efficiently, and effectively, and we would measure our success by meeting the challenges set forth by the Department of Transportation and the Federal Aviation Administration. As 2002 came to a close, we were confident our goals had been reached, and that we were admired for our people, our partnerships, our performance, and our results. We were also aware that the bar has been set a notch higher for the future.

Commitment to Reaching our Goals

We set out in 2002 with a clear view of our mission and goals.

- Mission - To provide research, development, and acquisition for products and services that enable the FAA to enhance the safety of the NAS and satisfy current and future operational needs of the US civil aerospace system for national and international operations.

The FAA vision represents a statement of who we are and what we believe, and includes our performance goals, our ambitions, and how we plan to conduct our business. The values represent our commitment to achieving goals with integrity, accountability, and open communication.

- Vision - To be a world-class acquisition and technology organization, universally recognized as the leader and expert in system acquisition, research and application of aerospace technologies. This is achieved by working together as a positively motivated, diverse, involved and informed workforce.

Our goals challenged us to aim high.

- Safety Goal: Reduce the fatal accident rate by developing and deploying those capabilities and systems needed to address aircraft failure, pilot and controller decision-making, aircraft survivability, and aviation weather.
- Capacity and Efficiency Goal: Improve aviation system capacity through developing and deploying those capabilities/systems needed to address the primary capacity limitations identified by the NAS Architecture and the FAA Operational Evolution Plan; and developing and deploying those capabilities/systems needed to sustain existing NAS infrastructure.

While the focus of our research program is directed to reaching important goals set forth by the FAA, the Human Factors Program strives to ensure that human factors policies, processes, and best practices are integrated in the research and acquisition of all FAA aviation systems and applications. We also continue to directly support a wide-range of aviation community initiatives and congressional mandates, such as research into the effects of fatigue in the controller workforce leading to the identification of effective fatigue countermeasures (including the distribution of educational materials on shift work and fatigue). Other key initiatives include:

- The FAA Operational Evolution Plan (OEP), which addresses air transportation needs for the next ten years, focusing on maintaining safety, increasing capacity, and managing delays. The human factors program provides research findings and guidance on air traffic decision support tools, airspace and route design, and advanced communication, navigation, and surveillance technologies. Integration of flight deck and air traffic control tools will use a wide range of methods, including human-in-the-loop simulation to ensure viability of procedures while balancing workload.

- The FAA 2002 Performance Plan identified areas of human factors research concentration that have led to collaborative efforts between the agency and industry. These include efforts to reduce operational error as a factor in aviation incidents and accidents and to integrate human factors into system acquisition.

- The Mission Goal for Safety identified in the FAA Strategic Plan fostered collaboration with the aerospace community in efforts that include: building on currently successful initiatives to identify the individual, organizational, and system factors associated with past accidents; using new data sources in a more proactive analytical approach to identifying and

reducing key human factors risks; and working with NASA, DoD, and other public and private organizations in studying issues and technologies with potential to improve policies, procedures, and equipment.

- Issues addressed by the Runway Safety Program, including training for tower controllers, pilot and controller communications phraseology, runway markings and lighting, air traffic control teamwork enhancement training, improved procedures designed to avoid runway incursions, and memory enhancement techniques.

- Human factors research associated with the Safer Skies program, which employs the latest technology to help analyze U.S. and global accident data to determine root causes and identify appropriate actions to break the chain of events that lead to accidents.

- Research guided by a coherent national agenda that ensures an adequate human factors emphasis in bioaeronautics with resulting insights utilized in making significant improvements in NAS safety and efficiency. These concerns were identified through extensive aviation community participation and were listed in the National Plan for Civil Aviation Human Factors: An Initiative for Research and Application.

- Research focused on priority issues associated with crew training, the collection and use of safety data, the application of emerging technologies, and aircraft maintenance procedures and inspection as identified in the Aviation Safety Plan.

- Research necessary to implement recommendations in an FAA report on The Interfaces Between Flight Crews and Modern Flight Deck Systems. The report resulted from a study of the interfaces between flight crews and advanced systems on highly automated airplanes, with primary focus on interfaces that affect flight path management.

- Research that is responsive to the FY 1998 Department of Transportation Appropriations Act which cites human factors as the greatest cause of aviation accidents and calls for high priority research.

- Research that addresses the Aviation Safety Research Act of 1988, requiring that human factors research be conducted to “enhance air traffic

controller performance, develop a human factors analysis of the hazards associated with new technologies, identify innovative and effective corrective measures for human errors, and develop dynamic simulation models of the ATC system."

- Research on issues identified by the RTCA "Free Flight Action Plan". This document addresses recommendations to: establish more flexible decision support systems involving collaborative decision making; conduct human-in-the-loop simulations for assessing controller and pilot perceptions of hazards, risks, and discomfort; measure performance, workload, and situation awareness associated with controller and pilot responses to time and distance buffers for aircraft separation; conduct real-time human-in-the-loop simulations to study controller and pilot behaviors, interactions, and effects within NAS environments that represent dynamic densities and sector configurations anticipated for free flight.

- On-site, realistic research made possible through access to the personnel and facilities of airline and aviation maintenance organizations. These organizations have benefited from research products, such as electronic job aids, intelligent tutoring systems, guidance on work site environmental conditions, shiftwork studies, and advanced training methods.

- Research in the protection and survival of aircraft occupants; medical accident investigation and airman medical certification; toxicology and the effects of drugs on human performance; and the impact of disease and disability on human performance, as required by Public Law 100-591 [H.R. 486]; November 3, 1988

- Toxicological analyses on specimens from, and special pathologic studies on, aircraft accident fatalities as required by DOT Order 8020.11A, Chapter. 4, Paragraph 170.

- Investigations of selected general aviation and air carrier accidents and searches for the biomedical clinical causes of accidents, including evidence of disease and chemical abuse, as required by DOT Order 1100.2C, Chapter 53, Paragraph 53-15.

- State-of-the-art toxicological tests on the blood, urine, and tissue of pilots involved in fatal accidents to determine the levels of both licit and illicit drugs at both the therapeutic and abnormal levels, as requested by National Transportation Safety Board Safety Recommendations A-84-93.

Our People – Skilled, Committed

The diversity of the human factors team reflects the research community where we operate and the customers we serve. Our people offer skills, backgrounds and points of view. They are unified by a common vision and values. The FAA human factors team has a track record of strong performance, stressing innovation and accountability while inspiring and empowering individuals to excel. World-class researchers, like those at the FAA's William J. Hughes Technical Center, are working to better understand human performance limitations, enabling human factors practitioners to identify and resolve risks, and to assess costs, benefits, and trade-offs. Equally gifted scientists at the FAA Civil Aerospace Medical Institute are exploring the far reaches of advanced ATC systems, aircrew performance and behavior, accident causation, organization performance, cabin safety and evacuation, vision testing, and forensic toxicology.

Our Partnerships - Collaborative Relationships, Building a Research Infrastructure

Other members of the human factors team are represented by our nation's leading research organizations, colleges, universities and small businesses, all of which are helping us achieve our goals for safety. Through these productive, collaborative partnerships, we're building a research infrastructure with unlimited potential.

- NASA-Ames: Flight Deck Risk Assessment, Air Carrier Operating Documents, Interruptions, Distraction, Lapses of Attention in the Cockpit, Night Vision, Human Error Risk Analysis in Maintenance
- Volpe National Transportation Systems Center: Simulation Fidelity, Head-Up Display Design, Runway Incursions, Electronic Flight Bags, Profile and RNP Map Displays
- DoD: Night Vision, Air Traffic Control Automation, Crashworthiness, Technical Interchange
- George Mason University: Analysis of Pilot Procedures and Practices for Automated flight Decks

- University of New Mexico: Training and Assessing Aircrew Skills
- University of Central Florida: Training of Cognitive Skills
- American Institutes for Research: Pilot Experience with the Advanced Qualification Program (AQP)
- Battelle Memorial Institute: Model AQP Database
- University of Texas: Human Error and Air Carrier System Safety
- University of Illinois: Causal Factors of General Aviation Incidents/Accidents
- Clemson University: Use of Advanced Technology to Support Inspection Training
- Ohio State University: Flight Deck Error Management, Collaborative Decision Making in Air Traffic Management
- San Jose State University: Airspace Modeling
- Massachusetts Institute of Technology: ADS-B Oceanic Simulation
- Embry-Riddle Aeronautical University: ADS-B En Route Issues
- Research Integrations, Inc.: Certification Job Aid
- CSSI, Inc.: Aircrew Performance Measurement

Many other organizations enhance the capabilities of the human factors office. For example, membership in the DoD Human Factors Engineering Technical Advisory Group provides a forum for the coordination of research across a variety of technical areas.

The FAA/NASA Ames Inter-Agency Air Traffic Management Integrated Product Team (IAIPT) joint research product description (JRPD-12) addresses human factors in evolving environments. It continued to conduct collaborative technical interchange meetings (TIMs) in FY 2002. The Human Factors Office maintains an active membership on all Society of Automotive Engineering G-10 Human Factors subcommittees related to on-going and future research areas to ensure transition of the results to standards and guidelines. Human factors researchers are collaborating with the Naval Research Laboratory in the collection of low-light visible and infrared imagery. The objective of this research is to investigate the feasibility of using enhanced vision technology to aid tower controllers in gaining and maintaining situation awareness at night and under low visibility conditions.

In addition, the Human Factors Office participates in collaborative research with EUROCONTROL on the reduction and management of human error in Air Traffic Management, human performance issues in the design of decision support tools,

and on developing a human-centered approach to integrating technologies to ensure aircraft separation. An effort is underway with the Joint Aviation Authorities (JAA) and Transport Canada Civil Aviation (TCCA) to identify and coordinate human factors research in areas of joint interest that will support enhanced certification harmonization. Included is a joint project focused on development of a methodology to identify potential human error and flight crew vulnerabilities during certification of flight deck interfaces. The Cabin Safety Research Technical Group brings together cabin safety research efforts of the FAA, JAA, TCCA, and Japan Civil Aviation Bureau by establishing an international framework to allow for the systematic joint identification, prioritization, and coordination of needed research.

The Office of Aerospace Medicine also formed partnerships with research and university laboratories. It also collaborates with the National Institute for Occupational Safety and Health on a study addressing the cabin environment and flight attendant and passenger symptomatology and diseases. In addition, a liaison is maintained with the American Society of Heating, Refrigeration, and Air Conditioning Engineers Committee addressing aircraft cabin air quality status and research. The Office of Aerospace Medicine maintains direct cooperative research processes with all the manufacturers responsible for safety products (seats, restraint systems, oxygen masks, evacuation slides, etc.). It is also represented on appropriate subgroups of organizations, such as the Aerospace Medical Association, the Society of Automotive Engineers, the Civil Aviation Medical Association, and the Professional Aeromedical Transport Association. Liaison with the military is maintained either through direct project collaboration (e.g., crashworthiness, eye injury from lasers) or through the more global participation in the Tri-Services Aeromedical Research Panel and the North Atlantic Treaty Organization (NATO) aerospace medical advisory group.

Performance – Focusing on Fundamentals

Equipped with a clear understanding of our goals, some of our nation's top human factors researchers, an alliance of partners, and a disciplined approach to management, we were able to stay focused on the fundamentals that drive performance consistent with the FAA's vision and values. Our core business model continued to define the standard for sound operations and business decisions.

- Human-Centered Automation: Here, the focus is on the role of the operator and the cognitive and behavioral effects of using automation to

assist humans in accomplishing their assigned tasks. Research addresses the identification and application of knowledge about the relative strengths and limitations of humans in an automated environment. Researchers investigate the implications of computer-based technology in the design, evaluation, and certification of controls, displays, and advanced systems.

- Selection and Training: Research in this area strives to understand the relationship between human abilities and aviation task performance by enhancing measures and methods for the prediction of current and future job/task performance; establishing a scientific basis for the design of selection systems, training programs, devices and aids for individuals and teams; defining criteria for assessing future training requirements; and, identifying new ways to select aviation system personnel.

- Human Performance Assessment: Within this area, researchers identify those human causal factors associated with accidents and incidents; examine the intrinsic cognitive and decision-making factors for individuals and teams that determine how well they are able to perform aviation tasks; characterize the impact of environmental and individual factors on human performance; and improve and standardize methods for measuring human performance.

- Information Management and Display: Research in this area addresses the presentation and transfer of information among components in the NAS. Scientists seek to identify the most efficient and reliable ways to display and exchange information; determine what, when, and how one might best display and transfer information to system components; design systems to reduce the frequency of information transfer errors and misinterpretations; and strive to minimize the impact when such errors do occur.

- Bioaeronautics: This research involves the bioengineering, biomedicine, and biochemistry associated with performance and safety. The objective is enhancement of personal performance and safety by maximizing crew and passenger protection, health, and physiological integrity. The program consists of three research areas: human protection and survival; medical and toxicological factors in accident investigation; and support for aeromedical certification and in-flight aeromedical applications through aeromedical applications.

Performance - A Successful Strategy - New Solutions

We are committed to excellence in everything we do and strive to continually improve our performance. We are passionate about achieving results that exceed expectations – our own as well as those of our customers and stakeholders. We measure success both for the goals we set and the ways we attain them.

Our strategy:

- Operational needs and problems involving human performance are identified and addressed.
- Comprehensive and systematic analyses of human causal factors in accidents are performed and intervention strategies are identified.
- Research projects which address operational priorities are funded and guided.
- Pilot, controller and aircraft procedures required with advanced systems (e.g., global positioning satellites) are evaluated.
- Partnerships with industry and academia are formed.
- Participation by the nation's top scientists and professionals is elicited.
- Resident research associate positions administered by the National Research Council are awarded at CAMI.
- Human factors guidance is provided to the FAA for development and implementation of new technologies, training and procedures.
- Transfer of research products to the operational community is facilitated.
- Data and other forms of information which support notices and regulations applicable to aircraft occupant health and safety is produced and analyzed.
- Recommendations and guidelines are developed in response to a public demand (e.g., better restraints for children in aircraft settings).
- Assessements of disease transfer and other aircraft occupant health factors are prepared.
- Recommendations are developed to support seat and restraint certification, protective breathing equipment and emergency medical equipment certification, evacuation and life support/rescue equipment certification.

Delivering Results and Measuring Success

During 2002, human factors and aerospace medicine researchers were fully engaged in every aspect of aviation. We increased the safety and efficiency of the National Airspace System (NAS) by developing scientifically validated information and guidance for improving the 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 are enhancing decision support systems and associated functional improvements that fully account for the proper role of people in the system. We are continually striving to improve the health, safety, security, protection, and survivability of aircraft passengers and aircrews.

Researchers are exploring and expanding human factors considerations in aircrew training. Through research grants with universities, we are considering the aircrew, evaluators, simulators and the management culture in addressing aviation-training systems. Human factors research is also exploring prospects for safety enhancement through automated analysis of flight-recorded data and through application of human factors in certification of new aircraft and equipment design and modification.

FAA, NASA, and university scientists are collaboratively addressing human factors issues in aviation maintenance and inspection. The research program is examining vision-testing requirements in aviation maintenance, improving maintenance technician and inspector training, and also improving aviation maintenance technician and inspector performance.

In general aviation, safety is being improved through data-driven research efforts to understand the underlying human causal factors associated with accidents. Advancements in safety are being realized through the application of human-centered principles in development of advanced displays and controls, in developing procedures that improve pilot decision-making and performance, and in evaluation of flight training devices.

Human factors research is integrating vertical flight into the NAS in a safe and efficient manner. Efforts directed toward measuring a visual flight rules (VFR) helicopter pilot's navigation performance when using instrument flight rules (IFR), examining qualified global positioning system receivers, and developing an

inexpensive, valid, and reliable night vision imaging system for rotorcraft civil operations are already underway.

In air traffic control, an improved approach to classifying the human factors associated with operational errors, incidents, and deviations is resulting in improved investigation techniques. Human factors design guidance, along with research findings and recommendations from assessments of human performance, is leading to development of human-centered automation and procedures that will enhance controller decision-making and reduce error-prone conditions. These efforts are also guiding development of tools and procedures to support collaborative decision-making in Air Traffic Management required for the future NAS to meet increased demand. Safety is being enhanced through development and distribution of educational aids to mitigate runway incursions and underlying human performance issues. This research is also designed to mitigate controller fatigue resulting from shift work.

Human factors research is providing improved techniques used in forecasting hiring requirements and in selecting applicants for Air Traffic and Airway Facilities positions. Other critical Airway Facilities research is identifying where improvements in communication and coordination can facilitate the transition to centralized maintenance operations. Researchers are also developing guidance to standardize the computer-human interface across different commercial and specialized systems providing monitor and control functions.

The FAA is exploring new and evaluating existing bioaeronautical guidelines, standards, and models for aircraft cabin equipment, procedures, and environments. This serves as a basis for new regulatory action and the evaluation of existing regulations to enhance human performance. By reviewing pilot medical histories, flight histories, and information from accidents and incidents, existing and advanced biomedical criteria, standards and assessment/certification procedures are being proposed to ensure optimal performance capability. By examining pilot, flight attendant, air traffic controller, and passenger work, environmental, behavioral, and disease issues, guidelines for actions to improve the health and safety of the aircraft occupant have been proposed based on rigorous scientific criteria.

Our Strengths will Carry Us Well into the Future

We built the most effective human factors team in the world, and the results solidified our reputation as a leader in human factors research. We are

committed to superior performance, and we have the depth to deliver outstanding results both in the near-term and in the long-term. At every level, researchers are developing efficient Web solutions to handle traditional business transactions and to share real-time information. Human factors research programs will continue to be directed at targets that have the greatest impact on safety and capacity. Many will be next generation, multi-year efforts. New human performance measurement strategies will be developed to ensure that the envelope of human performance capabilities and limitations is commensurate with intended safety benefits of new systems, procedures and training. Improvements in integrating human factors engineering in FAA system acquisitions will continue. Research into tomorrow's workforce will improve hiring processes and enhance the workplace. We will continue to emphasize the mitigation of accidents and reduction in the severity of injuries encountered in evacuation of passengers and crew from aircraft. We believe these strengths will carry us well into the future.

In the pages that follow, you'll see the results of our world-class performance in 2002. You will also gain an insight into the future.

FY 2002 Successes – Safety Through Human Factors Research

Human Performance Assessment

Linking the Flight Operational Quality Assurance (FOQA) and Advanced Qualification Program (AQP) – Analyzing Simulator and Flight Data to Improve Pilot Training

The Advanced Analysis Method for FOQA and Simulator Data Project is a research and development effort whose primary goal is to devise practical systems, methods and techniques for air carriers in the use of digital flight data recorded during line operations. The Flight Crew Training Management and Support emphasis area of this project seeks to develop the tools and techniques to allow FAA Flight Standards and air carrier training organizations to make use of digital flight data. Work in this emphasis area has been underway for five years, and has been closely linked to the Aviation Performance Measurement System (APMS) research effort. When the entire project is complete, it is envisioned that the project would use this expanded environment, functioning as a component of APMS.

- The primary task of the project is the analysis of flight data from line operations to assess the aggregate proficiency of the flight crew population, and to determine which operational tasks and task components should receive more or less emphasis in continuing qualification training. For these analyses, detailed formal standards of proficiency for flight crew operations are required. These standards are most clearly established at carriers who have completed the development of an AQP. Accordingly, a major objective of the Flight Crew Training Management and Support emphasis area is the identification of flight data parameter profiles that predict levels of proficiency in AQP Qualification Standards.

  The approach taken to establish these relationships is to gather flight data during simulator operations, and determine the statistical correlation between grades given to trainee performance and variations in various flight data parameters. Once these relationships are established in the form of predictor models, they can serve as a starting point for researchers to study the relative level of proficiency with which these same qualification standards are performed during line operations. During this analysis, it has become clear that only a part of the variance in instructor grades can be predicted by correlations with the flight performance parameters, so it has become increasingly important to analyze instructor grading patterns and to look for other contributors to the variance (such as Crew Resource Management - CRM, etc.).

Flight data is captured during simulator operations to help determine the statistical correlation between grades given to trainee performance and variations in various flight data parameters.

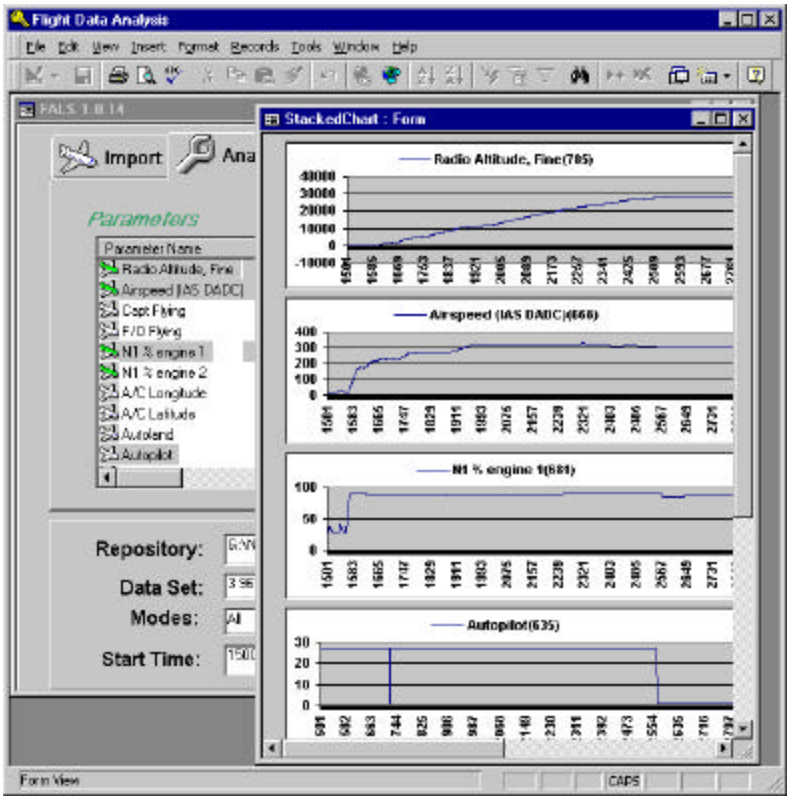
In FY 2002, CSSI, Inc. and University of New Mexico researchers continued collecting simulator data At the end of the year, the database reached 4285 hours of simulator session data in which 792 parameters were sampled every second. This is over 24 gigabytes of data at this point. The instructor grades given for the AQP related events in these simulator sessions constitute a database of 186,822 grades. Additionally, this valuable archive is being used by other FAA researchers for studies of cockpit automation.

During the year, four predictor models were refined by the statistical team, one each for V1 Cut, RTO (rejected take-off), normal takeoff and landing. These models, originally built in a progression of approaches (including logistic regression), were updated to newer recursive partitioning techniques.

As these models have matured, it has become clear that there are limits imposed on their eventual power by: instructors' grading patterns, the limited variance imposed by the performance of experienced crews in recurring training, the restricted grading scale in use, and the influence of factors not reflected in the performance of the aircraft as revealed by the parameter data. Among the

most obvious of these factors are CRM and procedural components of crew performance that do not result in a predictable change in aircraft performance (parameter data). The project has attacked these problems on several fronts.

- The project is also actively supporting the inter-rater reliability (IRR) and instructor training programs for the MD80 instructors, and providing and helping with the use of the IETC IRR analysis software. As part of this effort, the project has actively promoted and demonstrated alternative data representations for training (such as data animation). There is interest on the part of the MD80 AQP program in transitioning from a once-a- year IRR calibration exercise to continuing calibration, with recalibration at least monthly, through use of a new set of IRR problems to be distributed to the instructors every month. These problems would be provided by the project initially, until the AQP group is trained to do its own. Each problem would be a set of AQP events to be graded, and would be presented as an animated 3-D aircraft performing the events over terrain, coordinated with a completely animated set of cockpit instruments.



Analysis Software

Using this same capability, the project conducted a study in which 14 instructors graded 32 data animations of landings for which grades had been given in the simulator. Of a total of 23 animation sessions for which there was agreement

among instructor/evaluators, 14 animation grades were lower than the simulator grade, three animation grades were higher than the simulator grade, and six animation grades agreed with the simulator grade. The most reasonable explanation for this is that under the difficult circumstances often set up in the simulator by the instructors, somewhat uneven performance in the technical performance of the maneuvers is mitigated in grading if the instructor sees that the crew is aware of their performance and is actively working together to make the necessary adjustments. In the data animation, this mitigating information is not available, and the instructors grade only on the strict parameters of the technical performance.

