Federal Aviation Administration

Research & Development

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Contents

Every day the aviation community faces a number of challenges that range from ensuring the health and safety of passengers and crew to protecting the environment, increasing capacity and efficiency, and maintaining an aviation system that is performance-based and human-centered. To meet these challenges, we are dedicated to four goals: increased safety; greater capacity; international leadership; and organizational excellence. FAA's 47,000 employees are making a difference every day as they work to achieve these goals and create a better air transportation system.

We are making a difference every day.

We are succeeding, in part, because of the dedicated work of our research and development program. Our researchers, scientists, engineers, and professional staff are creating the tools, technologies, and procedures that continue to improve the air transportation system. We are conducting critical research for aviation's future.

The Fiscal Year (FY) 2005 R&D Annual Review highlights another successful year for our researchers. In these pages, you may review some of our ongoing work in support of the Agency's strategic mission and goals. For additional information on the R&D program, please see the *National Aviation Research Plan*, which includes a description of our R&D projects, our research partners, budget information, and expected future results.

Aircraft Safety

Evaluating Multiple-Site Damage in Fuselage Structure

In 1988, the FAA established a broad regulatory program to ensure the structural integrity of aging aircraft following the near catastrophic structural failure of a 737 flight to Honolulu, Hawaii. Since that accident, in which small cracks emanating from multiple rivet holes in a debonded lap joint resulted in a large portion of the fuselage crown tearing apart, researchers have focused efforts on developing methodologies to assess multiple-site damage in aircraft structures. (At the joint, the two parts of the fuselage are bonded, and then mechanically fastened with three rows of rivets. A debond happens when the glue in the joint no longer holds up. This results in the rivets carrying all the load across the joint, and when this happens, the rivet holes become hot spots for cracks to develop.) Research efforts sponsored by the FAA, National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD) include the development of various analytical tools that address this complex problem at several levels. Researchers have developed rigorous numerical methods and simplified engineering approaches to predict crack initiation, growth, linkup, and residual strength.

In an effort to provide experimental data for model validation, researchers used the FAA Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) facility to investigate multiple-site damage initiation and growth in a pristine fuselage lap joint panel. The test panel, representative of a generic narrow-body fuselage, included a stiffened structure containing six frames, seven stringers, and a four-rivet row lap joint. During the fatigue test, researchers monitored and recorded damage formation and growth in the lap joint in real time using the Rotating Eddy-Current Probe (RECP) system and high-magnification visual methods. Researchers initially detected cracks in the outer critical rivet row A in the lap joint after 12,600 flight cycles take off and landing using RECP. While manufacturers of today's large commercial aircraft originally anticipated their aircraft would remain in service for twenty years accumulating 60,000 flights, many are currently being flown longer.

Researchers found visually detectable cracks in the rivet head of the critical rivet row after 51,500 cycles and then in the lap joint outer skin after 80,500 cycles. The first multiple site damage linkup occurred after 106,217 cycles, forming a lead crack. Subsequently, the lead crack grew very rapidly along the outer rivet row eventually forming a 16.04" two-bay crack after 107,458 cycles.

Researchers conducted a residual strength test to determine the load-carrying capacity of the panel. They found that the panel failed catastrophically when the lead crack extended instantaneously in the lap joint across four skin bays. Researchers examined the fracture surfaces using a high magnification scanning electron microscope to determine initiation sites and mechanisms and to reconstruct subsurface crack growth behavior from marker band locations in the first visually detected crack. The results from this examination of a single crack revealed multiple initiation sites and extensive fretting damage along the faying surface of the skin. Results from this study provide key data to verify and validate fatigue damage assessment approaches. Additional details about this research can be found in Ahmed, A. and Bakuckas, J. G., *Development of Multiple-Site Damage in Fuselage Structure* (DOT/FAA/AR-05/38, September 2005), on-line at http://aar400.tc.faa.gov/Programs/AgingAircraft/Structural/reports/reports.htm.

Assessing Commercial Aircraft Lap Joint Damage

As part of its National Aging Aircraft Research Program, the FAA is developing and testing new technologies and techniques to predict, detect, and mitigate the deterioration of aircraft structures. Researchers are conducting comprehensive tear down inspections, collecting data, and performing structural evaluations and assessments of older, operational aircraft. During the past fiscal year, researchers disassembled the fuselage of a retired Boeing 727 aircraft to collect data on an aircraft near the end of its design service goal of 60,000 flights. During this tear down, researchers focused attention on the fuselage crown lap joint, which has a known history of multiple-site damage cracking.