A follow-on study for FY2003 using scripted events, including cockpit audio and video, will extend and refine this study and specifically investigate this hypothesis. If it is supported, it would suggest that there are definite limits to how powerful the predictor models will be, and the focus for providing feedback from FOQA into AQP should be at the finer level of granularity of individual AQP performance standards, rather than the larger scale of complex AQP events.

Identification of Automation Issues

Human factors researchers at George Mason University identified a set of crew performance issues in using automated systems in the operational environment based on a carrier's internal incident reporting system. These incidents were analyzed for common themes and potential causal patterns. One common theme was the set of difficulties crews had when working with the interfaces to the automated cockpit systems. Errors in providing input to the device and interpreting output from the device led to a number of problems on the flight deck. Another common theme was that pilots are often interrupted in the course of executing their duties. The procedures for using automated systems are long, requiring many steps that must be executed in a specific order. Interruptions were often followed by difficulties in resuming the task or errors in the resumption process. A third theme identified was a problem in coordinating communications about the automated systems. Crewmembers are required to cross-check and verify flight-critical changes in the status of automated flight management systems. The analysis of incidents suggested that flight-critical information is not always effectively communicated from one crew- member to another. These common themes were used as the basis for our cognitive modeling efforts.

Model Pilot/Crew Procedures and Processes

Based on the issues identified in the first phase of the project and an initial model of pilot performance developed under a related grant from NASA-Ames, George Mason University researchers constructed a crew model with a simulated PF (Pilot Flying) and Pilot Not Flying (PNF). These crewmembers were simulated by separate ACT-R software models based on a cognitive task analysis of the duties of each person. The simulated task scenario was the time period just before and after Top of Descent (TOD) in the descent phase of flight. The PNF tasks included verification and programming of the Flight Management System (FMS) computer as well as gathering appropriate information for completion of the flight. The PF monitors and flies the aircraft except for required briefings and responses. Required aspects of crew interaction such as crew

communication (e.g., briefings, acknowledgments) were implemented by a communication link between the PF and PNF simulations using a multi-model extension of ACT-R. Simulated communications involved goals, specific actions, or situational facts and features.

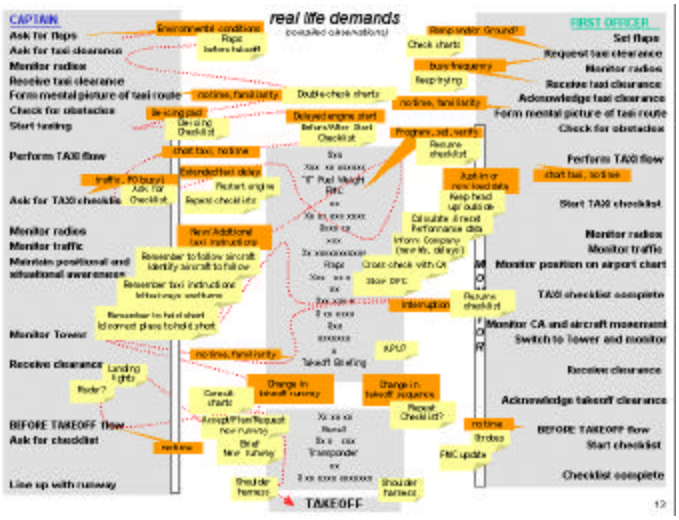
Ó**Aerowinx Boeing 747 Desktop Simulator Interface**

The linked PF and PNF models were evaluated by manipulating the simulated expertise of the crew. Expertise was simulated by changing ACT-R parameters and structures. Specifically, higher expertise was simulated by combinations of high strength of associative links for procedural behavior, higher working memory capacity, and less activation noise. One advantage of using the cognitive architecture was that a complete profile of cognition and performance could be measured for each simulation run. Model performance measures included: 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. Qualitative results such as step skipping, repetition, and intrusion of incorrect steps were observed at lower levels of simulated expertise. Additional results included crew miscommunication, differential situation awareness, and forgetting relevant goals under certain conditions of delays and interruptions. The precise profile of performance differences for different levels of crew expertise can be used to develop assessment items, strategies, and guidelines for assessing performance of commercial air carrier crews.

Interruptions, Distractions, and Lapses of Attention in the Cockpit

Pilots flying a routine segment from point A to point B follow explicit scripts (procedures and checklists) which describe the large number of separate tasks to be performed, with specific ordering and timing constraints within each of the flight phases. Such scripts are often designed without careful consideration of the fact that the aircraft

cockpit does not exist in a vacuum, but rather within the boundaries of a much larger, intricate operational environment. In the course of even the most routine flight, pilots must continuously interleave their well-learned scripts with concurrent demands for additional information exchanges and actions generated by copilots, cabin crew, gate teams, airport agents, air traffic controllers, and other aircraft in the vicinity. Managing an already high workload amidst the barrage of operational demands is especially challenging. A wide variety of errors are documented in daily operations despite pilots' expertise and dedication, and often in the most routine of circumstances. Pushing back from the gate without a logbook, taxiing on the wrong taxiway, neglecting to set the flaps prior to takeoff, forgetting to report crossing a waypoint, failing to reset an altimeter, landing without clearance all constitute an alarming portion of incident reports.



Real life demands for information

The goal of this FAA/NASA-Ames project is to help mitigate these seemingly negligent errors. Jump seat observations first help form a composite and detailed picture of the frequency and types of demands for concurrent attention and action that pilots encounter on a routine basis in flight operations. Next, using expertise in human cognitive abilities, it is shown how such demands threaten functions such as memory and attention and make pilots naturally susceptible to errors. In the final stage, researchers are developing suggestions for countermeasures by raising awareness and recommending teaching strategies and practical tools for use in the cockpit. Researchers are also assisting in the design of operational procedures that can better support pilots.

Training Pilots for Unexpected Events

Each day, thousands of passengers rely on flight crews to ensure that they arrive at their destination in a safe manner, and it is expected that crews are able to react to any situation that may confront them. Each year, airlines spend millions of dollars training pilots to prepare not only for routine or "expected" events, but also for novel and "unexpected" events. However, given the low likelihood of unexpected events and the high cost associated with training, training for all possible situations is not only

impractical, but also likely to be impossible. Therefore, research is needed on how traditional training approaches can be augmented to improve pilot ability to respond to unexpected events.

A research effort is underway to investigate the factors influencing pilots' reactions to unexpected events. University of Central Florida researchers developed a theoretical framework identifying key concepts related to the occurrence of and training for unexpected events. After conducting extensive literature reviews, the relevant literature was assembled and summarized to better understand the processes that occur during an unexpected event, specifically how the event is perceived, interpreted and resolved. The review concluded with suggested training interventions to manage these events, such as scenario-based training, meta-cognitive training, and adaptive expertise training. In cooperation with two air carriers, the research team is currently working on research to understand how preparatory information provided in pre-flight briefings may affect pilot performance when they are faced with an unexpected event in flight.

Loss of Primary Flight Instruments During Instrument Meteorological Conditions

A collaborative study with CAMI and the Air Safety Foundation (ASF) of the Aircraft Owners' and Pilots' Association (AOPA) assessed the effects of vacuum-system/attitude-indicator failures on pilot performance. Forty-one instrument-rated pilots were exposed to an unannounced failure of attitude and heading instrumentation during flight in single-engine general aviation aircraft: 25 in a Piper Archer PA-28 and 16 in a Beechcraft Bonanza A36. The PA-28 flights consisted of three groups: (1) Group A - a failure of the attitude indicator (AI) and directional gyro (DG), (2) Group B - same as Group A, but received 30-minutes of partial-panel instruction in a personal-computer-based aviation training device (PCATD) prior to the flight, and (3) Group C – same as group A, but had a failure-annunciator light (vacuum) on the panel. The A36 flights consisted of two groups: (1) Group A – a failure of the AI only, and (2) Group B – a failure of the AI and the horizontal situation indicator (HSI). All of the PA-28 pilots maintained control of the aircraft, sixty-eight percent of them flew successful partial-panel approaches, and likely would have survived if it had been an actual emergency. However, 25 percent of the Bonanza pilots could not maintain control, and the evaluator had to assume control of the aircraft. Use of the PCATD prior to the data flight reduced the time required to recognize a failure while airborne (mean A&C = 7.6 min., mean for B = 4.9 min.), but there were no other observed differences in performance between the Archer groups. Results indicated more problems with high-performance (complex) aircraft than with simple aircraft, and were consistent with the baseline data from the simulator studies. A manuscript detailing the effort was accepted to an international meeting (International Symposium on Aviation Psychology) and the technical report version of the manuscript has been approved for publication. The findings were briefed to interested parties in Flight Standards Service, and are being incorporated into an Advisory Circular. A paper detailing the results of the simulator trials appeared in the proceedings of the Human Factors and Ergonomics Society Annual Meeting.

FAA and ASF personnel with aircraft during flight testing (left) and interior photo of aircraft showing polarizing material and inset of polarized IFR hood used during experiment (right).

Runway Safety Interactive Training CD

Human factors researchers at Volpe NTSC developed a prototype training tool for tower controllers. The interactive CD was based on the highly successful booklet, *Runway Safety: It's Everybody's Business*. The CD contains "learn-by-doing" modules on memory, communications, attention and perception, teamwork, and fatigue. It contains information on:

- Limitations of short-term memory and the effects of distractions
- Effects of expectation and selective attention on information processing
- Common errors in controller-pilot communications and how to avoid them
- Effective teamwork strategies that can help mitigate the effects of individual errors
- Techniques for avoiding and managing the effects of fatigue

The module on memory was of particular interest to the Runway Safety Office (ARI) because of its charter to reduce the number of runway incursions caused by the failure of a controller's memory. ARI has convened a working group on controller memory enhancement as a result of recommendations from the Runway Safety Joint Implementation Team (JSIT). The CD has been reviewed by ARI, representatives from Air Traffic Training (ATX), and the controller memory enhancement working group, and ARI is funding its transition into a professional-grade training aid.

Research in Surface Operations

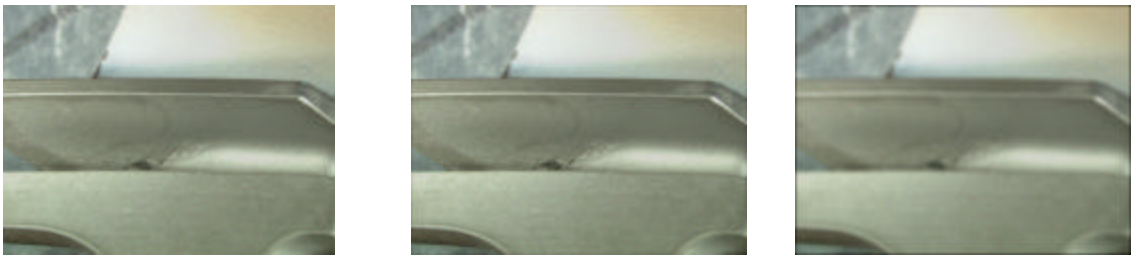
A Volpe NTSC paper entitled "Pilot and Controller Error in Surface Operations" was presented at the FAA-EUROCONTROL Air Traffic Management 2002 R&D symposium in Santa Fe, NM. The paper reported on the results of a study of FAA-sponsored

research on operational errors, pilot deviations, and reports submitted to the Aviation Safety Reporting System (ASRS). As a result of the presentation being awarded "best paper" in the safety track of the symposium, it was published in the Air Traffic Control Quarterly magazine. This work was also the foundation for current work in the area of runway safety, such as:

- More detailed analyses into pilot and controller factors in runway incursions, including an analysis of airport-specific factors
- Development of objective measures to classify the severity of runway incursions.

Task-Based Vision Requirements for Aircraft Inspection Personnel

The Federal Aviation Administration (FAA) Airworthiness requirement entitled "Vision Testing Requirements for Certain Persons Maintaining and Inspecting Aircraft and Aircraft Components" states: "At a minimum, determine standards for near and far vision and color perception in aircraft inspectors." FAA Advisory Circular AC#65-31 recommended examination guidelines for the vision of non-destructive inspection personnel, however additional research is needed to understand how degraded visual processes affect task performance. The AC states that near vision in at least one eye must be 20/25, and distance vision in at least one eye must be 20/50 (both near and far requirements may be with corrected or uncorrected vision). Color vision guidelines state that the inspector must "distinguish and differentiate between colors necessary for the inspection method for which evidence of qualification is sought." Further research is needed to determine the minimum standards for stereo acuity, peripheral vision, contrast sensitivity, visual fields, eye disorders, eye diseases, medication effects, corrective lenses, colored lenses, age effects, and other vision related processes that are acceptable vision standards for personnel involved in nondestructive inspection and testing, and visual inspection of aircraft and aircraft components.



Images show increasingly greater amounts of blur, simulating three levels of acuity: 20/20 (left), 20/40 (middle), and 20/100 (right)

The final goal of this research project will be to develop specific minimum visual requirements for essential tasks associated with nondestructive inspection and testing, and visual inspections that FAA Flight Standards can use to write a medical standard similar to Part 67 for pilots. To accomplish this goal, aviation maintenance personnel view typical structural defects in airframes that will be degraded with various visual deficits. This degradation is accomplished through video simulation (figure below) which is a well controlled, validated psychophysical paradigm currently used in medicine to investigate tumor detection by physicians. By adopting this experimental paradigm, research will be able to determine the level of visual deficit that renders a maintenance or inspection worker unable to safely and efficiently perform the critical

visual tasks required by the job. During the first phase of this research, a review of text and a Web-based search for occupational vision requirements was conducted. This knowledge, together with information gained from visits to major aircraft maintenance facilities, relevant information from technical, mechanical, and inspection textbooks, and the human vision literature revealed no studies that allow generalization of findings – the occupational tasks are too dissimilar. The standards for aircraft maintenance should reflect a more sensitive, evidence-based approach than to just use the existing literature based on other occupational needs. Any vision standard to be developed for aviation maintenance inspectors must take into account their specialized inspection tasks and the environments in which they work.

Alternative Night Vision Imagining System (NVIS) Lighting Compatibility Field Assessment

Interest and use of NVIS technology is increasing. The currently accepted practice for making a final determination of the compatibility of a lighting system with a night vision goggle (NVG) is to compare visual acuity through the NVGs with and without the lighting activated. The configuration for this procedure was developed by the military and requires relatively expensive illumination sources and radiometric measurement equipment (costs in excess of $100K). In addition, the military method has not been validated for repeatability or reproducibility. The RTCA organized a special committee (SC-196) to address the area. This committee has described one method for determining NVIS acceptability that is very similar to the method employed by the military. Although this procedure is currently the only approved evaluation process, applicants for NVG certification can use another method if it is appropriately documented and justified. The FAA and Department of Defense are concerned that these alternate means of compliance may not be proven safe and as a result, the FAA will be confronted with unverified alternative methods by applicants who cannot afford the more expensive equipment developed by the military.

This research at Wright-Patterson Air Force Base is investigating two alternative means to address NVIS acceptability. The first approach will investigate possible NVIS compatibility test methodologies that do not depend on any type of measurement equipment. The second approach will investigate methods that require a bare minimum of inexpensive or easily fabricated equipment. An example of the first approach is to have observers make judgments on light level by viewing through the NVGs. It is not critical to know the exact light level but rather just that the NVGs are operating at their optimum. In a similar fashion, an inexpensive, non-calibrated light meter could be attached to the output of the NVGs to achieve an output level of about 80% of saturated using the same basic technique.

In order to investigate NVIS acceptability, the researchers created a NVIS lighting simulator (NLS). The purpose of the NLS is to duplicate, in a precisely controlled manner, the types of lighting interference mechanisms that can occur in the cockpit. Ideally, the NLS should provide multiple adjustable levels of potentially interfering (non-compatible) light in a highly repeatable fashion. This will enable the systematic

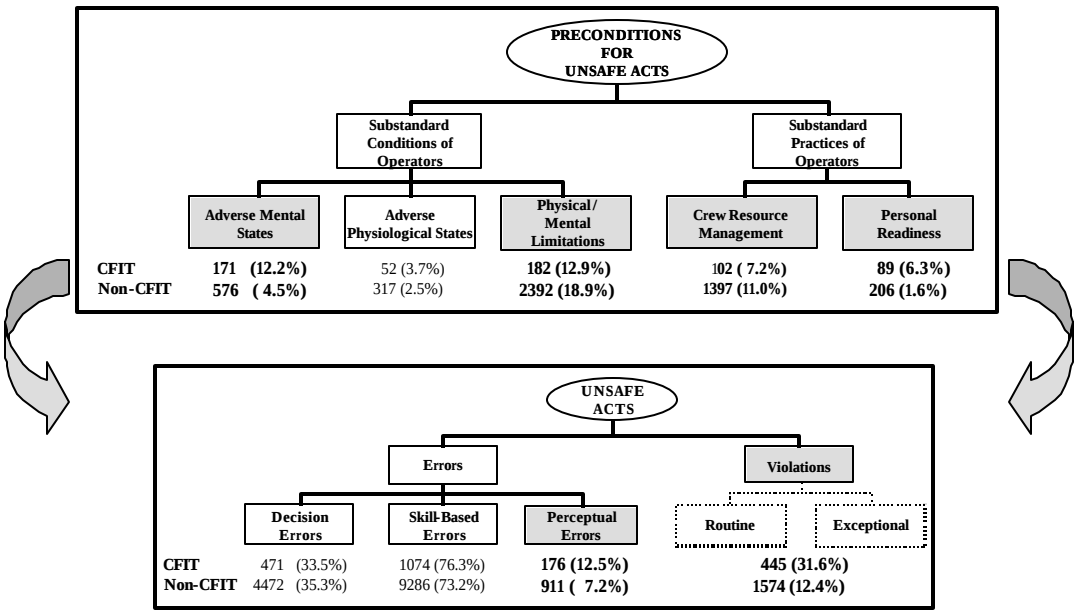
investigation of proposed NVIS lighting evaluation methods in a laboratory environment. It should be stressed that this entire research effort is directed only at the NVIS lighting interference with the operation of the NVGs, and does not address other important aspects of a full NVIS assessment such as day light and night time readability of cockpit instruments.

NVIS lighting simulator

To date, a baseline measurement methodology has been established and numerous alternate methods and their associated test equipment have been identified. Some methods require observers to view resolution charts while other methods (e.g., measuring NVG luminance output levels) are purely objective. The next phase is to perform laboratory studies to assess each method's ability the achieve baseline or better performance for the lowest cost and ease of implementation.

Human Error Analysis of CFIT Accidents

In an analysis of over 16,500 general aviation accidents using the Human Factors Analysis and Classification System (HFACS), it was found that CFIT accidents were more often associated with perceptual errors and violations of the rules than were non-CFIT accidents (see figure below). While not unexpected, this analysis quantifies what previously was opinion and conjecture. In many cases, CFIT accidents were the result of pilots continuing VFR flight into IMC (a violation of the rules using HFACS), and followed in many instances perceptual errors due to misjudging altitude or spatial disorientation (a perceptual error using HFACS). Perhaps more important was the fact that CFIT accidents were more often associated with adverse mental states such as diverted attention or overconfidence in one's ability, and failures of personal readiness like inadequate crew rest. A CAMI analysis of general aviation CFIT accidents, together with a comparison of CFIT versus flight into obstacles like telephone wires, was documented in an OAM Technical Report which is currently in the review process. The findings were also presented at the Annual Scientific Meeting of the Aerospace Medical Association in Montreal



Number and percentage of CFIT and non-CFIT accidents associated with at least one instance of each particular causal category. Statistics associated with violations have been collapsed across the type of violation committed. Significant differences (p<.001) are represented by shaded boxes.

General Aviation (GA) Accident Causal Factor Analysis – Overall

As part of the FAA's effort to better understand the causes of GA accidents, CAMI researchers previously analyzed nine years (1990-98) of fatal GA accident data using the Human Factors Analysis and Classification System (HFACS). The findings, though significant, reflected only about 20% of the total GA accidents that occurred during the time period. Therefore, an analysis of the remaining non-fatal GA accidents was conducted to provide a more complete picture of the human factors associated with GA accidents. Using HFACS, five pilots independently coded the causal factors associated with 15,744 GA accidents occurring between 1990-98. Of these, 12,033 accidents were associated with some form of pilot unsafe act (i.e., decision error, skill-based error, perceptual error, and/or violation). The research revealed previously unknown facts regarding fatal GA accidents:

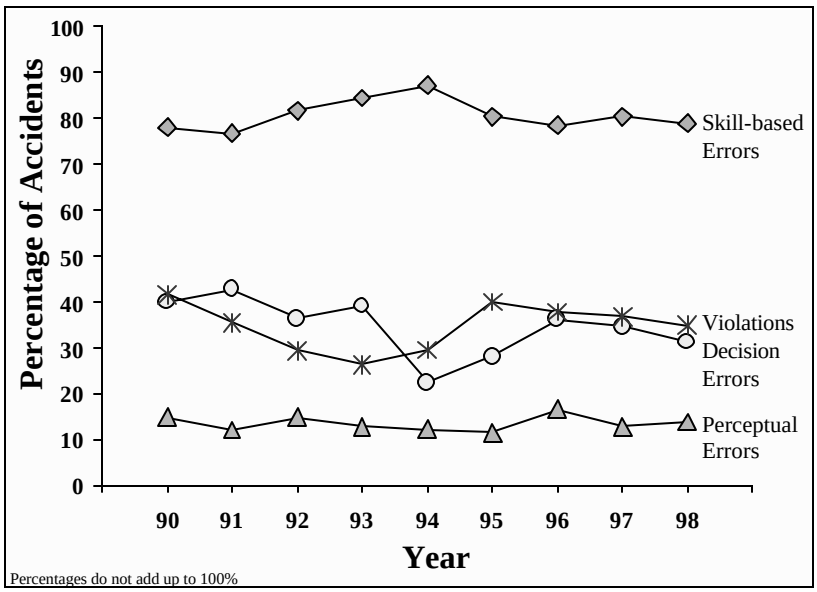
- Safety efforts over the last several years appear to have had little impact on specific types of human error associated with fatal GA accidents. The notable exceptions are a small dip in the percentage of decision errors in 1994 and 1995 and a gradual decline in violations observed between 1991-1994. Other than that, the lines are essentially flat. What these data appear to suggest is that any effect of safety and training efforts during this time period likely had a ubiquitous impact, if any.

- Skill-based errors have been associated with four out of every five accidents (roughly 80%) since 1990. These skill-based errors are primarily technique (stick-

and-rudder) type errors indicating failures associated with training and currency/proficiency.

- About 35% of all fatal GA accidents are associated with violations of the rules (e.g., visual flight rules [VFR] flight continued into instrument meteorological conditions [IMC]).

- Like violations, decision errors were also associated with about 35% of all fatal accidents, but perceptual errors (often due to visual illusions and spatial disorientation) were associated with less than 15% of all fatal accidents. Notably, many of our current intervention strategies and research efforts have been aimed at these last two error forms, which may explain their low incidence among GA accidents over the last decade.



Specific types of human error associated with fatal accidents between 1990-98.

Shift Work and Fatigue and the Effect on Performance among Air Traffic Controllers (ATC)

Researchers at CAMI finalized reports for the shift work and fatigue studies associated with Congressional interest. This included publication of three Office of Aviation Medicine technical reports and presentations of the data from the survey, field, and laboratory studies at the Annual Scientific Meeting of the Aerospace Medical Association in Montreal, Canada and the Annual Convention of the American Psychological Association in Chicago, Illinois. In addition, a pamphlet describing the results of the survey and the multi-media CD providing information on coping with shift work and fatigue were distributed to all controllers. A series of laboratory studies was completed in 2002. The first compared the traditional 2-2-1 backward rotating shift

schedule with a forward rotating schedule that allowed greater time between rotations. The results of this study suggest that the forward rotating shift schedule did not result in better performance or less fatigue, as suggested by some scientists. Having sufficiently defined the areas of concern with ATC specialist shift work, CAMI scientists began the process of evaluating putative countermeasures to the fatigue and performance decrements observed during the midnight and early morning shifts. The first two laboratory studies involved examination of strategic rest and physical activity during the midnight shift following a quick turn from an early morning shift. Analysis of the data from this study and additional analyses of the data from the previous studies were completed, and abstracts for presentations at scientific meetings in FY 2003 have been submitted. In addition, a protocol for use with the Air Traffic Control Advanced Research Simulator (ATCARS) to investigate the relationship between psychophysiological responses to workload in air traffic control was also completed. Initial pilot study data were collected with ATCARS to test the scenarios and to validate the utility of the subjective and physiological measures.

Shift work survey and CD-ROM

Air Traffic Control Operational Errors/Runway Incursions

A CAMI scientist participated with personnel from NATCA to conduct a field beta test of JANUS, a technique for analyzing the causal factors of human error in operational errors. A national memorandum of understanding was signed between the agency and NATCA for the beta test and validation processes. In the field test, researchers used a JANUS prototype laptop tool to collect data on 79 operational errors at towers, TRACONs, and ARTCCs.

Support was provided by a CAMI scientist using JANUS in assessing the runway incursion at Linate Airport in Milan, Italy. The results were provided to the Office of Accident Investigation for inclusion in its report to the Italian government. Results were also briefed to the Office of Runway Safety, regional offices during their Quarterly Performance Review, and to the Air Traffic Office of Investigations and the Northwest Mountain Regional Runway Safety group. An initial version of JANUS for ground operations has also been developed and is being tested using existing databases.

118 lives lost 10/8/01 Milan runway incursion

Human factors research is also improving runway safety by responding to recommendations from the Commercial Aviation Safety Team (CAST). A survey is being completed cataloging memory aids, while techniques, tools, and ways to supplement memory capabilities are being developed to address memory limitations.

Evaluation of Weather-Related Flight Behavior in General Aviation

CAMI scientists began investigating the major environmental and psychological factors related to GA pilots' voluntary flight into instrument meteorological conditions. In collaboration with risk-assessment researchers at the University of Maryland and the University of Melbourne (Australia), the FAA is attempting to identify predictors of weather-related risk-taking behavior as well as related environmental and cognitive stimuli. Phase I data collection is now underway on a planned group of 60 GA pilots. Phase I involved a number of paper-and-pencil and computer-based psychological tests and will be followed by Phase II behavioral data collection in CAMI's Advanced GA Research Simulator.

Selection and Training

CRM in the New Environment

The terrorist attacks of September 11, 2001 created a new set of security challenges for the aviation industry, including airports, airlines, pilots, passengers, and regulators. In addition, there are looming issues regarding the potential use of aircraft to conduct terrorist attacks with weapons of mass destruction, specifically biological and chemical agents. However, even before September 11th there were a number of new security challenges for flight crews. Specifically, the increased incidence of "air rage" put pilots and cabin crews into situations for which they had not been trained. Between 1995 and 2000, the number of reported air rage incidents in the FAA data base increased from 146 in 1995 to 314 in 2000 (i.e., one major incident almost every day). Thus, a number of training challenges for flight deck crews have come to the forefront with respect to prediction, prevention, response, and reporting of security threats.

To address these challenges, a training system was developed to give flight crews the declarative, procedural, and strategic knowledge to look for, spot, report, assess, and respond to a variety of security threats. Specifically, the new system concentrated on training for improved collaboration in predicting security threats to safety of flight and to the safety of the National Airspace System (NAS). This required the application of research results in the areas of vigilance, signal detection, signal augmentation, system automation, and crew information processing.

FAA-sponsored researchers at the University of Central Florida combined the results of the research with content material in the areas of terrorism, its history, motivation, and methods; criminal behavior; the psychology of aggression; forensic science; group dynamics and behavior; electronic, as well as nuclear, biological, and chemical warfare; navigation technology; and law enforcement. The training materials were made available to a test air carrier and have been incorporated by the airline into its crew training programs. Additional research activity is planned for 2003.

Simulator Requirements for Airline Pilot Training and Evaluation – Radio Communications and Motion Fidelity

The FAA/Volpe National Transportation Safety Center (NTSC) team is conducting a comprehensive review of simulator fidelity requirements pertaining to simulation of the airplane and simulation of the airspace environment. The goal of this project is to enhance safety by promoting use of effective simulators. Most air-transport pilots are trained and evaluated exclusively in flight simulators. New FAA regulations may soon mandate the exclusive use of simulators for all airline pilot training and evaluation, even for small airlines for whom it is currently less expensive to conduct some of their training in the air. For simulators to be most effective, the skills (or lack of skills) pilots show in the airplane need to fully transfer to the simulator during evaluation, and the skills pilots acquire in the simulator during training have to fully transfer to the airplane. For this

purpose, simulator features must be sufficient to represent all cognitive and motor challenges encountered in flight. To avoid unnecessary loss of training opportunities, however, requirements must also be restricted to simulator characteristics that truly affect transfer.

A series of literature and requirements reviews, surveys, and FAA-Industry Symposia came to the following main conclusions, which guide the current work:

- Realistic radio communication simulation (RRS) is optional, but its omission may decrease pilot workload while increasing instructor workload (with giving clearances). It also may reduce the pilot's ability to think "out of the box."
- Platform motion simulation is considered important for sudden-onset cueing with limited visual reference and thus mandatory, but there appears to be no scientific evidence of its effect on transfer to/from the airplane. It is also a major cost driver in both acquisition and maintenance of the simulator.

Radio Communications Simulation Requirements

Today's airline environment requires that simulations used for training and evaluation present airline pilots with realistic scenarios requiring both cognitive and technical skills. Although literature and experts agree on the importance of realistic radio communications from Air Traffic Control (ATC) and company during training and evaluation, a survey of airline practices showed that radio communications are typically simulated by the instructors/evaluators who are already busy with other tasks. This impoverishes the fidelity of radio communications and potentially jeopardizes the validity of simulator checks and training. The lack of realistic radio communications reduces pilot workload, relevance of the world outside the cockpit, and equivalence of workload across crews. This hypothesis was bolstered by a review of the Aviation Safety Reporting System (ASRS) incident reports on Initial Operating Experience (IOE), which indicates that not only does training continue during IOE, but also up to 87 percent of these reports involve radio communications as a contributing factor. This Volpe NTSC work has been published in conference proceedings, a government report, and an Air Traffic Control Quarterly article.

A follow-up study by NASA-Ames Research Center, which compared the effect of low and high fidelity radio communications, confirmed that in the presence of a realistic radio communications environment, crews might be less able to conduct the necessary planning discussions. The results also indicated that instructor's grading ability might be affected by having to impersonate ATC.

The lack of realistic radio communications is presumably due to the fact that airlines, given the lack of conclusive evidence for its benefit, deem the provision of communications by separate ATC impersonators as too costly. Another factor is the state of the art of the technology to simulate ATC/company and communications from other aircraft automatically. However, there have been promising attempts in this area by airlines and industry, and there has been progress in intelligent systems and automated speech generation/recognition.

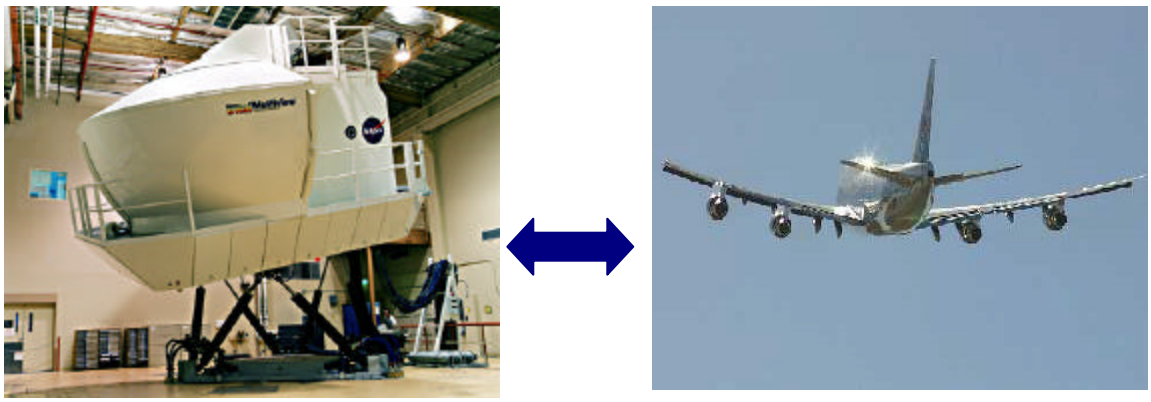
The goal of this work is to further investigate the requirement for realistic radio communications and to foster collaboration between regulators, airline industry, pilot organizations, ATC organizations, and the simulator and supporting industries to promote the development of automated RRS. One such effort is participation in the International Air Traffic Association's (IATA) initiative to specify a desirable system. The IATA Flight Simulator Working Group has drafted a paper that proposes standards for radio simulation systems with three levels of specificity and interactivity. The next step will be to refine the radio communications requirements while working with prototype developers and the air carriers.

Platform Motion Requirements

Ideally, a simulator will provide all the cues experienced in the airplane. For motion, however, the actuator travel and filter algorithms typical for the type of simulators accessible to airlines severely limit the ability to fully match the magnitude and phasing of the cues experienced in the air. This may have been one of the reasons why none of the earlier studies reviewed has been able to demonstrate an effect of motion on transfer of skills to the airplane. Motion systems have been greatly improved since these studies were conducted, and so has the ability to avoid other flaws in the experimental design. Volpe NTSC was therefore asked to obtain scientific data on simulator motion requirements.

A first study aimed at testing the effect of typical motion on sensitive tasks flown by regional airline captains did not find an operationally significant effect on the performance and control behavior of commuter airline pilots for recurrent evaluation, course of training, or transfer of training.

In FY 2002, a major follow-up effort was performed where the motion system of the test simulator, while still typical for the type of systems available to airlines, was tuned to provide the best possible performance within its operational envelope. Dependent on the results, researchers will: (1) develop motion qualification criteria and cost-effective alternative motion cues, (2) investigate the relevance of simulator motion for responding to vestibular-system induced illusions and initial training, and (3) investigate the contribution of vision to motion perception and also take a look at other systems such as force feedback.

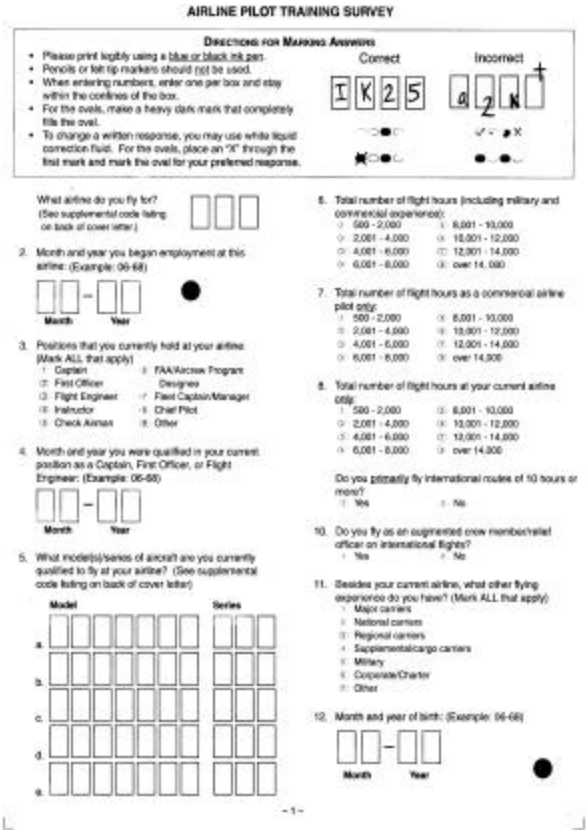


Platform motion; Transfer of skills – "Train as you Fly"

There is national and international interest gathered by this work, and the FAA and NASA-Ames Research Center are collaborating closely. Dependent on the results, researchers will: (1) develop motion qualification criteria and cost-effective alternative motion cues, (2) investigate the relevance of simulator motion for responding to vestibular-system induced illusions and initial training, and (3) investigate the contribution of vision to motion perception and also take a look at other systems such as force feedback.

Airline Pilot Training Survey

The primary purpose of this FAA research grant to the American Institutes for Research (AIR) was to assess airline pilots' reactions to, experiences in, and opinions about their professional training. To this end, researchers surveyed a nationwide, representative sample of over 30,000 pilots from 24 of the 30 largest U.S. passenger carriers. Over 10,000 usable responses were received



AIRLINE PILOT TRAINING SURVEY

DIRECTIONS FOR MARKING ANSWERS

- Please print legibly using a blue or black ink pen.
- Pencils or felt tip markers should not be used.
- When entering numbers, enter one per box and stay within the confines of the box.
- For the ovals, make a heavy dark mark that completely fills the oval.
- To change a written response, you may use white liquid correction fluid. For the ovals, place an "X" through the first mark and mark the oval for your preferred response.

Correct Incorrect

What airline do you fly for? (See supplemental code listing on back of cover letter)

2. Month and year you began employment at this airline: (Example: 06-68)

Month Year

3. Positions that you currently hold at your airline (Mark ALL that apply)
1 Captain
2 First Officer
3 Flight Engineer
4 Instructor
5 Check Airman
6 FAA/Airline Program Designee
7 Fleet Captain/Manager
8 Chief Pilot
9 Other

4. Month and year you were qualified in your current position as a Captain, First Officer, or Flight Engineer: (Example: 06-68)

Month Year

5. What model(s)/series of aircraft are you currently qualified to fly at your airline? (See supplemental code listing on back of cover letter)

Model Series

a. b. c. d. e.

6. Total number of flight hours (including military and commercial experience):
1 500 - 2,000
2 2,001 - 4,000
3 4,001 - 6,000
4 6,001 - 8,000
5 8,001 - 10,000
6 10,001 - 12,000
7 12,001 - 14,000
8 over 14,000

7. Total number of flight hours as a commercial airline pilot only:
1 500 - 2,000
2 2,001 - 4,000
3 4,001 - 6,000
4 6,001 - 8,000
5 8,001 - 10,000
6 10,001 - 12,000
7 12,001 - 14,000
8 over 14,000

8. Total number of flight hours at your current airline only:
1 500 - 2,000
2 2,001 - 4,000
3 4,001 - 6,000
4 6,001 - 8,000
5 8,001 - 10,000
6 10,001 - 12,000
7 12,001 - 14,000
8 over 14,000

Do you primarily fly international routes of 10 hours or more?
1 Yes 2 No

10. Do you fly as an augmented crew member/relief officer on international flights?
1 Yes 2 No

11. Besides your current airline, what other flying experience do you have? (Mark ALL that apply)
1 Major carriers
2 National carriers
3 Regional carriers
4 Supplemental/cargo carriers
5 Military
6 Corporate/Charter
7 Other

12. Month and year of birth: (Example: 06-68)

Month Year

-1-

Sample Pilot Survey

The survey covered several major content areas, including: training and checking intervals, general reactions to training, training content and instructional techniques,

CRM training, Special Purpose Operational Training (SPOT), Line-Oriented Flight Training (LOFT), check rides, and miscellaneous training issues. Early in the project, a Technical Advisory Board (TAB) – composed of members from the FAA, the ATA, and 3 major pilot unions – was established to provide project oversight and review all major deliverables.

The research team has written a draft report that summarizes the survey results. This report was provided to all the TAB members for their review and comment. Based upon their feedback, a draft final report was prepared which is being released. The team has also established a procedure for providing carrier-specific results (upon request) to training personnel at participating carriers. The purpose of these carrier-specific analyses is to help the airlines improve their pilot crew training programs. To date, only American Airlines and American Trans Air have requested copies of their data.

Preliminary survey results have been presented to key stakeholders: ALPA (May 2002), ATA (May 2002), the FAA (November 2001, January 2002), and the FAA's Research, Engineering and Development Advisory Committee, Subcommittee on Human Factors (August 2002). Invitations have been received to present survey results at the Society of Automotive Engineers World Aviation Conference.

Aviation Safety Action Program (ASAP) Taxonomy

Recently, the scope of the Airline Pilot Training Survey grant (above) has been expanded. Current efforts are focused on developing a taxonomy of human factors issues in Aviation Safety Action Program (ASAP) incident reports. The purpose of this taxonomy is to identify the causes of incidents. Armed with this information, carriers can then develop safety-related interventions and empirically assess the effectiveness of these interventions. Eventually, it is hoped that researchers can expand this taxonomy so that it can be used to classify and analyze AQP performance ratings and FOQA output.

During 2002, researchers conducted a comprehensive literature review of existing aviation human factors taxonomies, accident/incident reporting systems, and data collection tools. The purpose of this literature review was to identify best practices for inclusion in a taxonomy. The findings from this review are summarized in a detailed technical report. Recently, researchers revised this report for publication, where it is under review at the *International Journal of Aviation Research and Development*. They have also organized a session for the 2003 International Symposium on Aviation Psychology entitled *Error Reporting, Classification, and Analysis as Part of a Comprehensive Risk Management Strategy.*

AIR researchers are currently looking for airline partners with the help of the Voluntary Safety Programs Branch (AFS-230). In the meantime, they are continuing taxonomy development efforts. Included is an effort to schedule a series of card-sorting exercises with human factors researchers and students from George Mason University. The purpose of these exercises is to develop a first draft of the taxonomy. The results will later be compared and contrasted with results from airline pilots. To encourage carrier

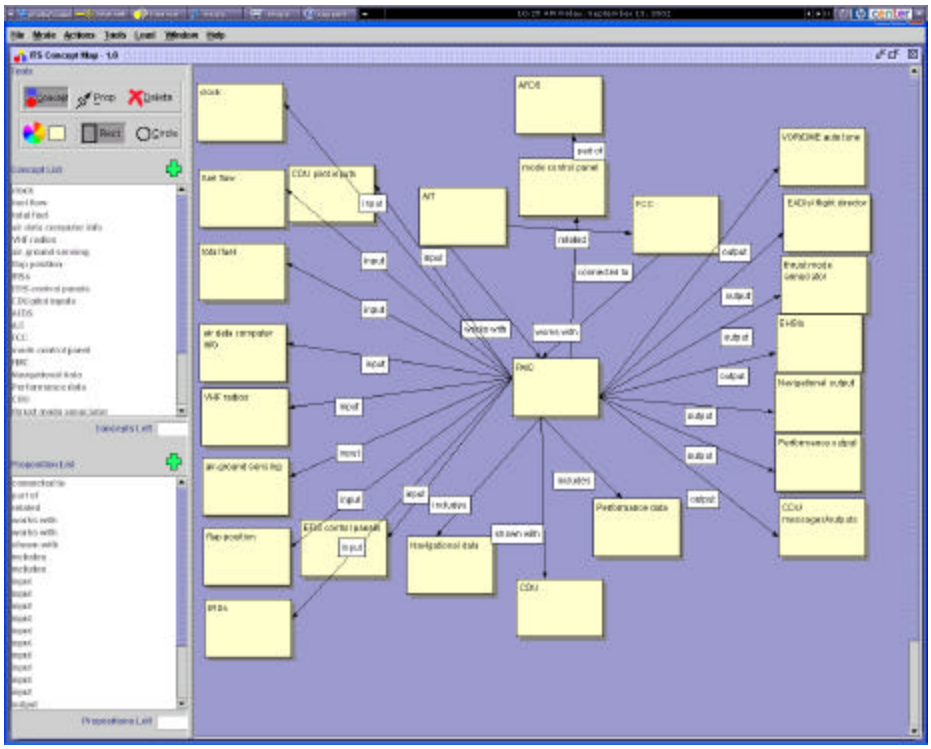
participation, work is also underway to develop a demonstration ASAP reporting/analysis database using Microsoft Access. This database, which should be available in February 2003, will include a first draft of the taxonomy. It will also include query capabilities and prototype data analysis reports.

Improving the Training of Auto-Flight Skills

In the past, only two evaluation types have been available to those training pilots on automation and other aviation skills: paper-and-pencil tests and oral examinations. Paper-and-pencil tests, while relatively inexpensive and easy to administer, are not highly diagnostic assessments. Conversely, oral examinations are highly diagnostic and flexible, but are often not cost effective.

To bridge this gap, FAA-sponsored researchers at University of Central Florida have created a new software tool for assessing complex knowledge structures and mental models necessary for the operation of advanced transport category aircraft. This tool, referred to as the Team Performance Laboratory Knowledge Assessment Tool Set (TPL-KATS), has the capability of performing computerized versions of both Card Sort and Concept Map techniques, two common knowledge elicitation methods. These procedures can assist in the evaluation of automation training among pilots. In addition to the computerized administration of these techniques, computerized scoring functions also exist within the software. The software program provides for the addition of multimedia into the evaluation and is easily reconfigurable for different scenarios. Since the software includes a tutorial and has the capability of scoring the knowledge elicitations automatically, many participants can complete the task at one time, using multiple computers. This helps to streamline the process of eliciting and assessing mental models of aviation automation training, saving time and energy while reducing the error associated with these assessments.

Currently, research is being conducted with the cooperation of several airlines investigating the capabilities of the TPL-KATS to effectively evaluate pilots' knowledge of automation. The purpose of the current project is to evaluate the scoring process and assess its diagnosticity when compared to a paper-and-pencil equivalent. Investigations have also been completed in the past year that compared the reliability and validity of computerized administrations versus more traditional manual assessments. 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.



The TPL-KATS software is currently being used to investigate air carrier pilots' understanding of complex autoflight systems, such as the relationships between system components (shown here).

Scenario Generation with the RRLOS Tool

The FAA/University of Central Florida research team has developed the "Rapidly Reconfigurable Line Operational Simulation" (RRLOS) computerized flight generation tool. This computerized *scenario generation system* logically combines training event sets and creates training materials. RRLOS was designed to generate scenario scripts in near real time and achieve changes of the scenario script in minimum time for remedial purposes. Using the software, a 2-hour training scenario can be generated in 5 to 25 minutes, as compared to 2 to 6 weeks previously. RRLOS also has a feature of targeting 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 material (e.g., situation reports, maps, weather data). The tool has been delivered to over 40 air carriers and other aviation organizations. In the past year, RRLOS was updated twice and was given increased functionality. Additionally, training was provided to multiple airlines in the use of the tool. Finally, the tool was adopted as a standard scenario generation tool by Airbus Industries and by Air Canada.

Line Operations Safety Audit (LOSA)

The primary focus of our research grant with the University of Texas is development of programs to identify safety targets for airlines to help reduce operational risk.

Researchers have documented that in real line flying, many pilots do not actually fly the aircraft as trained, and that operational and environmental factors quickly become potent factors outside the training environment (for example, ATC equipment failures or language problems).

One of the research programs is set in normal flight operations. Systematic observations of crew behaviors and crew interviews about safety concerns are made during normally scheduled flight segments by trained observers (primarily airline pilots). The observations and interviews are packaged in a program called Line Operations Safety Audit (LOSA). These are often augmented by attitudinal surveys about various flight operations and flight management issues using variants of the Flight Deck Management Attitudes Questionnaire (FMAQ). The purpose of LOSA is to derive safety targets from these sources of information instead of relying on incident or accident data.

LOSA uses the expertise of trained pilot observers to identify factors directly and indirectly relating to the management or mismanagement of threats and errors in the cockpit. LOSA directly collects observational data on threats, errors, and their management.

The LOSA database has grown to over 2,250 observed line flights, which yielded over 6,500 threats and 4,350 crew errors. These errors resulted in over 900 undesired aircraft states (most commonly speed too high, incorrect configuration of systems, vertical deviations, and unstable approaches). Thirteen LOSA analyses have been completed since 1997 with US major, regional, and commuter airlines, as well as a few Asian and South Pacific carriers. The resulting database is a rich source for scientific query.

Given the large and increasing demand for LOSA, researchers focused much of the 2002 effort into standardization and codification of essential LOSA elements. This work is also in support of transferring the LOSA technology to ICAO airlines. ICAO recently identified LOSA for its member airlines and ranked it as the number one safety priority.

Aviation Safety Action Partnership (ASAP) Incident Analysis

Another safety related program performed at the University of Texas relies on data provided by pilots about non-normal incidents that have occurred in daily flight operations. A new FAA developed program called Aviation Safety Action Partnership encourages pilots to voluntarily report incidents to their own airlines.

ASAP uses both the pilot as well as a review committee as the experts in identifying factors in the system that result in error. Like LOSA, ASAP programs have produced rich datasets that are conducive to assessment using the theoretical model of Threat and Error Management developed at the university.

Threats are the external, off-normal events that cockpit crews must manage in normal operations (e.g., weather, unusual ATC commands), along with the errors of non-cockpit groups (incorrect fuel loaded, dispatch paperwork errors). Even relatively minor

threats add to pilot workload. Management of these events is evaluated. The management or mismanagement of threats may cause cockpit crew errors. Crew errors may also be spontaneous in nature, and must be managed or they cause undesired aircraft states – the precursors to incidents and accidents. ASAP pilot reports and the reviews derived from the ASAP committee's analyses of incidents allow identification of the same elements.

The ASAP program saw several large developments in 2002. Beginning in August of 2001, researchers became involved in the direct development and implementation of the ASAP program started at Continental Airlines. One of the strongest statistics to come out of the initial analysis of the first year of ASAP data collection is the finding that 88% of all reports submitted to the program would not have been known outside the cockpit without the program.