Researchers developed a tear down procedure to characterize the state of damage to measure crack sizes, shapes, and distributions, to study crack initiation sources and sites, and to reconstruct crack growth histories through striation counts. Examination of the lap joint found over 350 cracks in 270 rivet holes in a fuselage section approximately 30 feet in length. The cracks typically ranged in size from 0.01 to 0.2 inches. The majority of holes had multiple cracks, up to six or seven in some cases, in a starburst pattern around the lower two-thirds region of the hole in the lower skin. Many of these cracks had multiple origins at the corner of the hole and the faying surface, which eventually formed a contiguous crack.

The FAA will use the data from this study to: characterize crack initiation; crack linkup, and residual strength; assess the inspection capability of nondestructive inspection techniques to detect cracks; and determine widespread fatigue damage average behavior in the structures removed and examined. Additional details about this research can be found in Bakuckas, J. G., Bigelow, C. A., Carter, A., and Steadman, D., "Destructive Evaluation and Extended Fatigue Testing of Retired Aircraft Fuselage Structure," *Proceedings of the 23rd Symposium of the International Committee on Aeronautical Fatigue,* June 6-10, 2005, Hamburg, Germany, on-line at http://aar400.tc.faa.gov/Programs/AgingAircraft/Structural/reports/reports.htm.

Detecting Structural Cracks in Helicopters

Increasing niche applications, growing international markets, and the emergence of advanced rotorcraft technology are expected to increase greatly the use and number of helicopters over the next decade. As the helicopter industry expands and adapts to new situations, it is critical to ensure the appropriate application of nondestructive inspection equipment to manage structural safety. Currently, the capabilities for nondestructive inspection of rotorcraft are essentially limited to the techniques established for fixed wing aircraft. Since the environments in which rotorcraft operate are significantly different than fixed wing aircraft, much smaller cracks must be found than current nondestructive inspection techniques can detect

Researchers at the FAA Airworthiness Assurance Nondestructive Inspection Validation Center at Sandia National Laboratories recently collaborated with Bell Helicopter and others in the rotorcraft industry to evaluate nondestructive inspection capabilities aimed at detecting small cracks under button head or raised head fasteners. The FAA and rotorcraft industry identified this as an important near-term issue because cracks in high cycle fatigue joints, such as those found in the tail boom and transmission assembly regions, can quickly grow from small initiation lengths to critical lengths in a relatively few number of flight hours. Researchers designed a series of tests to isolate and study the effects of different rivet scenarios using various eddy current and ultrasonic inspection techniques. Two of the most promising advanced methods are a remote field eddy current technique and a linear array ultrasonic system. The remote field eddy current technique is based on electromagnetic induction and is used to identify or differentiate among a wide variety of physical, structural, and metallurgical conditions in electrically conductive metals. Linear array ultrasonic inspection injects a short pulse of ultrasonic sound into a component to detect internal defects. Both techniques demonstrated the ability to detect small cracks under the rivet heads. Researchers are now working with industry to transfer these inspection methods to industry for routine use in rotorcraft maintenance depots. Successful transition will aid the rapid integration of these improved nondestructive inspection methods in a cost-effective manner.

Improving the Usability and Reliability of Aviation Technical Manuals

Aviation maintenance technical manuals provide critical information to aircraft maintenance, design, and inspection personnel. These manuals have increased in number and complexity as aviation systems have become more sophisticated, and the process for making changes to these manuals has grown increasingly cumbersome and expensive.

Research shows that the current generation of technical manuals may contain an unacceptable level of built-in errors generated from within the publication process. Tasks that are inadequately or incorrectly described are likely to generate process errors. Process errors, in turn, can lead to equipment failure and costly rework. In addition, researchers have discovered that some procedures are difficult to perform as described in technical manuals.

To improve the quality of these technical manuals, the FAA, under a cooperative agreement with Wichita State University National Institute for Aviation Research (NIAR), and in conjunction with aircraft manufacturers (Raytheon, Bombardier, Cessna, and Boeing), conducted experiments with engineers and technical writers to identify the most effective techniques for developing and validating maintenance procedures for technical manuals. Based on the research results, they developed the on-line Evaluation Toolbox for Aviation Technical Writers (http://www.niar.twsu.edu/humanfactors/toolbox/default.htm). This toolbox contains concepts, evaluation methods, tools, templates, and references to educate and assist technical writers in developing better technical documentation.