Although this program has been developed through collaboration with Continental Airlines, the entire program and each of these stages of development is supported by a customized database currently being designed and programmed in the laboratory. This database can be applied to any ASAP program currently being run by a commercial airline. Researchers have been in contact with several airlines in transferring the database framework and methodologies developed in the laboratory to their current ASAP programs. The overall goal for this project is to move toward an industry standard of ASAP data collection and incident review utilizing the Threat and Error Management Model.

Information Management and Display

Visual Symbols Research

Airway Facilities (AF) personnel are responsible for monitoring and controlling many different systems and equipment. Most of the interfaces used by AF specialists rely on visual symbols to represent objects and functions on a monitor. As new systems have been added over the years, the number of visual symbols to which the AF specialists are exposed has increased. Visual symbols for new systems are often introduced with little consideration to other symbols already present in that environment or the environmental conditions, as a whole. This practice leads to many different visual symbols and coding methods presented in a single environment, taxing user memory, and increasing the potential for error.

A research team from the National Airspace System Human Factors Group (ACB-220) of the William J. Hughes Technical Center, collected data on visual symbols used at Maintenance Control Centers (MCCs) through site visits to six MCCs, review of computer-based instruction programs for various systems, interaction with subject matter experts, and a review of software documentation manuals. These data provided information on the symbols used, their meaning, and some of the coding conventions,

along with general information about operational environments such as estimated viewing distances, ambient lighting, and number of systems in a work area. These symbols were compared against human factors best practices. The complete study, including recommendations toward standardization, is contained in the new technical report entitled *A Catalog of Graphic Symbols Used at Maintenance Control Centers: Toward a Symbol Standardization Process*.

The Human Factors Design Standard for Acquisition (HFDS)
The Human Factors Design Guide (now Standard) for Acquisition of Commercial Off-the-Shelf Subsystems, Non-Developmental Items, and Developmental Systems is a compilation of human factors standards, principles, and guidelines integral to the procurement, design, development, and testing of FAA systems, facilities, and equipment. Information in the document is updated by the William J. Hughes Technical Center's NAS Human Factors Group (ACB-220) to keep up with current knowledge and to maintain its status as a viable tool. Released as a design "standard," the purpose of the publication is to provide a single, easy-to-use source of human factors design criteria oriented to the needs of the FAA mission and systems. An additional goal is to facilitate use of appropriate design criteria by organizing the document so that users can easily locate the needed information. Changes to the document incorporate major revisions to the chapters on computer human interface and automation and enhancements to previously published material. It broadens the focus to include both Air Traffic and Airway Facilities systems, and was modified into a set of standards instead of a set of guidelines to provide a common source of FAA-specific design requirements.

Work on this standard is scheduled to be available to the public either by downloading it from the internet or by requesting a CD from either the internet site or through a written request to ACB-220, The NAS Human Factors Group, WJHTC Bldg 28, Atlantic City International Airport, 08405.

Integration of System Enhancements in the TRACON Environment
The growth of air traffic, combined with the increased demand for flexibility and elimination of current restrictions, requires enhancements in the terminal architecture to enable controllers to maintain safety and increase efficiency. These enhancements include: improved weather information, improved communication equipment, and new decision support tools (DSTs). Specifically, this includes:

- Center TRACON Automation System
    - Passive Final Approach Spacing Tool (pFAST)
    - Active Final Approach Spacing Tool (aFAST)
- Integrated Terminal Weather System (ITWS)
- Controller-Pilot Data Link Communications (CPDLC) and Next Generation Air-Ground Communication System (NEXCOM)

The successful integration of any subsystem into the legacy system is necessary for full realization of the expected benefits of the subsystem. System benefits are projected on

assumptions of a given level of human performance. This includes correct and efficient data entry, correct interpretation of displayed data, correct and efficient response input, etc. Systems that are poorly designed or poorly integrated can induce user errors. Such errors can lead to poor user acceptance, poor system performance and unrealized system benefits. As subsystems are developed to address specific operational needs, their development is usually independent of the evolution of the legacy system. This means that the issues surrounding integration of the systems are usually not identified until the first stages of operational evaluation.

Volpe NTSC has identified likely future integration issues associated with planned enhancements within the TRACON environment and between the TRACON and other environments. An example of an integration issue across environments is that information (e.g., regarding aircraft position) and conflict resolution advice provided to en route controllers and the tower must be compatible with that provided to the TRACON controllers with whom they coordinate and interact. In addition to the integration issues surrounding systems within and between ATC environments, there are also air-ground issues to be considered. If the information regarding the position of potential threat aircraft provided to the pilot is substantially different from the information provided to the controller, errors and inefficiencies can result. A final report on this work has been prepared.

Human Factors Considerations in the Design of Surface Map Displays

There is a great deal of interest in developing surface map displays to enhance safety and reduce incidents on or near the airport surface. The airport surface is a complex and highly dynamic environment. The FAA Administrator noted that "taxiing on the airport surface is the most hazardous phase of flight … when accident statistics – including those of near misses [sic] – were analyzed, today's airport surface was found to have the greatest potential for major catastrophes" (Gerold, 2001). The National Transportation Safety Board (NTSB) has listed runway incursions as one of its top ten most wanted transportation safety improvements every year since 1991.

It is expected that surface map displays will enhance safety by providing information which supplements that available on an electronic chart or paper map, with the additional capability of providing real-time information regarding ownship and traffic positions on the airport surface. The current application for surface map displays is to aid the visual acquisition of surface elements (e.g., runways, taxiways, or other aircraft) during taxi. Expected benefits for the use of surface map displays are increased awareness of ownship position on the airport surface; increased awareness of traffic, especially near runways and taxiways; reduction of navigation errors during surface movement; increased efficiency in surface movement; increased ability to detect data entry and flight planning errors; and the reduction (and/or prevention) of runway incursions.

A technical report developed by Volpe NTSC is intended to support aircraft certification in review of surface map displays. It contains examples of surface map prototypes in

development by vendors and research organizations. For each of these prototypes, the display elements are depicted and control functionality is noted.

ÓRockwell Collins Surface Map Display

Additionally, this document provides information for FAA evaluators about human factors considerations that may be associated with surface map displays. Guidance presented here addresses the following topics:

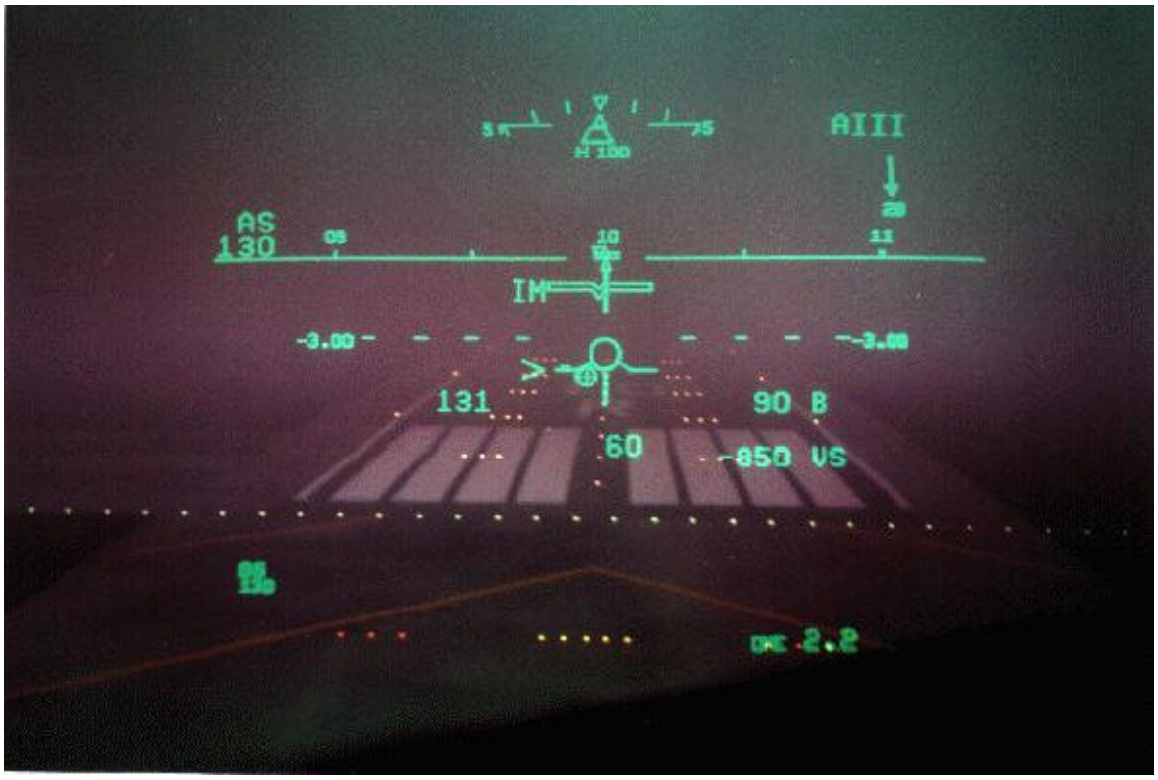
- The depiction of display elements on surface maps.
- The depiction of traffic and issues related to the representation of traffic.
- The depiction of status indications.
- The implementation of functionality.
- The layout and appearance of surface map displays.
- Operational considerations in the introduction of new equipment.

Certifying Head-Up Displays

A research project is underway at Volpe NTSC to provide the FAA with empirically based guidelines for certifying head-up displays (HUDs) for use in civil air transports. Scientists are summarizing the existing literature on HUDs and providing the current knowledge and research directions for developing certification guidelines. HUDs are being installed in air transports in order to allow manual approaches, landings, and takeoffs in poor visibility, down to and including Category IIIA conditions.

Through the course of certifying these HUDs, FAA experts have identified 22 HUD design issues, each representing a potential adverse impact of a HUD design on pilot performance. In order to improve the consistency and validity of the certification process of HUDs, the FAA needs to know exactly how pilot performance is affected. The Volpe Center has prepared a literature review of issues encountered by the FAA during the certification of HUDs for use in air transports. Each issue represents a

potential adverse impact of a HUD design feature on pilot performance. For each issue, the document summarizes the current knowledge, certification recommendations based on this knowledge, and direction of the ultimate resolution of the issue.



View through a HUD while landing in Category IIIA conditions (©Rockwell Collins Flight Dynamics).

The Volpe Center is also developing a method to measure the clutter of a HUD. Other HUD design issues are: task-display compatibility, display-display consistency, discrimination, symbology attributes (such as brightness, ghosting, flashing) in representing various states and values, evaluating a HUD's effectiveness in displaying and guiding recovery from unusual attitudes, consistency, discriminability of HUD symbology, and pilot physiological stress associated with HUD optical design. The Volpe Center has proposed a series of research programs to address issues in both task-display compatibility and display-display consistency and discrimination.

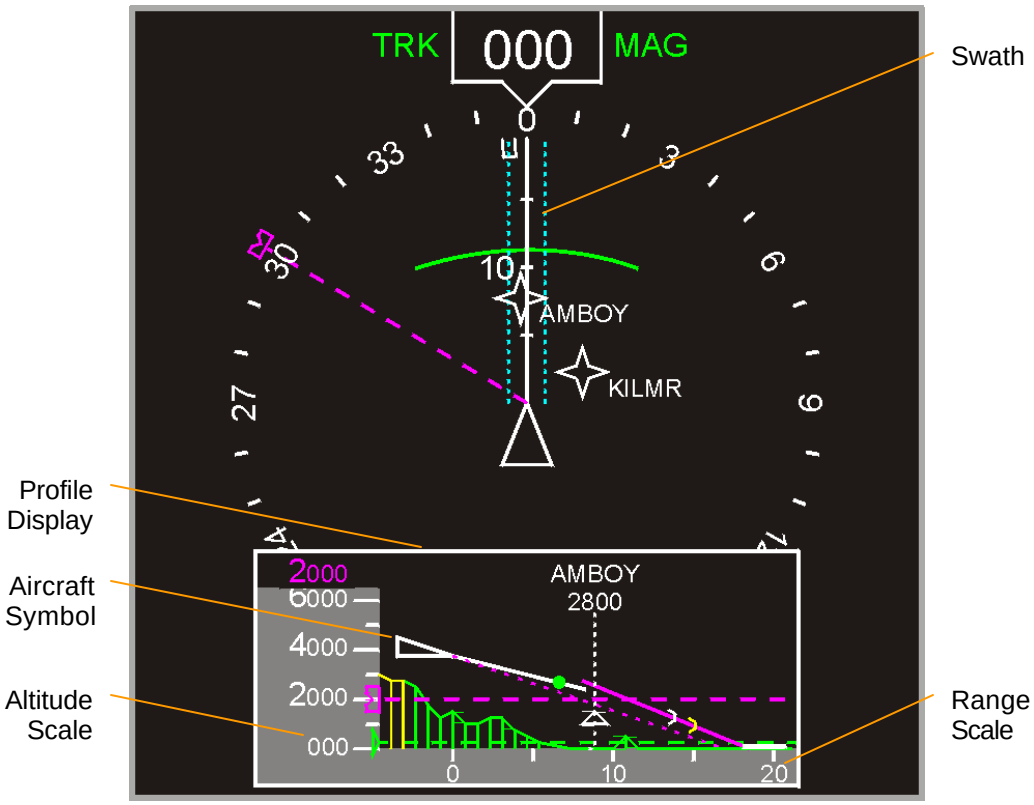
Issues and Standards for Profile and RNP Map Displays

Volpe NTSC is identifying human factors issues and information that can be used to support development of pilot interface industry standards for new types of map displays that will soon be appearing on flight decks. These include the following:

- Profile displays that show the longitudinal (forward) dimension of flight on one dimension and the vertical dimension on the other, thus providing a side or profile view of the flight environment. To determine the objects to display, a profile display

has a "swath" or horizontal zone of a specified lateral width typically about the aircraft's path or track. Only objects within the swath are shown.

- Required Navigation Performance (RNP) displays that are top-down navigation displays similar to that currently seen on advanced flight decks, but designed to operate in the new RNP air space.

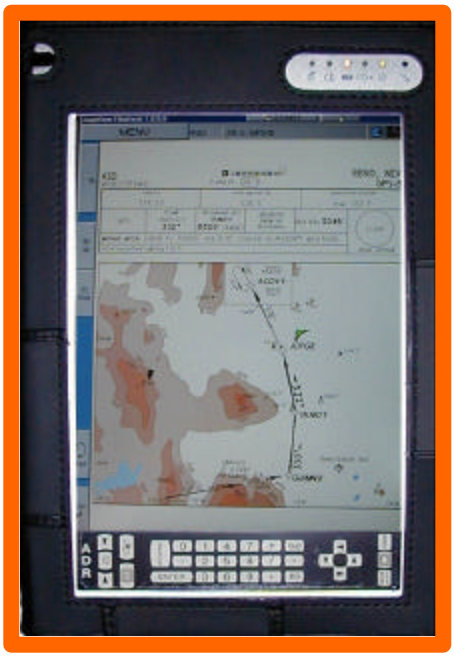


Conceptual illustration of Boeing's profile display, shown below a conventional navigation display.

Most current profile displays under development adequately address human factors concerns. However, as production profile displays proliferate, and profile displays are applied for more purposes, the following issues become significant: smaller screens, lack of terrain, traffic and weather compatibility, consistency and integration, path swath mode, and integration with 3-D displays. There are other human factors issues concerning the navigation information necessary for display on the flight deck, particularly on a map display. Among these issues are the following: use of a map for fine course guidance in manual flight, and map agreement with other avionics.

Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags (EFBs)

There is currently great interest in developing electronic information management devices for use by pilots in performing flight tasks. These devices are sometimes referred to as “Electronic Flight Bags” (EFBs). EFBs typically consist of a screen and controls in a self-contained unit that is relatively small, weighing only a few pounds at most. They were originally seen as a repository for electronic documents such as checklists, operating manuals, and navigation publications. In the future, many airlines envision that EFBs may become multi-function devices supporting an array of applications beyond those of a traditional flight bag, from electronic messaging to display of live weather.



Ó **ADR Flight Guide 3600**

EFBs are lightweight, hand-held portable or cockpit mounted. They are less expensive and more flexible than traditional avionics, and have a wide functionality range. They may be passive display or interactive, and can stand alone or connect to on-board and/or ground systems. The FAA will approve EFBs for installation and operational use in aircraft. The approval process will be a multi-dimensional effort requiring an understanding of how the device functions and is used by crews, how the device interacts with other flight deck equipment, and training and operating procedures.

Human Factors Consideration in the Design and Evaluation of EFBs, Version 2.0 , developed at the Volpe NTSC is intended to support FAA EFB Advisory Circular (AC 120-76). It contains information for FAA evaluators, system designers/manufacturers, and users about the many human factors considerations that may be associated with

EFBs. The considerations apply generally to all operations (Part 91, Part 121, Part 125, and Part 135), except where explicitly noted. Guidance is given in the form of *requirements*, *recommendations*, *suggestions*, and *issues* statements. Note, however, that this document is not regulatory. Where appropriate, FAA regulations and other industry documents on best design practices are referenced. An industry review of EFB technology will be included as an appendix to this document. The industry review captures the state of the market as of the summer of 2002.

Version 2.0 contains background information on the Advisory Circular from the FAA, an overview of the structure of the document that covers system considerations, and a description of the following EFB functions in detail: electronic documents, electronic checklists, flight performance calculations, and electronic charts. Human factors guidance for more complex functions, such as surface moving map and weather applications, may be found from the work of the appropriate standards committees sponsored by RTCA and SAE G-10.

AC120-76 defines three classes of EFBs. Class 1 EFBs are self-contained devices that do not interface electronically or mechanically with the aircraft. These are portable electronic devices subject only to Flight Standards approval. Class 2 EFBs are connected to the aircraft in some way. They are subject to approval by both Flight Standards and, to a lesser extent, Aircraft Certification. Class 3 EFBs must undergo a full review by Aircraft Certification.

From a human factors perspective, these distinctions are important in that they denote *two* major levels of capability; devices that read data from aircraft systems (Class 2 or Class 3 EFBs) support more integrated functionality than those that do not. These EFBs could sense the status of aircraft systems and automatically bring up information, if necessary, to address an abnormal situation. Throughout *Version 2.0*, issues relevant only to EFBs that are integrated with other aircraft systems are distinguished from issues relevant to EFBs that do not communicate with aircraft subsystems.

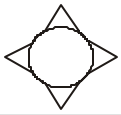
Version 2.0 contains guidelines on specific topics for the FAA and avionics manufacturers. The document contains guidance statements related to the installation of the EFB in an aircraft, training/procedures for the use of the EFB, and guidance statements related to the hardware/software aspects of the EFB equipment. The next project goal is to develop a human factors evaluation procedure for EFBs that is based on the full document. Work has begun toward developing a first draft of this evaluation procedure.

Aeronautical Chart Symbology

In 2000, the Volpe Flight Deck Human Factors Program supported a short-term rapid-response request from the FAA to conduct a study comparing the United States (US) fly-over and fly-by waypoint symbols with those of the International Civil Aviation Organization (ICAO) (Report No. DOT-VNTSC-FAA-00-23). At issue were the international standards for the depiction of these symbols. The symbols in use by the US and ICAO are currently in conflict. Because fly-over waypoints are often used to ensure obstruction clearance, it is critical for safety of flight that the symbols are unambiguous and salient to pilots. Volpe NTSC collected limited data in a paper-pencil

study. The FAA representative presented results of the study to the ICAO Obstacle Clearance Panel (OCP). The results supported a change to the ICAO standard fly-over symbol.

Volpe has collected data on which symbols are easiest to find on instrument charts, and the results support use of a circle around fly-over waypoints. This information has influenced the ICAO OCP to recommend a change to ICAO symbology.

	US	*ICAO*
Fly-Over Waypoint		
Fly-By Waypoint		

US/ICAO Symbology

Currently there is a broader US initiative to improve charting symbol consistency and usability. It is considered that symbols be coded based on navigation requirements (fly-over vs. fly-by), equipment requirements (intersection vs. navaid), and communication requirements (compulsory vs. on-request). In the short term, researchers will evaluate electronic display of current vs. proposed symbology, training impacts of the proposed convention, and the impact of making exceptions to the new convention. In the longer term, researchers will need to identify properties of "good" chart symbology that is consistent for both paper and electronic media, and determine a rational for choosing standard symbology to help in future efforts to define symbology.

Human Factors Aspect of NOTAM Understanding Among Pilots

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 due to construction. The goal of the current NASA project was to analyze the human factors aspects of the NOTAM system to determine how pilots can obtain the most useful information from the system and whether changes might lead to substantial performance improvements.

A survey completed by 79 pilots revealed they agreed 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.

In addition to the pilot survey, a human factors analysis was performed comparing NOTAMs to the FAA's *Human Factors Design Guide* which specifies basic principles to which all FAA systems should adhere. A simple evaluation of the NOTAM system

demonstrated that it does not follow many of the basic human factors principles described in the *Design Guide*. The next step in this project is to take the results of the survey and the human factors analysis and translate these into concrete methods for improving the system. One possibility is to create a training program that will give pilots a better understanding of the current NOTAM system. This, in turn, should improve pilot performance.

NOTAMs provide important information to pilots, such as notices of runway closures.

NASA/FAA Operating Documents Project

The NASA/FAA Operating Documents Project began in FY 1997, bringing together air carriers (including regionals and cargo), 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. Strong industry interest and participation in three NASA/FAA Operating Documents Workshops culminated in the assemblage of guidelines and examples for the publication entitled *Developing Operating Documents: A Manual of Guidelines.* This document was distributed to the aviation industry on CD in FY 2001.

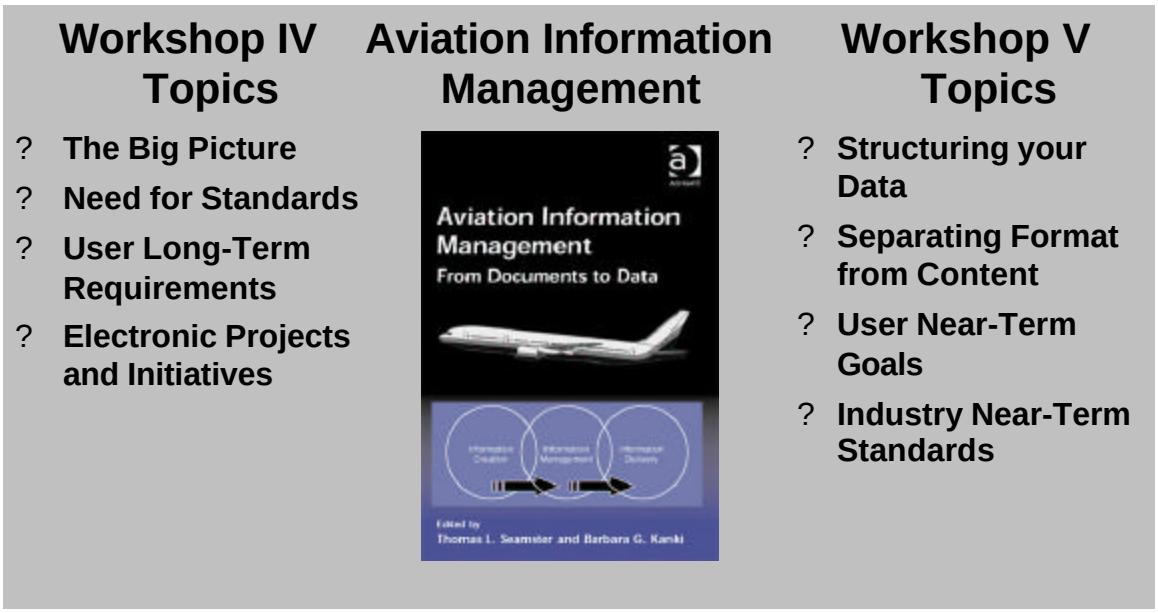
The Manual provides practical information for developers of operating document systems and has been used for guidance in industry standardization efforts. For example, the ICAO Flight Safety and Human Factors Study Group adopted the Operating Documents Guidelines for incorporation into ICAO documents and international standards, and the Transportation Safety Board of Canada (TSBC) adopted the Operating Documents Guidelines for use in assessing airline documents and procedures in investigation.

As operators and manufacturers transition to electronic media, Workshop IV, Structuring Operating Information was developed to help industry address issues of information management and restructuring. Workshop IV took place in May 2001 in Tampa, Florida. It included a user requirements session in which data from operators was collected in order to characterize the current status, needs and techniques used for developing effective information systems.

Key presentations from Workshop IV were expanded and integrated as a book entitled *Aviation Information Management: From Documents to Data* recently published by Ashgate. This book makes a strong case for structuring operational information and working within industry standards.

In July of 2002, the NASA/FAA Operating Documents Group met in San Diego for Workshop V, “Making your Data Smart: Directions, Tools and Techniques”. Over 75 representatives from major, regional and cargo operators participated. Presentations focused on industry standards, company strategies, human factors considerations of safety-critical data, tools for conversion, integration and management of data, techniques for document structuring from both writer and user perspectives, and operational implications for training and for use on the flight deck (electronic flight bag).

Workshop V participants engaged in small group discussions that surveyed airline near-term goals and needs, as well as industry priorities for data transfer standards. One of the outcomes of these discussions was the collaboration between the NASA/FAA Operating Documents Group and the ATA Flight Operating Working Group (FOWG) in evaluating a new common structure for operational data. The FOWG Operational Testing Group (OTG) has been formed to help evaluate this new data structure within the operators' document revision process. The kickoff meeting of the FOWG OTG took place at the ATA Technical Information and Communication Committee (TICC) Forum 2002, Advancing Digital Data in Aviation.



Operating Documents Workshops

The NASA/FAA Operating Documents Project will support the FOWG OTG in FY 2003, focusing on usability testing changes to the document revision process as manufacturers and airlines transition to a common data structure. This will be a key topic for the FY03 industry workshop, NASA/FAA Operating Documents Workshop VI.

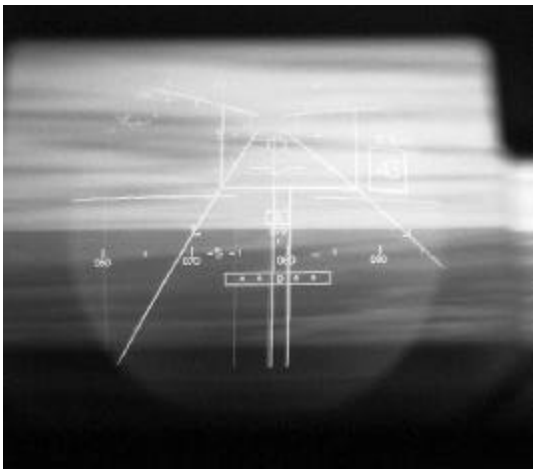
Flight Strip Reduction

Scientists from CAMI and the University of Oklahoma continued their assessment of en route controllers' usage of paper flight progress strips. Following the FY 2000/2001 project to observe flight strip usage in centers that received the User Request Evaluation Tool (URET) during Free Flight Phase 1 (FFP1), a similar project was planned for sites that will receive URET during FFP2. Data were collected during the summer of FY 2002 concerning the usability of URET at the FFP1 sites, and a summary report is currently being prepared. Another project to observe how flight strips and other handwritten notations are used in control towers is under review. Data collection will begin in FY 2003.

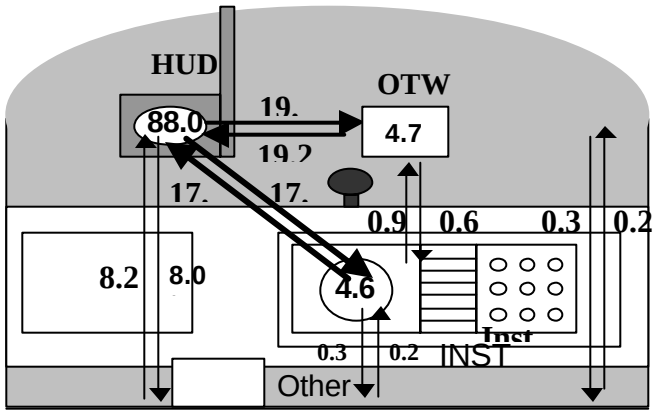
Pilot Field-of-Vision Capabilities / Head-Down Time

A study was conducted to compare pilot eye movements and flight performance attainable using highway-in-the-sky (HITS) format displays in both head-up display (HUD) and head-down display (HDD) configurations and conformal (with outside world) and compressed forms within the HUD, with a baseline conventional-instruments condition. Results were mixed, and the HUD was not clearly superior to the equivalent HDD when comparing flight technical error. Workload appeared to be comparable for the HITS formats, but slightly elevated for specific tasks in a baseline condition using conventional instrumentation. The need for a conformal HUD for GA operations was

not supported for most flight operations, and pilots preferred the HUD to the HDD and the compressed HITS format over the conformal HITS or conventional instruments. Results were reported in the Proceedings of the Annual Meeting of the Human Factors and Ergonomics Society. Results had been presented to the FAA sponsor in the previous year.



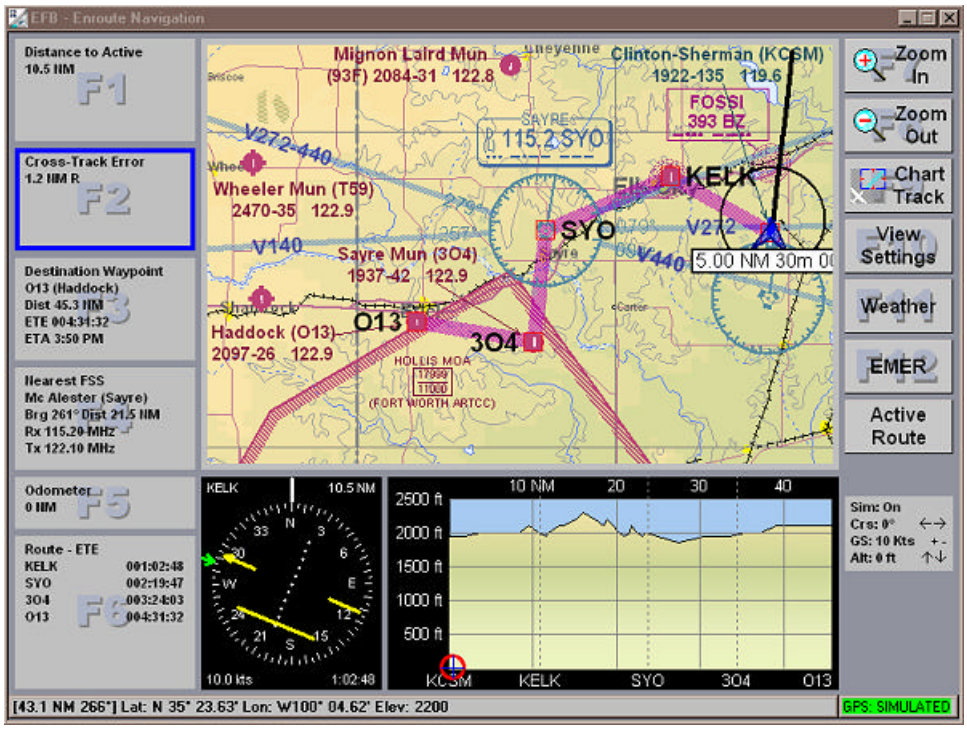
Compressed HITS display on the HUD



Visual transitions and dwell times (in % total) for head-up compressed format (OTW= out-the-window).

Multi-Function Displays (MFDs) / Controls

Usability testing of a flight-deck version of Jeppesen's Electronic Flight Bag (moving map with aircraft position/orientation) was completed by CAMI as part of the close-out activity for the Advanced GA Technology Experiment. A paper based upon these data was accepted for publication in the proceedings of the Annual Meeting of the Human Factors and Ergonomics Society. These data were also used for comparison with ratings of the system by human factors experts and as a baseline for comparison with data collected at an Aircraft Certification Officer (ACO) using Aircraft Certification Service personnel. Data collected at the ACO were both the pretest and final validation data (two sessions) for a pocket human factors guide developed for use in certification of multi-function displays, and data were collected for both the Jeppesen display and for the KMD-150 moving-map display. A final version of the pocket guide was developed based upon ACO personnel's comments and review by Small Airplane Directorate and industry subject-matter experts, and is in the publication process.



Multifunction Displays / Controls

Safeflight 21 / Alaska Capstone

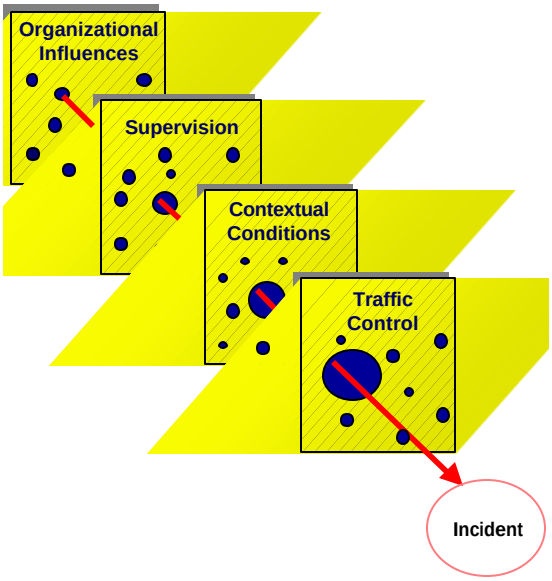
A human factors work group was formed under the direction of the Safe Flight 21 Office. The group consists of personnel from the FAA, Volpe NTSC and NASA. The group met both individually and with personnel from the Capstone Program office in Anchorage, Alaska to review, recommend, and implement human factors research activities. Accomplishments to date include a data collection effort in Bethel, AK, by members of the working group. The group conducted individual interviews with Capstone pilots and also collected self-administered questionnaires from the pilots. Members of the group accompanied pilots during normal flight operations to observe use of the Capstone avionics under actual working conditions. In addition, a usability study of the Capstone I avionics was conducted using the CAMI research flight simulation capabilities. CAMI researchers also assisted in the design and conduct of a usability study of Capstone I avionics installed in an aircraft. Future research will look at Phase I avionics usability by Part 91, VFR-only pilots, Phase II avionics usability research, and a training requirements study in coordination with personnel from Embry-Riddle Aeronautical University in Prescott, Arizona.

Several CAMI scientists served as members of the human factors team in support of the Ohio Valley Automatic Dependent Surveillance Broadcast (ADS-B) and Cockpit Display of Traffic Information (CDTI) application project. On several occasions during the year, they provided research briefings to the team. In addition to evaluating air traffic control and pilot voice communication from previous operational evaluations, an

analysis of air-ground communications derived from day and night operations is underway. In light of the events surrounding 9-11, the third operational evaluation of ADS-B and CDTI applications that was planned for the summer of 2002 was postponed. The survey instruments, questionnaires, briefing materials and observer forms that were developed in support Safe Flight 21 human factors projects were provided to the program office. Planning activities to collect data have slowed due to changes in program focus and the deactivation of existing ADS-B/CDTI from UPS aircraft. Current plans call for greater participation of the general aviation community.

FAA EUROCONTROL Action Plan 12: Management and Reduction of Human Error in Air Traffic Management (ATM)

Several joint activities were conducted with EUROCONTROL to enhance progress in harmonizing the development, beta testing, and validation of the JANUS technique used for identifying human causal factors of operational incidents and errors. Interim results were presented at the FAA/NASA Inter-Agency Integrated Product Team (IAIPT J12) meeting in Washington, DC and a paper entitled *Development of an FAA-EUROCONTROL Technique for the Analysis of Human Error in ATM* was presented at the 4th USA / Europe Air Traffic Management R&D Seminar in Santa Fe, NM. Additional information concerning the technique is available in the OAM Technical Report. The field beta test involved 26 FAA field facilities and resulted in collection of JANUS data for 79 operational errors. Seven European states participated in the beta test, and the FAA attended the EUROCONTROL feedback session to assess their success with the technique and share lessons-learned, problems encountered, and requested enhancements. Further FAA-EUROCONTROL discussion identified mutually beneficial activities to progress harmonization in validating the technique.



Swiss cheese model of causal factors of human error

Controller Teamwork

Previous studies by researchers at the Williams J. Hughes Technical Center suggested that the benefit derived by adding an additional controller to aid the radar controller is not as great as one might expect. To better understand this finding, data from a previous study was reanalyzed to determine how ATC teams differed based on their levels of workload, situation awareness, and intra-team communication. The results suggest that assistance provided through intra-team communication appears to come with a cost. Although help is provided, intra-team communication competes for a radar controller's attention (i.e., increases mental workload) and focuses his/her attention on a specific situation (i.e., narrows situation awareness). This may be one reason why additional staffing of the radar position does not always produce the expected benefits.

A joint program of research was initiated between CAMI and Future Flight Central at NASA-Ames. Intra-team communication research will be conducted using NASA's tower simulator. Ground and local communication exchanges will be examined under two conditions. The first condition represents current FAA policies and practices as they relate to "taxi-to" and "multiple runway crossings". The second condition incorporates "taxi to" and "multiple runway crossings" procedural changes that were recommended by the National Transportation Safety Board.

The en route controller-to controller communication and coordination taxonomy (C^4T) was adapted to the tower environment. The adaptation provides categories for coding communication exchanges between ground and local control. Software was developed to enable coding using a hand held computer. The computer will be used in FY 2003 field studies.

BASIC General Aviation Research Simulator (BGARS)

BGARS underwent extensive upgrading this past year. This included a transition to flat panel displays of cockpit instrumentation and side out-the-window views. Microsoft Flight Simulator 2002 was integrated as the flight simulation package, which significantly expanded the capability to emulate weather conditions and provided an advance in the capability to simulate the visual environment. Modification to the radios and controls provides for dual controls and a central radio stack. This PC-based flight simulator uses networked PCs to generate five out-the-window views spanning a 225-degree field. A combination of flat-panel and projected displays allows numerous cockpit configurations to be depicted, and interfaces are available to drive external multi-function navigational displays for usability assessments. Controls and avionics hardware are represented with realistic reproductions. Programmable weather and digitally driven air-traffic communications further enhance realism. Several models of general aviation aircraft and various instrument panel variations are available. This system provides CAMI researchers with a stable-aero-model medium-fidelity device for conducting rapid-response screening experiments and for examining questions involving the use of new types of advanced navigation displays. The capability to

integrate various GPS and multi-function displays into BGARS allows CAMI scientists to gather human factors usability data.

Basic General Aviation Simulator (BGARS)

Human-Centered Automation

Air Traffic Control Advanced Research Simulator (ATCARS)

While the contractor is developing an approach that will facilitate scenario development, ATCARS development was completed. A pilot study was completed by CAMI in FY 2002 using ATCARS to compare physiological measures of mental effort with subjective workload assessments.

Air Traffic Control Advanced Research Simulator (ATCARS)

ATC Collaborative Decision-Making

Frequently, ATC System Command Center (ATCSCC) provides reroute advisories to a number of groups to inform them of the need to consider a reroute in order to avoid a weather or traffic constraint. This is done by the issuance of a Traffic Management Reroute Advisory. The current process is very cumbersome because all of the advisories are sent to all airline dispatchers and FAA traffic managers instead of to only those users for whom a particular advisory is relevant. The advisories are also difficult to interpret due to how flights are identified and how flight information is retrieved from airline databases. Further, the advisories are not machine-readable and must be manually re-entered by the user.

Researchers proposed to the FAA Collaborative Decision Making (CDM) Program development and distribution of an automated tool for handling ATCSCC Reroute Advisories. The CDM Program endorsed this Reroute Advisory Tool (RAT) with accelerated implementation of an operational version integrated in the Enhanced Traffic Management System (ETMS) set for Spring 2003.

Development of the Reroute Advisory Tool proceeded through a series of steps, and researchers from Ohio State University provided human factors input in the development of the requirements document, in the design of the prototype, and in conducting an analytical and empirical evaluation of the prototype design.

American Airlines Systems Operations Center, Dallas-Ft. Worth Airport

Support to ICAO

Volpe NTSC continues to provide support to the US Delegation to the International Civil Aviation Organization (ICAO) to help ensure that human factors requirements are incorporated into all requirements documents for future systems. Substantial support was provided to develop Required Communication Performance (RCP) for future controller-pilot communication systems; the RCP is now being developed into a manual. Researchers will also support the ICAO delegation on human factors issues associated with applications of ADS-B technology.

Human Factors Certification Job Aid

The Human Factors Certification Job Aid is a software decision support tool developed by the FAA and Research Integrations, Inc. to assist certification and design personnel in identifying, assessing, and resolving potential design-induced human performance errors that could contribute to aviation incidents and accidents. It has three major databases addressing regulatory information, flight deck components, and human factors considerations respectively. In the current version, the information in the databases is focused on CFR Part 25 flight deck displays. In FY 2003, the databases will be expanded to address controls.

FAA Aircraft Certification
JOB AID
for Flight Deck Human Factors

The Need for Supporting Error Management on Modern Flight Decks through Improved Training and Design

- The findings from instructor survey and jump seat observations during earlier stages of this project at Ohio State University (OSU) have highlighted the need for a revised model of error recovery. Analytical work on this model has begun, and a first paper discussing this effort was accepted for presentation at the Annual Meeting of the Human Factors and Ergonomics Society in October 2002. Current models of error recovery are based on analytical work and a small number of software usability studies in domains that involve individual users performing self-paced tasks on a computer. These models do not necessarily capture the range and effectiveness of possible error recovery strategies in highly dynamic domains, such as aviation, where numerous agents interact and collaborate on an overall goal. Therefore, researchers propose a revised model that, using a puzzle analogy, illustrates why forward recovery to a revised goal state is often the only option in highly interactive environments. In these domains, an initially intended state (such as a specific airplane position) is part of an overall intended configuration (such as a landing sequence). In case of an erroneous action, it is often neither possible nor desirable to recover backwards to the initial state (before the erroneous action) since the overall (traffic) configuration has changed. Instead, a new, alternate goal state must be identified and achieved (e.g., a new slot in the landing sequence must be assigned to the airplane). A transition from the current centralized air traffic system to a more flexible distributed Free Flight environment will likely affect the error management process, as the identification of an alternate goal state may become more difficult in the absence of shared intentions.

- In addition to line observations and the instructor survey, OSU researchers recently completed a review of ASRS reports that involve the management of automation-related errors on modern flight decks. A total of 935 reports were reviewed. Of those, only 38 reports contained sufficient information on the error management process to be included in the sample. These reports were analyzed with respect to error type as well as error detection, explanation, and recovery. Lapses and mistakes were the most frequently reported error type in these reports. This is likely due to the trend for slips (which tend to be the most frequent error type) to be detected more readily and corrected before leading to

a problem worth reporting. In the majority of cases, error explanation was not mentioned. It is not clear whether pilots simply did not include any information on this stage, or whether/when they actually moved directly from the detection to the recovery from an error. Future research will examine this question in more detail. Forward recovery was the predominant recovery strategy in the database – thus supporting the findings that led to the development of the above revised model of error recovery. The complete results of this activity are described in a technical report published in 2002.

- OSU Researchers are establishing cooperative research partnerships with NetJets and Boeing Commercial Airplane Company which will allow them to conduct the next two steps in this research project: training observations and a simulator study. A proposal has been submitted to the Columbus, OH branch of NetJets – a fractional ownership carrier with a large fleet of modern highly automated corporate jets – to ask for permission to conduct training observations and focus group interviews on error management with pilots and instructors at their facility. These activities will build on previous survey data and help expand on the modeling work described above. Furthermore, in order to move beyond observations and analytical work, researchers have submitted a proposal to Boeing for a controlled simulator study at their facilities in Seattle, WA. Initial discussions indicate an interest in this research topic, and it appears possible to use one of their development simulators for this study on the management of autoflight-related errors. The goal is to conduct the simulator study in 2003.

Next Generation Air-Ground Communications Program (NEXCOM)

The Next Generation Air-Ground Communications program plans to replace aging analog radio equipment with a digital system, the Very High Frequency Digital Link Mode 3 (VDL3). VDL3 will include both digital voice and data link communications, and will include special features such as controller override, pilot anti-blocking, and a transmit status indicator. Two human factors concerns with the VDL3 system were the quality of the synthetic voice communications and the additional delay in transmitting the signal. Two previous studies by personnel at the William J. Hughes Technical Center's Research, Development, and Human Factors Laboratory (RDHFL) determined that the intelligibility of the digital voice was acceptable for air traffic control operations. In 2002, researchers conducted a high fidelity, human-in-the-loop simulation to compare system efficiency and controller performance and workload under three ground delay conditions: 250 ms (current specification), 350 ms (practical alternative), and 750 ms (to demonstrate the sensitivity of the simulation measures). Ten controllers from Level 11 and 12 en route centers participated in the study. The results indicated that there were no significant differences between the 250 and 350 ms delay intervals. Controllers were able to perform very well in high traffic/intense communications scenarios with any of the delays as long as they had the special features. However, the 750 ms interval did produce a significant increase in controller overrides and pilot blocks, and the controllers rated it as interfering with some aspects of their communication (e.g., providing optional services). The conclusion of the study is that

the VDL3 system with special features can be implemented with a 350 ms delay without any negative effects on system efficiency or controller performance and workload.

Automated Flight Service Station Voice Switch (AFSSVS)

The Product Team for Voice Switching and Recording (AND-320) is developing the Automated Flight Service Station Voice Switch (AFSSVS) that will replace the Integrated Communications Switching System currently used in AFSSs nationwide. Engineering Research Psychologists from the William J. Hughes Technical Center's National Airspace System Human Factors Group have been supporting the program since FY 2000. These efforts included developing a prototype computer-human interface (CHI), conducting an early user involvement event, and writing a description of the prototype CHI that could be distributed to potential vendors. In FY 2002, researchers developed a test plan (including scenarios, procedures, and data collection instruments) and conducted the human factors evaluation of down-selected vendor prototypes during the Operational Capability Test. During the test, flight service specialists completed an extensive series of realistic tasks using each demonstration system. The human factors researchers analyzed the data and wrote the human factors sections of the report, identifying human factors strengths and weaknesses of each system. The Product Team considered this information in addition to technical performance criteria in selecting the vendor to build the deployed voice switch.

Standard Terminal Automation Replacement System (STARS)

Since 1997, Engineering Research Psychologists from the William J. Hughes Technical Center's National Airspace System Human Factors Group have conducted multiple human factors efforts on the Standard Terminal Automation Replacement System (STARS). These efforts include usability assessments, rapid prototyping, early user involvement events, and computer-human interface (CHI) validations for the different versions of the terminal radar approach control (TRACON) workstation, the tower display workstation, and the monitor and control workstation. In FY 2002, researchers conducted a CHI validation simulation of the full STARS 2+ (FS-2+), which is the nationally deployable version of STARS. It adds several new ATC functions, most importantly the Converging Runway Display Aid (CRDA). The CRDA helps controllers visualize traffic spacing, and is necessary for deployment to larger TRACON facilities such as Philadelphia International Airport.

The CHI validation collected usability data during human-in-the-loop simulations. Controllers from the STARS AT CHI Working Group completed each new FS-2+ function while controlling traffic in a realistic simulated environment. They provided feedback regarding usability of the functions on questionnaires and during interviews and group caucuses. The results indicate that most of the STARS FS-2+ functions met controllers' expectations for usability and performance. The CRDA functions generated no major usability issues. Observers noted several minor issues, some of which had already been identified in other forums. The vendor will address each of the issues with software or hardware changes prior to initial operational capability at Philadelphia. The CHI validation supported the FAA Acquisition Management System requirement to identify and mitigate human factors-related risks in the deployment of all FAA information systems.

The Study of an ATC Baseline for the Evaluation of Team-Configurations (SABET)
In the Study of an ATC Baseline for the Evaluation of Team Configurations, a team of Engineering Research Psychologists from the William J. Hughes Technical Center's National Airspace System Human Factors Group (ACB-220) examined the effectiveness of a new multi-sector planning position in maintaining safety and improving the efficiency of controlling air traffic. Several proposals have suggested that the FAA implement a new multi-sector planning position that would be part of a multi-layered ATC system. The proposals for the multi-sector planning position involve a range of roles and responsibilities from minor modifications to current operational positions [e.g., upstream Data-side (D-side)] to a position that would only perform strategic planning actions and coordinate through Radar-side (R-side) controllers (e.g., Airspace Coordinator).

Thirty controllers from en route centers controlled traffic in a human-in-the-loop simulation in three operational team configurations and under low and high task loads. Controllers, in teams of three, acted as 1) three individual R-side controllers, 2) two R-side controllers with an Upstream D-side assisting the one R-side controller or 3) two R-side controllers with a shared Airspace Coordinator assisting both sectors. The controllers indicated that the information needs differ significantly between radar and multi-sector controllers. This finding has direct implications for the design of tools that take controllers from a tactical focus on a single sector to a more strategic focus on several sectors.

In this experiment, the airspace coordinator position moved a large number of aircraft through coordination with sectors outside his/her airspace of responsibility. Controllers suggested that implementation of a multi-sector position was possible with current equipment, as long as current procedures, i.e. coordination through the sector-based controllers, stay in place. The airspace coordinator had the advantage of not having a direct responsibility for tactical separation of aircraft or direct support to the radar controller and, because of that, could step back and assist the individual sectors by streamlining traffic, removing potential for conflicts, or coordinating with sectors to fly aircraft direct. When implementing a multi-sector position, there are some differences in how that position will function depending on its physical location. It seems that multi-sector controllers pick up information from sector controllers when they are in the same physical location, even though they are not in direct communication with one another. When the multi-sector position is not collocated with the sector teams, they tend to compensate for that indirect information flow by calling the sector controllers more often.

Collocation of User Request Evaluation Tool, Traffic Management Advisor, and Controller Pilot Data Link Communication
The FAA is deploying new automation systems for use by Air Traffic Control Specialists (ATCSs) under Free Flight Program Phases 1 & 2 (FFP1 and FFP2). The User Request Evaluation Tool (URET), Traffic Management Advisor (TMA), and Controller Pilot Data Link (CPDLC), however, were developed independently, as stand-alone

tools. Deploying these as stand-alone systems meets the Free Flight Program's goal of achieving early benefits for aviation with low-risk technologies. Collocating the systems may result in both benefits and human factors issues for ATCSs. Identifying the issues and applying human factors guidelines can mitigate potential collocation problems.

During FY 2002, Engineering Research Psychologists at the William J. Hughes Technical Center conducted an analysis and cognitive walkthrough to examine human factors issues of collocating the three systems. Four primary human factors issues emerged from the analysis: CHI consistency, information presentation on the radar associate side, new roles and responsibilities for the radar and radar associate sides, and updating the National Airspace System (NAS) database. This study presented the first systematic human factors evaluation of collocating all three systems. These findings will be evaluated using human-in-the-loop simulations in FY 2003. The FAA can address these potential issues in the course of the Free Flight Program's spiral development plans.

Workforce Performance Optimization

Statistical Retirement and Attrition Model (SCRAM)
CAMI scientists completed development of a prototype application for estimating future retirements from the en route and terminal air traffic control specialist workforce. SCRAM uses historical retirement data to estimate future retirements based on the controller optional retirement rules. Developed in Visual Basic for Applications, SCRAM is designed to run in the MS Office 97 environment. A working prototype was demonstrated to personnel from the Air Traffic Resource Management Program (ATX) in July 2002, and the Airway Facilities Resource Management Program (AFZ) in September 2002.

Air Traffic Services Occupational Workforce Plan
A CAMI scientist and representative from OTS, Inc. completed the first draft of the Air Traffic Services (ATS) Occupational Workforce Plan in FY 2002. At the direction of the Office of Management and Budget, every executive agency is developing an occupational workforce plan for mission-critical occupations. Guidance from the General Accounting Office and the Department of Transportation required workforce plans to identify critical occupations, significant business drivers, anticipated changes in staffing and knowledge, skill, and ability requirements, identification and analysis of gaps between current and future workforce requirements, and plans to close any identified gaps. The ATS Occupational Workforce Planning Team turned to CAMI for analytic and statistical support in developing the workforce plan for five critical occupational groups:

(a) Computer Specialists (FV-0334)
(b) Engineers (FV-08XX)
(c) Airways Transportation Systems Specialists (FV-2101)
(d) Terminal and en route Air Traffic Control Specialists (FV-2152)

(e) Flight Service Station Air Traffic Control Specialists (FV-2152)

The analyses developed by CAMI and OTS were used to brief the ATS Management Team in late July 2002.

A CAMI scientist revised the automated crediting plan for the Airways Transportation Systems Specialist (ATSS; FV-2101) occupation in FY 2002. Revisions included changes to the content, scoring, and pay band eligibility determination. The Airway Facilities Computerized Applications Processing System (AFCAPS) is now the sole means to be used by Airway Facilities to assess external applicants for positions in the technical workforce.

Air Traffic Controller Selection

AHR and the National Black Coalition of Federal Aviation Employees (NBCAFAE) asked CAMI scientists to review the scoring of the Air Traffic Selection and Training (AT-SAT) battery. Their concern was that the passing score of 70 should more accurately reflect personal ready to be trained to become air traffic controllers, rather than reflecting the abilities of proficient air traffic controllers. NBCFAE found that AT-SAT is a "model program" after CAMI and HumRRO collaborated in a reweighting of the subtest scores. AT-SAT was subsequently operationally implemented in June 2002. Research on the AT-SAT equating study (to develop a parallel form of AT-SAT and to upgrade the software platform on which the tests are run) commenced following signing of a memorandum of agreement with the US Air Force and the US Navy. Data collection was initiated at Keesler Air Force Base, MS and Pensacola Naval Air Station, FL for students entering air traffic controller training at the respective facilities. The tests are being administered as part of a contract with Caliber Associates.

A project comparing biodata to AT-SAT scores was completed and demonstrating the utility of using biodata to predict AT-SAT scores.

Employee Attitude Survey (EAS)

CAMI provided continued support for the EAS 2000. For example, EAS 2000 was re-administered to two offices in AFS; a summary describing the EAS administrations over the past decade was provided to GAO; and information concerning EAS results for ACS relative to administrations that occurred from 1995 through 2000 was provided in response to a Freedom of Information Act request.

CAMI, AHR, and the EAS Point of Contact (POC) drafted a survey to gather information about the 2000 EAS process and subsequent action planning. The survey was distributed to the EAS line of business (LOB) and major organization (MO) POCs, field POCs, and other individuals involved in the EAS 2000 survey design or action planning workgroups. Respondents also included some LOB, organization, and division or facility supervisors and managers who were not directly involved in the EAS process. One hundred eighty-one individuals responded to the survey. Four data summary reports were delivered to the EAS POCs and union representatives. Currently, LOB and MO

summary reports are under review. A summary paper of the overall results is being drafted.

In preparation for the next administration of the EAS, CAMI scientists met with AHR-40 to discuss the EAS 2003. A package designed to outline the EAS 2003 development process and timeline, advise POCs of their responsibilities, and solicit input on issues of interest was provided to POCs and stakeholders. A draft incorporating the proposed content for the EAS 2003 will be submitted to POCs for review. Additionally, a list of the agency's organizational demographics with specified requested reports across all LOBs and MOs is being prepared.

CAMI scientists served as research consultants to the ATS council group for MWE. These scientist have identified additional EAS and agency metrics that could serve as performance indicators.

In coordination with AMC-8, CAMI completed a request to survey ANI employees concerning the quality of TDY services that they receive. Surveys were distributed to over 1400 employees. CAMI delivered twenty-six summary reports generated from the completed ANI surveys (total N=540 approximately). Included were summary reports for the sub-organizations (e.g., ANI-100 to ANI-900) within ANI. The results of this survey have established a baseline to assess future progress toward improving the quality of TDY services.

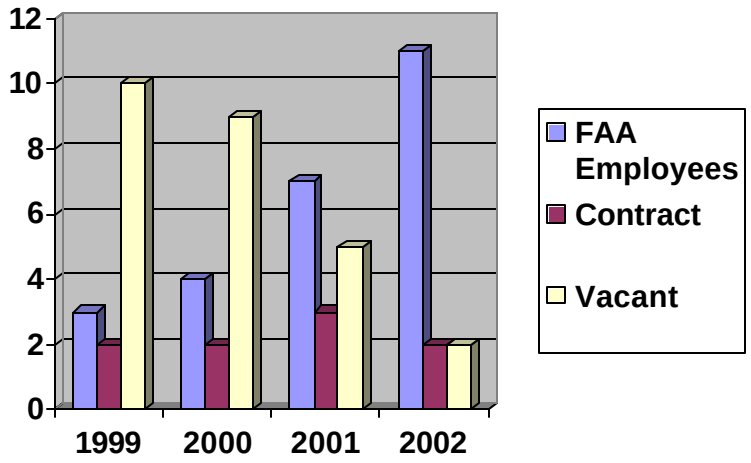
Human Factors Engineering

As part of the FAA's effort to integrate human factors engineering into all systems and applications, the strategy addressing human factors engineering in system acquisition continued to evolve in FY 2002. Under this strategy, efforts were directed toward integrating human factors in and across systems, ensuring that they satisfy (or have initiated actions to satisfy) human factors policies, processes, and best practices. Two elements support the acquisition engineering strategy: (1) institutionalizing policy, processes, and best practices; acquiring technical tools, capabilities, and techniques; and conducting human factors training; and (2) conducting risk assessment and mitigation activities across systems and applications to determine the percent of systems that meet or exceed human factors standards; assessing and establishing human factors infrastructure requirements; ensuring that human factors issues/potential impacts and risks continue to be identified, documented, and resolved; ensuring that resource requirements and implementation plans are established to resolve outstanding issues; and, ensuring activities are conducted to apply human factors engineering principles. During the year, 35 general tasks/milestones were completed in support of these system acquisitions endeavors.

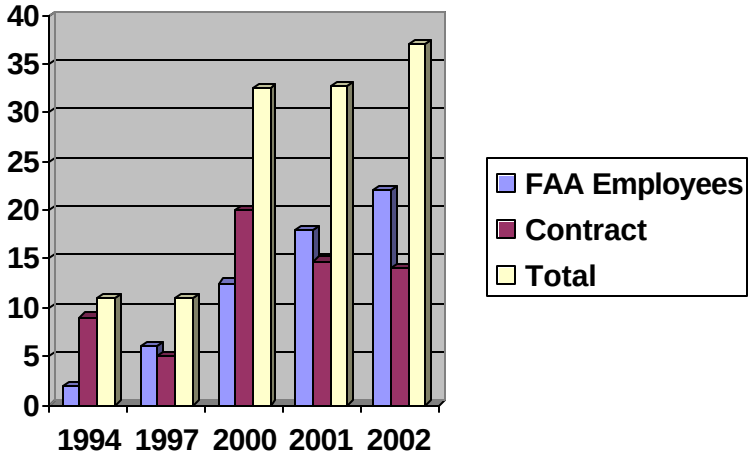
Within the two human factors engineering strategies, important developments occurred in several areas, including: a) human factors infrastructure development, b) direct system acquisition support, and c) connectivity between human factors research/development and acquisition-related system engineering.

For the human factors infrastructure, policies and processes have been established to institutionalize and document the conduct of human factors endeavors, training activities have been established to promote the awareness and understanding of human factors engineering concepts, and personnel staffing decisions have resulted in an increase in the availability of human factors professionals.

One of the most critical sub-elements of these strategies is to ensure that the appropriate level of human factors expertise is available. A staffing plan was prepared to manage and document this important objective. Availability of human factors professionals to support system acquisitions has steadily improved, increasing the number of human factors practitioners across systems, and leaving only two uncovered essential positions within the staffing plan.



Number of HF Professionals in Essential Positions



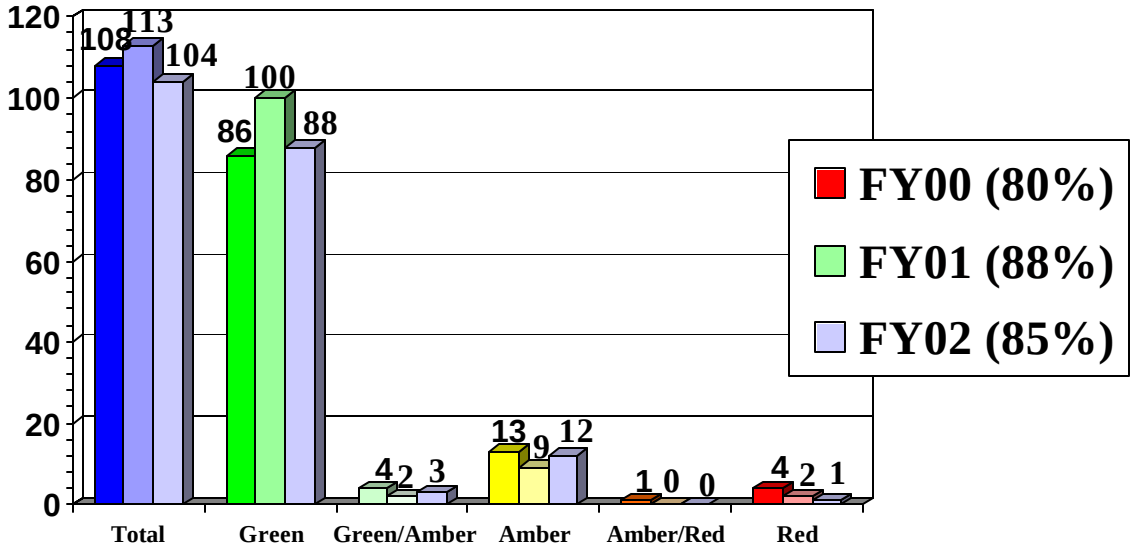
Number of HF Professionals

For the year, staffing goals were achieved by acquiring two human factors professionals to support Integrated Product Teams.

Training of the acquisition population continued to be emphasized principally through two means: a) general awareness training, and b) technical training. Efforts to reach the broader population were initiated with development of the first three of 10 modules of a Web-based Human Factors Awareness Course/Tool. Other efforts to reach the acquisition population included eight training activities for a total of 179 attendees.

The increased availability of trained human factors professionals and the other supporting infrastructure initiatives have improved direct human factors support of requirements development, investment analysis (including cost, benefit, and risk analysis), and system design and development. During the year, human factors practitioners achieved two key tasks/milestones objectives by participating in 11 Investment Analysis activities and nine Integrated Requirements Development activities.

The increased availability of human factors professionals also helped support the identification and mitigation of human factors risks. During the year, 104 system assessments were conducted revealing an 85% rate of integration of human factors best practices in acquisition systems.

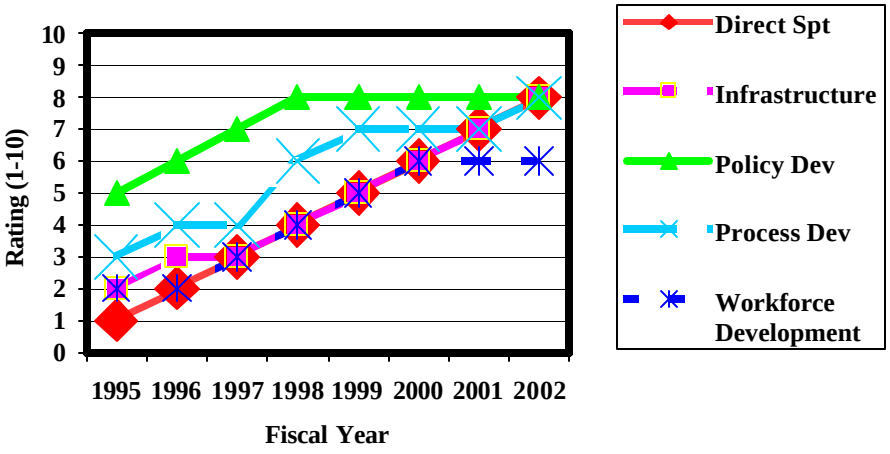


In 2002, 104 system assessments were conducted, revealing an 85% rate of integration of HF best practices in acquisition systems

Connectivity between the application of human factors engineering in system acquisitions and the necessary supporting human factors research has been enhanced through the management of two research initiatives: a) increase human factors considerations and mitigate problems in the acquisition, design, operation, and maintenance of air traffic control automation systems, and b) develop effective methods for the assessment and amelioration of causal factors underlying operational errors/deviations, human error, and performance degradation. Through these strategies and initiatives, human factors issues affecting the incorporation of human performance considerations in NAS acquisitions and operations have been substantively addressed.

In addition, initiatives are underway that support a closer integration between human factors engineering and system engineering -- portent to eliminate barriers to achieving human factors objectives for system acquisitions. These initiatives were met with widespread agreement and resulted in plans for further development during FY 2003. Development of FAA acquisition doctrine, changes in organizational responsibilities, and staffing decisions all supported the strengthening of ties between human factors engineering and system engineering.

Overall, the improvements in integrating human factor engineering in FAA system acquisitions have continued. Many of these longer-term improvements require several years of development. Under subjective and objective criteria, greater integration of human factors engineering (in qualitative and quantitative terms) is evident.



Human Factors Program Evaluation

Aeromedical Research

Access to Egress: Evacuation through a Type III (Overwing) Exit

CAMI's Access to Egress study evaluated aircraft passenger evacuation from a Type III (overwing exit). This research was conducted to provide the FAA rule-making process with information relating to aircraft evacuation through a Type III exit. The study evaluated the passageway configuration (access aisle width leading to the exit), hatch disposal location (hatch placed inside the aircraft or thrown out), subject group size, and subject group motivation level (high motivation subjects received extra pay to exit first). Additional variables of interest included individual subject characteristics (gender, age, waist size, and height), all of which had been shown in previous studies to significantly affect emergency egress. Evacuation trials were conducted with 48 groups of 30, 50, or 70 subjects per group, for a total of 2,544 subject participants, making this the largest cabin evacuation study ever conducted. Each subject group completed four evacuation trials, totaling 192 evacuations. Measures of merit included hatch operation time and the time for individual subjects to egress.

High motivation egress and human factors effects

Data compilation and analysis resulted in the publication of results from the first or naive subject portion of the study. Findings indicated that hatch disposal location (throwing the hatch out) slowed egress in some access aisle width configurations but not in others. Significant main effects on individual subject egress time were found for waist size ($p<.0001$), gender ($p<.0001$), and age ($p<.0001$). A small, but significant, main effect was also found for passageway configuration ($p<.001$), which was confounded by improper hatch disposal and a between-groups imbalance in individual subject characteristics. The findings replicate prior research showing that passageway configuration has only minimal effects on emergency egress, as long as ergonomic minimums involving hatch removal are respected. In contrast, differences in the physical characteristics of individual subjects produce large differences in emergency evacuation performance, as does subject naïveté.

Precious Cargo: Emergency Aircraft Evacuation with Adults Carrying Infants

Twenty-nine survivable aircraft accidents between 1970 and 1995 required the emergency evacuation of 67 infants. Thirty-four percent of the infants received minor to fatal injuries. With the exception of full-scale Type Certifications in which infant dolls are included but not studied, simulated emergency evacuations and evacuation research rarely include infants and young children. The CAMI Cabin Safety Research Team completed a research program to determine the most favorable methods for evacuation of infants using inflatable emergency evacuation slides and the Type III (over wing) exit.

Simulated emergency evacuations were conducted from the CAMI Aircraft Evacuation Facility, using a Type I exit fitted with a Boeing 737 evacuation slide. Six groups of 32 adult evacuees participated in six evacuation trials. Eight evacuees in each group carried one of eight dummies representative of infants ranging from two to 24 months old. Results were analyzed with respect to speed of egress relative to the effects of the carrying and boarding positions. Subject responses to a questionnaire regarding comfort and safety were also analyzed. For speed of egress, the study demonstrated that jumping onto the slide facilitated faster egress times than sitting to board the slide. Subjects also reported that jumping onto the slide was easier than sitting to board the slide. Results also suggested that appropriate carrying and boarding positions would be those most comfortable for the parent and those providing support for the child's head and neck.

Six groups of 25 adult evacuees participated in five evacuation trials with evacuees in each group carrying infant/child dummies. In some trials, subjects were instructed on how to carry the dummy or to pass the dummy to another subject who had already exited. Results confirm the expectation that passing an infant to another subject would produce slower egress than carrying the infant. Results also suggest that the appropriate carrying position would depend on the size of the infant. These research results will support cabin evacuation training and procedures development for improved infant evacuation.

Subject carrying infant dummy during evacuation using slide

Laser Eye Surgery and the Air Traffic Control Specialist

Approximately 150 million Americans use some type of ophthalmic device to correct a vision deficiency. Eye glasses with corrective lenses constitute the vast majority of the ophthalmic devices used for vision correction; however, the use of refractive surgery, particularly laser refractive surgery is rapidly increasing in popularity. With refractive surgery, many individuals can gain needed vision correction and eliminate the need to wear glasses or use of other correction procedures. This popular procedure can have negative effects that should be recognized by Air Traffic Control Specialists and others who have positions that involve stringent visual standards.

A brochure was produced by the CAMI Vision Research Team to provide the air traffic controller with information regarding the compatibility of refractive surgery with the duties and medical requirements of air traffic controllers. The brochure includes descriptions of vision problems, a discussion of refractive surgery techniques, contraindications to surgery, benefits and risks from the surgery, and the compatibility of the surgery with air traffic control duties.

Photo, cover for ATC laser eye surgery brochure

CAMI 747 Aircraft Environmental Research Facility (AERF)

The CAMI 747 AERF was used continuously through FY 2002 for CAMI research programs and Transportation Safety Institute (TSI) training. In addition to research

activities, the facility was used as the focal point for a major aircraft emergency preparedness exercise conducted by Will Rogers Airport and Oklahoma City disaster teams. The 747 AERF supported highly realistic search and rescue scenarios that required the disaster teams to conduct rescue operations in a smoke filled wide-body aircraft environment. The rescue teams found that victim location in a smoke filled aircraft cabin was extremely difficult. Findings allowed the teams to reassess their search techniques. The disaster teams lauded the use of the facility and confirmed that the lessons- learned would support development of improved aircraft (and other public facility) rescue techniques and planning.

CAMI 747 AERF during an exercise

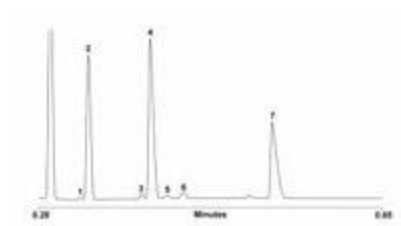
MADYMO (MAthematical DYmanic MOdel) Implementation

The CAMI Biodynamics Research Team initiated a project to utilize the MADYMO program to support impact testing of aircraft occupant seats and restraints. An initial model of a double-occupant passenger seat was completed and a dynamic test was conducted to compare the results derived from the model with the actual impact test results. Additional MADYMO seat models can be developed and actual seat testing will be conducted to enhance capability and improve accuracy in the seat and restraint system modeling process. The long-term objective of this project is to determine potential areas of model applicability in the aircraft seat certification process.

MADYMO simulation of mannequin action during impact

Establishing a New and Improved Gas Chromatographic (GC) Analytical Methodology for Determining Carbon Monoxide (CO) Concentrations in Whole Blood

This research project was completed in FY 2002. Researchers made the new GC carbon monoxide procedure a routine part of the confirmation of CO. The research paper for this new procedure has been approved for presentation at the Society of Forensic Toxicology meeting and as an OAM report and in the peer-reviewed literature.



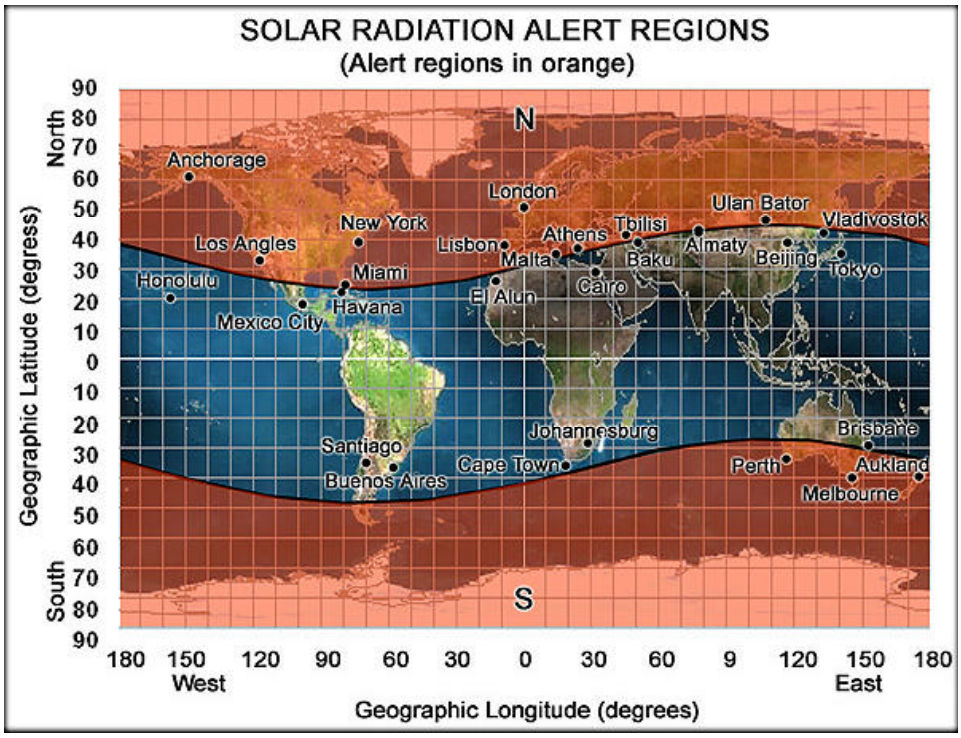
A complete analysis of cabin air quality, including hydrogen, nitrogen, CO, and CO_2, in less than four minutes on a four-channel system

.

Implement Method for Rapid Evaluation of Radiation Exposures to Air Travelers from Solar Particle Events

CAMI researchers completed development of a computer program, which calculates the effective dose of galactic cosmic radiation received by an individual on an aircraft flying a great circle route (or a reasonable approximation) between any two airports in the world. The program takes into account changes in altitude and geographic location during the course of the flight, as derived from the flight profile entered by the user. Deviations from a great circle route of up to 200 miles have very little effect on the flight dose. Based on the date of the flight, appropriate databases are used to account for effects of changes in the earth's magnetic field and solar activity on galactic radiation levels in the atmosphere. The program also calculates the effective dose rate from galactic radiation at any location in the atmosphere at altitudes up to 87,298 feet. The program requires MS-DOS and can be run on most personal computers. Of interest to epidemiologists, the computer program calculates effective doses and dose rates back

to 1958. An article on this research entitled “Radiation Exposure of Aircrews” was published in Occupational Medicine: State of the Art Reviews in 2002.



Development of a Solar Radiation Alert System for the Aerospace Community- Solar Radiation Alert Regions

Toxicology Analysis

The CAMI laboratory received toxicology samples and processed data from 294 fatal aircraft accidents and 364 aviation fatalities that occurred in FY 2002. A total of 351 fatal aircraft accidents were reported nationwide during the same time. The laboratory conducted testing on specimens from 12 living pilots and 17 cases from the previous fiscal year involved with aviation accidents. The laboratory received 17 surface cases for analysis during this fiscal year. A total of 402 cases were analyzed from this fiscal and the previous fiscal year. During the past 12 months, the laboratory received and analyzed 84% of the fatal accidents reported in the Administrator’s Daily Accident Bulletin.

Gene Expression Research

A demonstration on the operation of the Typhoon 9200 imager for gene expression research was made to AAR-1 and AAR-100 during their CAMI visit. A gene expression associated research proposal on performance and ethanol consumption from the

University of Utah was approved. This proposal is related to a collaborative study between the university and CAMI. The DNA laboratory was remodeled to create new office space and a contaminant-free biological sample-preparation room. Methods have been developed for the gene expression/performance impairment research that is being conducted at CAMI. Those methods have been tested and modifications are being made based on the results. Contracts were developed with the Center for Human Toxicology (CHT) at the University of Utah to conduct alcohol performance research based testing in conjunction with the collection of specimens for analysis utilizing gene expression. For the ethanol-related gene expression pattern study, biochemical and chemical reagents have been prepared. Specimens for gene expression testing have been received from the Center for Human Toxicology (CHT) at the University of Utah in a joint effort between CAMI and CHT. These specimens will be analyzed to determine the genes being expressed and compared with performance results reported by CHT. Three new DNA contract scientists have been retained and have reported to duty to assist in the completion of this project.

Urine Validity Testing Colloquium

CAMI conducted a Urine Validity Testing Colloquium. Two meetings of DHHS/DOT representatives from Washington, D.C., and the CAMI members took place at CAMI and in Washington, D.C. A committee consisting of these representatives/members was formed and named as "Urine Validity Testing Steering Committee." During these meetings, the details of the conference were discussed. The visiting representatives were also given a tour of the AAM-610 Toxicology Laboratory. AAM-1 participated in the first meeting as well. The “Urine Validity Testing Colloquium” will be held in Tampa, FL in February, 2003. A list of potential speakers and participants has been developed and these individuals are being formally invited to participate. A report with recommendations will be the final product.

Environmental Safety

A response was prepared on environmental and safety issues associated with polybrominated diphenyl ethers (PBDEs) used in aircraft materials as flame-retardants. Upon the suggestion of the CAMI Director and subsequent approval of AAM-1, an article on PBDEs was published in the Federal Air Surgeon's Medical Bulletin.

Certification of Toxicology Laboratory

CAMI’s Toxicology and Accident Research Laboratory successfully passed its 2001-2003 College of American Pathologists (CAP) inspection without any deficiency and achieved its CAP recertification with the prestigious “Certification with Distinction” rating. The team lead inspector, who is on the CAP advisory board for blood toxicology proficiency-testing, has also received permission to use some of our actual case findings (blinded as to victim identification) as examples of levels of analytes and their metabolites to be used as targets in preparing CAP's proficiency-testing samples for national use. This is an excellent example of an academic and scientific interaction between a national level private sector scientific certifying agency (CAP) and a public sector group (CAMI) in achieving common educational and research goals to ultimately enhance aviation and general transportation safety. The inspector greatly appreciated

observing the unique things done at CAMI and the extensive documentation provided in verifying every aspect of the research currently underway.

Cosmic Radiation

Radiobiology researchers continue to work with the U.S. Air Force to upgrade their version of the CARI-6 computer program for calculating radiation exposure to air crews. The Air Force provides CAMI with ground level radiation data from their measurement site in Thule, Greenland. This data is used to estimate solar activity as data is accumulated for analysis. Several CAMI representatives visited the National Oceanic and Atmospheric Administration's (NOAA) Space Weather Center in Boulder, CO, to discuss implementation of a Solar Radiation Alert system using data from NOAA's GOES satellites. At the request of NASA, CAMI provided information on how the FAA estimates flight doses and provides health risk estimates from radiation exposure. A Solar Radiation Alert system was deployed on the CAMI ftp server using data from NOAA's GOES satellites. An alert is issued when the radiation level at 40,000 feet in higher latitudes from solar protons equals or exceeds 20 microsieverts per hour for at least 15 minutes. An abstract entitled "A Simulated Mission To Mars: Health Effects of Radiation Exposure" was a panel presentation at the 73rd Annual Scientific Meeting of the Aerospace Medical Association.

Bioinformatics Research

CAMI's Bioinformatics Research Team was established in 2002 to integrate safety research efforts across the Aeromedical Research Division. The efforts in bioaeronautical modeling, database and warehouse development, and molecular biochemistry (gene expression) all require expertise in the area of computational science.

Benefits and logic of the Advanced Aerospace Medical Database (AAMD) development that integrates the Toxicology TOX), Airman Certification (DIWS), National Transportation Safety Board (NTSB), Accident Incident Data System (AIDS), and Consolidated Airman Information System (CAIS) into a research data warehouse that serves to enhance our understanding of the relational causes and factors of aerospace accidents and incidents.

Modeling efforts include computational fluid dynamics of cabin airflow, crash dynamics, cabin evacuation and aircraft accident/incident injury patterns. This data warehouse is being designed to aid bioaeronautical scientists in navigating the boundless life sciences data sources that are being generated. The ultimate goal of the database/warehouse system is to provide an integrated environment that searches across multiple data types and dimensions, to find commonalities and relationships between the data, and to provide mechanisms to experiment with these findings in the virtual realm. As new aerospace and medical technologies/techniques provide an increase in the scope and extent of data output, new tools will be developed to analyze this data.

Annex 1 – Financial Highlights

Air Traffic Control/Airway Facilities Human Factors

Budget Authority ($000)	FY 2001 Enacted	FY 2002 Enacted	FY 2003 Enacted	FY 2004 Request	FY 2005 Request
Contracts:					
Air Traffic Control/Airway Facilities Human Factors	2,277	2,756	2,115	2,800	2,832
Personnel Costs	3,984	4,071	4,270	4,457	4,693
Other In-house Costs	1,721	1,673	1,650	1,642	1,619
Total	**7,982**	**8,500**	**8,035**	**8,899**	**9,144**

Flight Deck, Maintenance, System Integration

Budget Authority ($000)	FY 2001 Enacted	FY 2002 Enacted	FY 2003 Enacted	FY 2004 Request	FY 2005 Request
Contracts:					
Flightdeck/Maintenance/System	7,016	6,617	6,711	4,697	4,750
Personnel Costs	2,283	2,398	2,855	2,865	3,015
Other In-house Costs	779	891	845	832	812
Total	**10,078**	**9,906**	**10,411**	**8,394**	**8,577**

Aeromedical Research

Budget Authority ($000)	FY 2001 Enacted	FY 2002 Enacted	FY 2003 Enacted	FY 2004 Request	FY 2005 Request
Contracts:					
Aeromedical Research	938	491	498	353	357
Personnel Costs	3,893	4,268	4,534	4,238	4,232
Other In-house Costs	1,156	1,362	1,571	1,790	2,007
Total	**5,987**	**6,121**	**6,603**	**6,381**	**6,596**

Annex 2: Program Highlights

The human factors team has a clear set of goals and values, and a strategic framework designed to achieve significant products that will improve aviation safety and capacity. This philosophy has carried us through past years with enormous success, it underpins our day-to-day business now, and it is what we aspire to. Some 65 projects are already in-line or in formulation for 2005.

Air Traffic/Airways Facilities 2005

Program Goals:

- The FAA intends to improve air traffic control (ATC) safety by:
- Developing more effective methods for investigating, reporting, analyzing, and mitigating ATC operational errors and Airway Facilities (AF) incidents.
- Developing human factors training aids to mitigate controller performance issues associated with operational incidents and runway incursions.
- Developing human factors educational aids and assessing fatigue countermeasures to mitigate degradation in controller and maintenance specialist performance resulting from shift work.
- Increasing human-system integration in the acquisition and design of ATC automation systems through development of guidelines and standards.
- Improving techniques for forecasting hiring requirements and selecting applicants for Air Traffic (AT) and AF positions.

Outputs: Human performance constraints and other human-system integration issues associated with the acquisition, design, operation, and maintenance of ATC systems are addressed through human factors research that develops guidelines and standards to ensure effective integration of product improvements including communication and surveillance technologies. Human factors analysis of operational errors including runway incursions identifies improvements in how errors are investigated and reported, which in turn will lead to more effective safety interventions. The study of the relationship between shift work schedules and fatigue identifies techniques for mitigating degradations in controller and AF specialist performance. Tests and criteria for the selection of operational personnel will improve applicant screening efficiency and validity, and reduce costs associated with attrition and training failures.

Customer/Stakeholder Involvement: The ATC/AF Human Factors Research Program is directly tied to ARA Performance Goal 1. Safety: In support of the FAA's mission goal related to system safety, contribute to the FAA goal to reduce the fatal aviation accident rate 80% by FY 2007 as compared to 1994-1996 baseline data. Goal 1 implementation involves safety performance measures and safety strategies leveraging human factors research on operational

errors/deviations and runway incursions as part of an overall system engineering effort to mitigate the risk of safety hazards.

The ATC/AF Human Factors Research Program is the product of continued coordination between the Human Factors Research and Engineering Division (AAR-100) and its ATS customer base through the Air Traffic System Requirements Service (ARS).

Research is addressing the highest priority human factors issues among the 70 recommendations identified by the National Research Council in its 1997 and 1998 reports on current and future ATC automation. Research assesses human performance issues associated with National Airspace System advances identified in the Operational Evolution Plan (OEP). The program examines advanced automation and technologies integrated as part of FAA and industry Concepts of Operations, the AF maintenance concept for NAS Infrastructure Management, and the NAS Architecture Version 4.0. Applied research provides the information necessary to understand human performance limitations, enabling human factors practitioners to identify and resolve risks, and to assess costs, benefits, and trade-offs. The ATC/AF Human Factors Research Program addresses the recommendations of the congressionally mandated Research, Engineering, and Development Advisory Committee (REDAC).
The FAA human factors program is coordinated with NASA through the Inter-Agency Air Traffic Management Integrated Product Team (IAIPT), and with the DOD through the Human Factors Engineering Technical Advisory Group. This program is developed around the research thrusts identified in the 1995 joint FAA-NASA-DOD *National Plan for Civil Aviation Human Factors: An Initiative for Research and Application* consisting of the following:

- *Information Management and Display* - Determine what, when, and how to best display information through the computer-human interface (CHI); design the system to reduce the frequency of information transfer errors; and minimize the impact when such errors do occur. Display designs are optimized to reduce information overload.
- *Human-Centered Automation* - Keep the operator in the loop and situationally aware of automated system performance while balancing operator workload; resolve issues related to the degradation of basic skills should the automation fail.
- *Human Performance Assessment* – Improve the quality of critical decisions; assess cognitive and contextual factors leading to human error; develop effective countermeasures to reduce errors and performance inefficiencies; assess the impact of organization culture on performance; and improve and standardize methods for measuring human performance.
- *Selection and Training* - Assess the knowledge, skills and abilities needed to excel in highly automated environments; assess retirement and attrition patterns to predict hiring requirements.

Accomplishments: The program has supported the following research with resulting products:

Information Management and Display

- Human Factors Design Standard (HFDS) – Updated and formalized design information into the HFDS to provide Integrated Product Teams with standards and guidelines for effective human factors design of automation and advanced technologies.
- Human-system integration – A risk assessment identifying inconsistencies in the design of user interfaces between terminal radar baseline systems and their anticipated product improvements and other subsystems to be integrated as part of the NAS evolution.
- Maintenance user interface standardization – Assessed inconsistencies in display symbology and aural tones in monitor and control legacy and acquisition systems.
- Standard Terminal Automation Replacement System (STARS) – Developed recommendations addressing issues with the STARS radar display and maintenance control workstations.

Human-Centered Automation

- Flight strip studies – Identified operational functions in controller use of paper flight progress strips to support transition to Free Flight decision support automation.
- Multi-tool interoperability analysis – Adapted a cognitive walkthrough methodology to identify human factors, operational, and functional issues with en route decision support and data link capabilities collocated in controller workstations.
- Controller performance using decision aids – Completed a complex human-in-the-loop simulation to develop recommendations for improved controller performance and team communications in use of a conflict probe.

Human Performance Assessment

- ATC operational errors – Completed initial field beta testing and validation of a new methodology called JANUS for reporting and analyzing causal factors associated with ATC operational errors.
- Controller fatigue – Completed the congressionally mandated fatigue study through surveys and field and lab biomedical studies, and distributed an informational CD on countermeasures to fatigue resulting from shift work.
- Impact of shared separation on ATCS situation awareness – Conducted a study of impacts from distributed air/ground separation responsibility on air traffic controller performance.

- Dynamic airspace boundaries – Assessed the impact of airspace restructuring on controller performance through modeling and simulation.

Selection and Training

- Prototype air traffic applicant screening system – Developed a prototype biographical assessment tool for screening job applicants.
- Computerized selection test battery – Completed concurrent validation of a new computerized Air Traffic Selection and Training (AT-SAT) test battery for ATC.
- Statistical Attrition and Retirements Model (SCRAM) – Developed prototype model for projecting retirements and attrition from AT/AF critical occupations from historical data.
- Runway safety training aid – Developed an aid for controllers and pilots containing relevant human factors information on communications, attention, and memory to help prevent runway incursions.
- Human factors training aid for controllers - Prepared aid providing information controllers can use to enhance job performance.

Partnerships: Research is coordinated with NASA in the areas of distributed air/ground separation responsibility, decision support automation, and controller task load measurement through the IAIPT, which also provides a framework for coordination with MITRE. University grants are addressing tower controller use of paper flight strips, human factors with advanced surveillance technology, and collaborative decision making in Air Traffic Management (ATM). Internationally, collaborative research with EUROCONTROL and the Icelandic Civil Aviation Administration addresses human error in the design and operation of ATC systems and assessment of human factors in advanced oceanic technologies and procedures.

Major Activities and Anticipated FY 2004 Accomplishments:
Information Management and Display

- Display of weather products on terminal controller displays – Conducted studies assessing controller operations with use of enhanced weather products such as storm movement and wind shear.
- Human-system integration issues – Conducted detailed assessments of inconsistencies and other human factors risks in integration of enhanced capabilities in oceanic and offshore ATC legacy systems.
- Enhanced surveillance data – Developed controller information and display requirements to effectively use Automated Dependent Surveillance-Broadcast.

- Electronic flight data - Developed recommendations for display techniques for flight progress data to meet tower controller information needs. Developed design guidelines for tower flight data display.

Human-Centered Automation

- Interoperability between advanced decision aids – Assessed the cumulative impact on controller performance, situation awareness, and workload resulting from the incremental integration of decision aids and data link.
- Multi-sector planning position assessment – Evaluated controller performance and inter-sector communications, and identified information requirements for decision support automation, associated with a new en route operational position to facilitate traffic flow.
- Human-in-the-loop simulation of centralized maintenance – Developed maintenance specialist information requirements for decision making through simulations of advanced monitor and control capabilities.

Human Performance Assessment

- Incident causal factors – Evaluated a web-based prototype knowledge management system to integrate and analyze causal factors data from assessments of operational errors and runway incursions.
- Reduction of operational errors – Assessed improvements to the JANUS technique for the mitigation and reduction of human and system errors in air traffic operations.
- Reduction of runway incursions – Assessed human factors improvements to tower team operations for improving runway safety.
- Maintenance communication workload - Recommended inter- and intra-facility communication and coordination flows to mitigate impacts from workload and human error.
- Maintenance specialist cognitive performance – Identified recommendations to mitigate human factors impacts from off-normal maintenance operations.
- Organizational assessment – Reported on lessons learned, organizational issues, and successful practices in developing a Model Work Environment from the FAA-wide Employee Attitude Survey.
- Task load and performance assessments - Assessed use of objective task load and performance measures in Performance and Objective Workload Evaluation Research (POWER) to assess controller task load across different ATC systems.

Selection and Training

- Maintenance training issues – Assessed specialist and technician training strategies and equipment to identify shortfalls in use of new monitor and control systems and technologies.
- Selection of applicants ATS positions – Developed technical enhancements and continued longitudinal validation of screening and testing tools for selection of applicants into ATS positions.
- ATS management training assessment – Identified recommendations to resolve ATS management training and succession planning shortfalls relative to requisite skills and experience for management positions.

Projected FY 2005 Research Program

The FY 2005 program supports ATS with research to address human-system integration issues in the acquisition, design, operation, and maintenance of ATC systems over the next several years. Research projects will provide timely information to answer critical human factors questions.

New Initiatives:

Information Management and Display

- Develop design guidelines addressing human factors issues in integrating collocated decision support tools in en route controller workstations.

Human-Centered Automation

- Evaluate the distribution of separation responsibility between controllers and pilots.

Ongoing Activities:

Information Management and Display

- Examine HSI issues with surveillance product improvements for terminal systems.
- Develop baseline requirements for tower controller flight data information needs and assess display requirements.
- Assess controller information and display requirements to effectively use Automated Dependent Surveillance-Broadcast (ADS-B) in oceanic operations.

Human-Centered Automation

- Assess interoperability of advanced decision aids and data link for effects on Radar and Radar Associate controller responsibilities.

- Assess how interdependencies in use of collocated decision support tools impacts controller roles and responsibilities.

Human Performance Assessment

- Develop recommendations and guidance addressing airspace design issues and supervisory best practices to reduce the incidence of operational errors.
- Develop a training aid prototype addressing tower controller team situation awareness and communications.
- Assess differences and develop recommendations for use of commercial and specialized training for AF specialists.
- Recommend best practices through an organizational assessment addressing the Model Work Environment.
- Validate task load and performance measures obtained before and after implementation of new controller automation tools.
- Fatigue and shift work - Validate use of key countermeasures in operational settings to mitigate fatigue from shift work.

Selection and Training

- Identify changes to controller selection tools required to address knowledge, skills, and abilities (KSAs) associated with enhanced controller tools.
- Assess longitudinal validation of ATS selection processes.
- Develop recommendations addressing ATS management training shortfalls limiting succession planning.

Key FY 2005 Products and Milestones:
ATS-related research within the *National Plan* research thrusts include:
Information Management and Display

- Human-system integration issues – Recommendations and guidance addressing inconsistencies and other human factors risks in integration of enhanced surveillance terminal legacy systems.
- Electronic flight data – Display and automation recommendations for flight progress data meeting tower controller information needs.
- Oceanic surveillance – Findings and guidance addressing controller workload, situation awareness, and procedures from use of ADS-B in non-radar operations

Human-Centered Automation

- Advanced decision aids interoperability –Guidance to resolve issues to support integration of decision aids and data link to mitigate impacts on controller performance.
- Free Flight design guidance - Automation guidelines and design recommendations addressing the interoperability between Free Flight decision aids and data link.
- Shared air/ground separation responsibility –Recommendations addressing controller performance effects from distributed air/ground responsibility for pilot self-spacing and separation.
- Centralized maintenance – AF specialist training needs supporting information requirements, situation awareness, and decision making with integration of controller workstation technologies.

Human Performance Assessment

- Reduction of operational errors causal factors – Human factors guidance for mitigating operational error causal factors associated with airspace complexity and supervisory best practices.
- Runway safety – Prototype training aid facilitating shared situation awareness through improved tower controller communications.
- AF specialist error management –Recommendations addressing trends in human error and maintenance incidents associated with centralized maintenance centers.
- Organizational assessment – Lessons learned, organizational issues, and successful practices in developing a Model Work Environment from the FAA-wide Employee Attitude Survey.
- Task load and performance assessments – Validation of objective task load and performance measures in Performance and Objective Workload Evaluation Research (POWER) to assess controller task load across different ATC systems.

Selection and Training

- Changes in AT/AF KSA profiles – Changes in KSA profiles for selecting applicants to AT and AF positions n
- Selection necessitated by transitions of NAS enhanced capabilities of applicants ATS positions –Technical enhancements and continue longitudinal validation of screening and testing tools for selection of applicants into ATS positions.
- ATS management training assessment – Recommendations to support ATS management training and succession planning.

Flight Deck, Maintenance, System Integration 2005

Program Goals:
The FAA intends to improve air transportation safety by:

- Developing more effective methods for aircrew, inspector, and maintenance technician training.
- Enhancing the understanding and application of error management strategies in flight and maintenance operations.
- Increasing human factors considerations in certification of new aircraft and equipment design and modification.
- Improving aircrew, inspector, and maintenance technician task performance.

Outputs: The FAA is concerned with ensuring the safety and efficiency of operator performance through guidelines, handbooks, advisory circulars, rules, and regulations. It provides industry with human performance information and guidance critical to the design, operation, regulation, and certification of equipment, training, and procedures. With this in mind, the human factors program conducts and manages research that provides the technical information necessary to generate these products and services.

Customer/Stakeholder Involvement: The human factors program directly supports a number of aviation community initiatives:

- *FAA Strategic Plan Mission Goal for Safety*. By FY 2007, reduce U.S. aviation fatal accident rates by 80% from 1996 levels.
- The FAA/Industry *Safer Skies* initiative, which will use the latest technology to help analyze U.S. and global data to find the root causes of accidents and determine the best actions to break the chain of events that lead to accidents.
- This program is also developed around the research thrusts identified in the 1995 joint FAA-NASA-DOD *National Plan for Civil Aviation Human Factors: An Initiative for Research and Application* consisting of the following:
  - Information Management and Display - Determine what, when, and how to best display information through the computer-human interface; design the system to reduce the frequency of information transfer errors; and minimize the impact when such errors do occur. Display designs are optimized to reduce information overload.
  - Human-Centered Automation - Keep the operator in-the-loop and situationally aware of automated system performance while balancing operator workload; resolve issues related to the degradation of basic skills should the automation fail.
  - Human Performance Assessment – Improve the quality of critical decisions; assess cognitive and contextual factors leading to human error;

develop effective countermeasures to reduce errors and performance inefficiencies; assess the impact of organizational culture on performance; and improve and standardize methods for measuring human performance.

- Selection and Training – Understand the relationship between human abilities and aviation task performance; develop a scientific basis for the design of training programs, devices and aids; enhance the measures and methods for prediction of job/task performance; assess the knowledge, skills and abilities needed to excel in highly automated environments; identify methods by which to select aviation system personnel.

- NASA's Aviation Safety Program
- The FAA report entitled "The Interfaces Between Flight Crews and Modern Flight Deck Systems". Public Law 100-591, which establishes requirements for human factors research and its application.
- The Advanced Qualification Program (AQP), which has been adopted by every major U.S. carrier, incorporating human factors training into pilot qualification and recurrent training programs.
- Crew Resource Management (CRM) training procedures, a variant of which has been adopted by virtually every major domestic air carrier.

Accomplishments: The program output of data packages, models, and regulatory documents includes:

Information Management and Display

- Developed a manual that addresses appropriate human factors considerations in designing flight deck operating documents. This manual was adopted by the International Civil Aviation Organization (ICAO) for distribution to its member states.
- Published the Aviation Maintenance Human Factors Guide.
- Developed and implemented the Agency's first virtual collaborative research team to communicate and disseminate information in real time regardless of distance or other constraints on research team members.
- Developed (with industry) the first industry standard and guidance document on implementing an aviation maintenance human factors program.
- Developed the Aviation Maintenance Document Design Aid incorporating simplified English and utilizing advanced technology to standardize aviation maintenance documentation.
- Developed guidance and recommendations on human factors best practices in fluorescent penetrant, borescope, and visual inspection. These projects provide a more systematic view of human/system interaction for aviation maintenance personnel.
- Completed human factors guidelines for assessing advanced general aviation transportation experiment (AGATE) cockpit controls/displays.

- Developed human factors design and evaluation considerations for electronic flight bags, version 1.0 and version 2.0.
- Completed assessment of human factors issues and current knowledge concerning use of head-up displays in air transports.
- Addressed human factors issues for cockpit head motion box associated with air transport head-up displays.
- Completed data link lessons learned compendium for inclusion in RTCA DO-238A, “Human Factors Requirements and Guidance for Controller/Pilot Data Link Communications Systems”.

Human-Centered Automation

- Completed human factors certification job aid version3.0 for FAR Part 25 flight deck displays.
- Developed aircraft certification human factors and operations checklist for stand-alone global positioning system receivers.
- Developed initial performance models for automation usage in air carrier cockpits.

Human Performance Assessment

- Developed guidance and recommendations for an advisory circular that permits the use of personal computer aviation training devices in instrument training programs conducted under FAR Part 61 and Part 141 and authorizes the use of a personal computer aviation training device to be substituted for 10 of the 15 hours authorized for an approved flight.
- Complied a list of interventions, encompassing initial and recurrent pilot training, organizational and procedural enhancements, and modifications to information display and format, that will improve pilot aeronautical decision making so as to reduce the instances of fatal general aviation accidents.
- 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 speaker technicians’ comprehension for aircraft maintenance work cards.
- Completed a geographical regional analysis on pilot error - found no differences between FAA regions (including Alaska) in the relative distribution of errors and violations committed by general aviation pilots involved in accidents.
- Developed prototype Automated Performance Measurement System (APMS) which allows air carriers to gather and analyze flight data from aircraft data recorders. This information and analysis capability provides the backbone for

the Flight Operations Quality Assurance Program (FOQA), a joint FAA, industry and labor initiative to enhance aviation safety.

- Provided industry and FAA with preliminary reports on the antecedents of flight deck error.
- Developed guidance and standardized shift turn over procedures for use in aviation maintenance.
- Developed pilot performance profile, through flight simulation, for use in establishing certification standards for general aviation auto-navigation and control systems.
- Provided expanded APMS methodologies and analysis capabilities in order that air carriers can collect and analyze increasing amounts of flight and simulator data.
- Developed initial mapping of flight data parameters onto AQP qualification standards.
- Completed a comprehensive human factors analysis of scheduled air carrier and fatal general aviation accidents using the human factors analysis and classification system (HFACS).

Selection and Training

- Developed standards and implemented a distance learning Aviation Maintenance Technician and Aviation Maintenance Technician Transport (AMTT/AMT-T) training curriculum.
- Developed and validated a proceduralized pilot CRM training and assessment system.
- Developed the Model AQP to support regional air carrier participation. AQP is a proficiency-based approach to pilot training that is considered to be highly effective and efficient for aircrew training.
- Developed air carrier training data analysis tools used by carriers and the FAA for quality assurance efforts.
- Provided Flight Standards guidance for developing pilot training regulations based on data from a study of 30,000 domestic air carrier pilots. The study examined pilot's perceptions of training effectiveness across the entire U.S. aviation industry.
- Developed line operations safety audit (LOSA) methodology used by air carriers to help determine safety vulnerabilities. This methodology has been adopted by ICAO and was distributed to member states.
- Provided industry and FAA with preliminary guidelines on air carrier training for flight deck interruptions and for the performance of concurrent critical tasks.

- Provided industry and FAA with air carrier training guidelines for pilot decision-making, addressing first officer's hesitancy to challenge the captain in potentially high-risk situations.
- Developed a system to allow air carriers to reconfigure FAA approved flight scenarios to unique training segments and developed a generic line oriented evaluation event set database to be used by any air carrier.
- Incorporated air carrier and FAA user comments into an enhanced reconfigurable event set scenario development system.
- Provided FAA and Industry preliminary guidelines on managing pilot skill degradation through innovative training schedules.
- Provided industry and FAA preliminary training guidelines for automated flight decks.
- Provided FAA and Industry guidance on approaches to incorporating realistic radio communications into simulators to train pilots for the complex operating environment.
- Developed the Maintenance Resource Management (MRM) handbook for use by industry.
- Completed the prototype MRM distance learning project that will be implemented and used by the U.S. Navy for training their aviation maintenance technicians. Further application can be applied to U.S. Coast Guard aviation maintenance technicians.
- Developed an Advisory Circular on training, qualification, and certification of nondestructive inspection personnel.
- Developed a prototype automated system of self instruction for specialized training for the industry aviation maintenance inspector workforce.
- Developed a CD-ROM training program that guides general aviation pilots through the creation of a personal checklist that incorporates minimum operating conditions and procedures based upon their own personal capabilities and experience.
- Developed a CD-ROM training program which describes the structured decision-making style of experienced general aviation pilots compared to less experienced pilots. The program stresses situational awareness, diagnosis, resolution, and vigilance.
- Developed a CD-ROM training program that teaches general aviation pilots to recognize the cues associated with deteriorating weather while in-flight, and to take appropriate action to avoid weather.
- Defined critical flight task performance that decays over time in air carriers.
- Developed methodologies to analyze cognitive strategies for using automation systems in air carrier cockpits.
- Developed methods to incorporate automation specific training scenarios into the system that reconfigures event sets for unique training sessions.

- Developed advanced data analysis methods for linking FOQA and simulator training data.
- Analyzed data from line observations and laboratory studies to provide training guidance on human error management.

R&D Partnerships: Collaboration has continued between the FAA and industry partners to develop intervention strategies and reduce aviation accidents through the various Joint Safety Analysis Teams (JSATs) and Joint Safety Implementation Teams (JSITs) developed as part of the Safer Skies agenda. The program is coordinated with NASA through the NASA Aviation Safety Program's emphasis on human factors concerns associated with air carrier and general aviation pilot training, aviation maintenance, human performance modeling, and weather displays. DOD joint efforts are in automation and enhanced vision. Additionally, the FAA is represented on the DOD Human Factors Engineering Technical Advisory Group, a forum for the coordination of research across a variety of technical areas. A collaborative research effort is underway with the Joint Aviation Authorities (JAA) and Transport Canada (TCCA) to produce human factors input for the harmonization of regulatory guidance material. Through aviation maintenance partnerships with industry, the FAA and industry are receiving real world applied research results. Aviation maintenance human factors is also working with other countries (such as Transport Canada) for globalization of aviation maintenance and inspection human factors. The FAA participates on all of the Society of Automotive Engineers G-10 human factors subcommittees related to human factors research areas, ensuring transition of the results to standards, guidelines, etc. The FAA also has extended seventeen grants to universities supporting research on air carrier training, flight deck automation, aviation accident analysis, general aviation, and aviation maintenance technician and inspector training.

Major Activities and Anticipated FY 2004 Accomplishments:

Information Management and Display

- Completed analysis on whether digitizing maintenance data (manuals, work cards, inspection information, and/or procedures for sign off) affects maintenance performance.
- Expanded research into the design and certification of primary flight displays that may contain terrain representations and flight guidance cues.
- Completed guidance on human factors improvements to NOTAMs.
- Identified human factors issues for instrument procedure design.
- Conducted human factors investigations of advanced terrain and weather displays.

Human-Centered Automation

- Completed human factors certification job aid for FAR Part 25 considerations and applications.
- Provided human factors guidance for certification of non-profile RNP navigation displays.

Human Performance Assessment

- Continued research to validate rotorcraft pilot precision VFR routes metrics to performance in a simulator.
- Expanded research into causal factors of general aviation accidents and incidents attributed to human error.
- Completed analysis on Part 145 operators language related error patterns, and measure the effectiveness of recovery / mitigation strategies in improving written, and perhaps also verbal, comprehension of maintenance related documentation.
- Completed analysis on the potential impact of a proposed visual standard on the current maintenance personnel involved in nondestructive inspection and testing (NDI/NDT) and visual inspection of aircraft.

Selection and Training

- Completed guidance on the effectiveness of the Personal Computer Aviation Training Device (PC-ATD) and Flight Training Device (FTD) in conducting instrument proficiency check flights.
- Continued assessment of the actual types of maneuvers, procedures, or tasks taught in various flight training devices and personal computer aviation training devices.
- Continued development of the knowledge base of problems in visibility in the aviation environment, suggested possible solutions to such problems, and produced interactive educational materials to train pilots to recognize hazardous visual conditions and take appropriate action.
- Continued development of capability to extend earlier work on computer-based inspection training for the commercial aviation system to the general aviation inspection training system.
- Developed Aviation Safety Action Program (ASAP) enhancements to reporting of factors contributing to aviation incidents.
- Continued development of guidance on new air carrier CRM training post 9/11.
- Continued development of guidance on training air carrier flight crews for unexpected events.

- Continued expansion of Knowledge Assessment software tool for assessing knowledge structures and mental models necessary for the operation of automated aircraft.
- Developed software enhancements to Rapidly Reconfigurable Line Oriented Evaluations (RRLOE) scenario generation tools and collected air carrier user data.

Projected FY 2005 Research Program:

The program continues to focus on providing technical information and consultation to improve aircrew, inspector, maintenance technician, and aviation system performance. Emphasis is on developing guidelines, tools, and training to enhance error capturing and mitigation capabilities in the flight deck and maintenance environments; and on developing human factors tools to ensure that human performance considerations are adequately addressed in the design and certification of flight decks and equipment.

New Initiatives

Human Performance Assessment

- Develop a robust general aviation-training program that can integrate different technologies into any aircraft platform.

On-going Activities

Information Management and Display

- Evaluate pilot performance resulting from the use of terrain representations in primary flight displays.
- Develop human factors guidance for instrument procedures design.
- Develop human factors guidance for certification of weather displays.
- Assessment of air transport and general aviation head-up/head-down displays.
- Develop flight data recording and analysis capability for flight simulators.
- Evaluate whether broadband technology may aid maintenance personnel tasks and work environment.

Human-Centered Automation

- Evaluation of human factors issues regarding RNP information on navigation displays.
- Provide expanded guidance addressing training for automated cockpits.
- Development of the human factors certification job aid.

Human Performance Assessment

- Expand research into causal factors of general aviation accidents and incidents attributed to human error.
- Develop improved guidelines for accident investigation and reporting.
- Refine air carrier flight and simulator data analysis tools.
- Examine simultaneous non-interfering operations for helicopter and fixed-wing aircraft to determine human performance implications.
- Develop enhanced capabilities for APMS.

Selection and Training

- Evaluate computer-based inspection training for general aviation inspection training.
- Continue research to quantify pilot visual recognition under non-optimal visual conditions.
- Continue research to determine the number of credit hours for which various Flight Training Devices (FTD) and Personal Computer Aviation Training Devices (PCATD) may be used in lieu of actual flight.
- Expand development of pilot error safety management interventions and enhancements to reporting of accident/incident causal factors.
- Develop advanced analysis methods linking FOQA and simulator data.
- Develop methodologies to link air carrier pilot performance data to curriculum modification.
- Develop guidelines for air carrier pilot training intervals.

Key FY 2005 Products and Milestones:

Information Management and Display

- Provide human factors guidance on of how broadband technology may aid maintenance personnel tasks and work environment.
- Expand research into the design and certification of primary flight displays that may contain terrain representations and flight guidance cues.
- Continue investigation of human factors issues and concerns for instrument procedure design.

Human-Centered Automation

- Complete human factors certification job aid for FAR Part 23 flight decks.

Human Performance Assessment

- Provide guidance for rotorcraft precision visual flight rules routes and air traffic control procedures that use global positioning system to enhance helicopter pilots' ability to navigate more efficiently in the national air space.
- Complete guidance on error frequency, patterns of error types, effectiveness of intervention strategies and recommendations for action to mitigate language related errors for maintenance facilities and third-party repair stations.
- Provide guidance for a recommended visual standard for maintenance personnel involved in nondestructive inspection and testing (NDI/NDT) and visual inspection of aircraft and aircraft components.
- Expand research into causal factors of general aviation accidents and incidents attributed to human error.

Selection and Training

- Continue research on the revision of FAR 61-141, by specifying the number of credit hours for which various FTDs and PCATDs may be used in lieu of actual flight.
- Provide education materials designed to improve pilot recognition and performance under non-optimal visual conditions, and ultimately reduce accidents related to poor visual conditions.
- Complete guidance on an industry-wide benchmark for general aviation inspection training including a prototype training system on appropriate media.
- Develop software tools to assess current automation knowledge with appropriate retraining strategies.
- Complete the first phase report on the linking of RRLOE and Model AQP.
- Complete initial guidelines for self-report safety systems.
- Develop FOQA software analysis tools.
- Complete evaluation of the safety.
- Complete guidance on an industry-wide benchmark for general aviation inspection training including a prototype training system on appropriate media.
- Develop software tools to assess current automation knowledge with appropriate retraining strategies.
- Complete the first phase report on the linking of RRLOE and Model AQP.
- Complete initial guidelines for self-report safety systems.
- Develop FOQA software analysis tools.
- Complete evaluation of the safety implications of the monitored approach.

- Complete initial guidelines for effective decision making among Voluntary Safety Program teams.
- Complete initial report on pilot performance skill decay in mixed fleet flying.

Aeromedical Research 2005

Program Goals:

The FAA safety mission dictates that:

- Injury and death patterns in civilian flight accidents be investigated and meticulously analyzed to determine the cause and develop prevention strategies.
- Recommendations for protective equipment and procedures be developed.
- Options be evaluated on behalf of FAA regulatory and medical certification staff charged with the proposal of safety and health regulations addressing all aircraft.

The identification of pilot, flight attendant, and passenger medical conditions that are incompatible with in-flight physiological and performance demands, both in the absence and in the presence of emergency flight conditions is a concurrent mission. The resulting bioaeronautical data is to be effectively shared using advanced, user-friendly simulation/modeling and visualization technologies.
Outcomes/Outputs: The outcomes addressed by this research program are improved health, safety, security, protection, and survivability of aerospace craft passengers and aircrews. This research program identifies human tolerances, capabilities, and failure modes (physiological, psychological, and performance) both in uneventful flight, and during aerospace craft incidents and accidents. Formal recommendations for protective and supportive countermeasures and techniques are derived from research.
The FAA is able to exploit new and evaluate existing bioaeronautical guidelines, standards, and models for aerospace craft cabin equipment, procedures, and environments. This serves as a base for new regulatory action and the evaluation of existing regulations to enhance appropriate human performance. By reviewing pilot medical histories, flight histories, information from accidents and incidents, existing and advanced biomedical criteria, standards and assessment/ certification procedures can be proposed to ensure optimal performance capability. By assessing pilot, flight attendant, air traffic controller, and passenger work, environmental, behavioral and disease issues, guidelines for actions to improve the health and safety of the aerospace craft occupant can be proposed based on rigorous scientific criteria.
The program has developed the following guiding research outcomes to support regulatory and certification processes:

- Quantitative bioengineering criteria to support optimum aerospace craft seat and restraint system certification.
- Quantitative bioaeronautical criteria to support flotation and onboard life support/rescue equipment certification.
- Quantitative biomedical and performance criteria to support development of optimum protective breathing equipment, emergency medical equipment, and operational procedures certification.
- Identification of biomedical/toxicological factors in uneventful flight and in aerospace craft incidents and accidents.
- Fact-based recommendations for aircrew medical standards, assessment/certification procedures, and special issuance.
- Quantitative data about the health risks of flight deck, cabin crew and other occupants to support regulatory oversight.
- Quantitative data about aerospace radiation and other aerospace craft environmental factors and their threats to all occupants.
- Quantitative bioaeronautical, bioengineering and performance criteria to support cabin evacuation certification.

Customer/Stakeholder Involvement: This program contributes to meeting the FAA Strategic Plan Mission Goal for Safety. The program is developed around a research agenda set forth in the *National Plan for Civil Aviation Human Factors: an Initiative for Research and Application:*

- Bioaeronautics – Improve the health, safety, protection, survivability and security of aircraft passengers and aircrews through identification of human tolerances, capabilities, and failure modes (physiological, psychological, and performance) both in uneventful flight, and during aircraft incidents and accidents.

The program contributes significantly to the application of emerging technologies, as highlighted in the FAA Aviation Safety Plan. The program is an integral participant and research provider under the FAA, Joint Aviation Authorities (JAA), and Transport Canada Aviation (TCA) Aircraft Cabin Safety Research Plan established in 1995 as a coordinated, living plan to maximize the cost-benefit of aerospace craft cabin safety research nationally and internationally. International Civil Aviation Organization (ICAO) initiatives addressing the health of the aircraft occupant (crew and passenger) are developed under this program before final FAA recommendations are provided to ICAO. This program is the only research component of the FAA that can legally access confidential medical data about pilots for use in epidemiological research studies. Multi-year collaborative studies performed by the FAA and other agencies, both governmental and industrial, evaluating flight crew and passenger symptomatology and diseases have been funded by this budget item to satisfy

the mandate placed by Congress upon the agencies in the FY 1994 Appropriation Act and the Wendell H. Ford Aviation Investment and Reform Act of the 21st Century.

Accomplishments: The program output includes the following :

- In 2000, an effort was initiated to develop a computational fluid dynamics model of airflow and particle distribution in aircraft cabins. The events of September 11, 2001, disease transmission risk, cabin air quality concerns, and the potential for a bioterrorist attack heightened requirements for an aeromedical research effort to develop a program to determine the distribution of potential aerospace craft cabin contaminants or chemical-biological agents. The model supports determination of the number/location of aircraft occupants who may be affected in an attack, areas of cabin contamination, and potential sensor/warning system requirements, and is supported by studies conducted in the CAMI 747 Aircraft Environment Research Facility (AERF). In the summer of 2002, CAMI hosted a colloquium on cabin airflow modeling that enhanced research collaboration and supported industry-wide dissemination of the modeling information.
- Data are continuously provided to research sponsors on the role of toxicological and clinical factors associated with aircraft accidents and incidents. The FAA has worked in close collaboration with the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) to implement Congressionally-mandated cabin air quality research recommended by the National Research Council.
- Current findings indicate that about one in four pilots fatally injured in a civilian aircraft accident show evidence of using a prescription drug; one in six has taken an over- the-counter drug; one in twenty has alcohol in excess of FAA regulations; and one in eleven is using a significant controlled dangerous substance.
- Long-term aerospace forensic and epidemiological research has helped the FAA to identify bioaeronautical roles in accident/incident causation. Medical and other factors indicative of pilot incapacitation and inability to perform optimally are under continuous evaluation.
- To promote radiation safety in civil aviation, Web-based materials on cosmic and solar radiation exposures in-flight are continuously provided to the aviation industry in addition to a continuous Solar Radiation Alert System.

R&D Partnerships: In addition to the previously described partnerships (e.g., FAA/JAA/TCA; FAA/ASHRAE, academic, industrial, and other governmental organizations) coordination and cooperation are maximally leveraged in all research activities. In each of the program area output categories, the FAA maintains direct cooperative research processes with all the manufacturers responsible for the safety products enumerated (seats, restraint systems, oxygen masks, evacuation slides, etc.). FAA investigators also maintain memberships on every Society of Automotive Engineers committee addressing safety research

conducted under this program. Besides active involvement in the FAA/JAA/TCA process of oversight for safety research, participants in this program are represented on appropriate subgroups of organizations such as the Aerospace Medical Association, the Civil Aviation Medical Association, and the Professional Aeromedical Transport Association. Appropriate liaison with all military branches and NASA is maintained either through direct project collaboration (e.g., crashworthiness, aerospace medicine, eye injury from lasers, exposure to cosmic radiation), or through participation in aerospace medical advisory groups, the European Union, or collaborations in scientific organizations. Collaboration with the National Academy of Science (NAS) in the NAS Associate program is on-going.

Major Activities and Anticipated FY 2004 Accomplishments:

- Performed epidemiological assessment of biochemical and toxicological factors from fatal civilian aerospace accidents.
- Evaluated aircraft accidents involving pilots using new anti-depressant medications (selective serotonin re-uptake inhibitors, SSRI's).
- Evaluated autopsy data from fatal aviation accidents to provide recommendations for improvement of protective equipment and design practices.
- Completed report on vision standards for NDI/NDT aviation maintenance inspectors.
- Conducted evacuation research evaluating planned egress into water.
- Initiated research investigating passenger decision-making in transport aircraft emergency evacuations.
- Provided enhanced guidelines for aircraft cabin occupant health maintenance, including improvement of the CARI series radiobiological computer programs that estimate galactic radiation exposure.
- Issue recommendations to establish neck injury criteria for side-facing seats.
- Established correlation of neck injury and impact dynamics measured using anthropomorphic test mannequins to assess the potential for improved aircraft seat test criteria.
- Established molecular biological (gene expression) technology for identifying alcohol impairment in aerospace accidents/incidents.
- Utilize the recently upgraded CAMI narrow body Aircraft Cabin Evacuation Facility (ACEF) to support a NASA/FAA research program to define operational requirements for clear air turbulence warning systems.

Projected FY 2005 Research Program:
The Office of Aerospace Medicine encounters complex medical decisions during the initial and follow-up medical assessments of airmen who request special medical issuances (e.g., cardiac conditions, neurological deficits, corrective vision surgery, etc.) to permit their continued flying. The prospective epidemiological assessment of special issuance methodology and medical outcomes in the airman population is required to ensure that medical issuances do not result in unexpected or increased aircraft accident or incident rates or risks. Continual enhancement of the safety and health of all occupants of an aerospace craft is also required. The following activities are therefore planned.
New Initiatives:

- Initiate enhanced passenger safety, health, and survival knowledge research.
- Initiate cabin layout simulation modeling for improved cabin evacuation performance.
- Lead a combined FAA/Industry research effort to develop state of the art cabin air quality and chemical-biological agent sampling equipment.

Ongoing Activities:

- Support improved aircraft cabin evacuation approval guidelines and applications under routine and emergency operational conditions.
- Reduce head, neck, torso, and extremity injuries in aircraft crash environments.
- In response to congressional directives, develop methods for reducing cost, time, and complexity of airplane seat certification.
- Evaluate trends in toxicological, biochemical, physiological, and clinical findings from all major civil aviation aircraft crashes.
- Support Aviation Rule Making Advisory Committee reviews of cabin air quality and altitude safety rules.
- Improve programs dedicated to the enhancement of passenger performance in emergencies.
- Evaluate in-flight use of medical kits, and determine the adequacy of those kits.
- Track special medical issuance pilots and pilot medical incapacitation to evaluate relative risk and the continuance of specific aeromedical certification standards.
- Provide recommendations for limits to radiation exposure (laser and ionizing).
- Develop an advanced aeromedical research accident database that is user friendly, has rapid response, and produces advanced statistical and graphics analysis.

- Conduct performance and protection assessment of pilot eye-respiratory protective equipment, including protection from chemical/biological agents.

Key FY 2005 Products and Milestones:

- Provide recommendations for guidelines related to aircraft ditching.
- Develop CARI series computer programs for estimating radiation exposure to passengers and crew during flights to low earth orbit.
- Evaluate pilot reported medication usage with actual toxicology findings to determine the accuracy of self-reporting.
- Submit revision to ANSI Z136.6 (Outdoor Laser Safety Standard) for publication.
- Evaluate aircraft cabin airflow characteristics to support evaluation of cabin environmental quality and health.
- Assess bioaeronautical research data that will support aeromedical certification aimed at reduction of in-flight sudden/subtle incapacitation.
- Evaluate sport-pilot medical accident data.
- Assess molecular biological (gene expression) techniques that will enhance forensic toxicological aspects (fatigue/altitude) of aircraft accident investigation.
- Provide recommendations related to the use of crash dynamic modeling for compliance with FAA regulations.
- Benchmark passenger knowledge of evacuation and safety.
- Explore research to determine crew and passenger safety requirements in advanced technology very high altitude transport air or spacecraft.