At a June 2005 workshop sponsored by the FAA, NIAR, and the aircraft manufacturers, researchers disseminated their results to approximately 50 technical writers from the aircraft manufacturers, the FAA, National Transportation Safety Board, and Boeing, as well as directors of technical publications from Cessna, Bombardier, and Raytheon. The local general aviation manufacturers are currently working with the Kansas Technology Enterprise Corporation, a private/public partnership established by the state of Kansas to promote technology-based economic development, and to develop a training program for technical writers based on this research. The FAA also plans to use the research results to develop an advisory circular.

Studying Side Load Factors During Aircraft Ground Operations

The FAA Operational Loads Monitoring Research Program is defining the service-related factors that affect the operational life of commercial aircraft by collecting, analyzing, and publishing data in statistical formats that will enable the FAA to reassess existing certification criteria. Equally important, the new data will also enable the FAA, the aircraft manufacturers, and the airlines to understand better and control those factors that influence the structural integrity of commercial transport aircraft.

In support of a number of FAA certification initiatives, FAA researchers completed a study of ground operations using airplane data recorded by digital flight data recorders to assess 0.5G limit lateral load criteria for wide body aircraft, in particular, the Airbus 380. Airbus had requested a reduction in the 0.5G Limit Load specified in Title 14 Code of Federal Regulations (CFR), Part 25.495. The study provided the technical data for the regulatory agencies to make an informed decision. Lateral acceleration certification criteria described in the CFR for commercial aircraft operations are based primarily on the two ground events considered the most critical to the aircraft structure: the touchdown and ground turns.

Researchers found a significant difference in the touchdown lateral acceleration between wide body airplanes and narrow body airplanes. Data show that, in general, the size and weight of the aircraft is a significant factor affecting the magnitude of the touchdown lateral acceleration. Smaller airplane models, such as the Boeing 737, tend to incur most of their higher lateral acceleration values while turning, probably because of higher speed and landing gear configuration. Heavier airplanes are prone to encounter lower values of lateral acceleration while taxiing and tend to have their highest lateral accelerations occur during the touchdown event and subsequent rollout.

As a result of this work, the FAA Aviation Rulemaking Advisory Committee recommended a special condition to 14 CFR 25.495 to reduce the ground turning requirement from 0.5G to 0.42G for the Airbus A-380. The results of this study are documented in *Study of Side Load Factors During Ground Operations* (Technical Report DOT/FAA/AR-05/7), which can be found on-line at http://www.tc.faa.gov/its/worldpac/techrpt/ar05-7.pdf.

Updating and Commercializing the Metallic Materials Properties

The Metallic Materials Properties Development and Standardization (MMPDS) process is an effort led by the FAA to collect, analyze, and publish statistically based, standardized information on aircraft and aerospace material and fastener properties that comply with FAA regulations. The publication, *Metallic Materials and Elements for Aerospace Vehicle Structures,* formerly known as Military Handbook-5 (MIL-HDBK-5), is recognized worldwide as the most reliable source for verified design standards needed for metallic materials, fasteners, and joints used in the design and maintenance of aircraft, missiles, and space vehicles.

In August 2005, Battelle Memorial Institute issued the first commercial version of the MMPDS-02 handbook. The FAA granted Battelle, a not-for-profit organization, an exclusive license, subject to annual renewal, to reproduce and distribute the handbook and related products. The latest version of the handbook includes descriptions of 12 new alloys. The volume includes:

Volume 1 - Introduction and Guidelines (Chapters 1 and 9)
Volume 2 - Steel and Magnesium Alloys (Chapters 2 and 4)
Volume 3a - 2000-6000 Series Aluminum Alloys (First part of Chapter 3)
Volume 3b - 7000 Series and Cast Aluminum Alloys (Second part of Chapter 3)

Volume 4 - Titanium and Heat-Resistant Alloys (Chapters 5 and 6)

Volume 5 - Miscellaneous Alloys & Structural Joints (Chapters 7 and 8)

Additional information can be found on-line at http://www.mmpds.org.

Developing Nondestructive Inspection Methods for Composite Aircraft Structures

The use of composite materials in commercial large transport aircraft structures is becoming more common as evidenced by the planned production of the Boeing 787 and the production of the Airbus 380 aircraft. Composites offer lighter weight and equivalent strength to the metals they replace. By the nature of their fabrication, however, composites offer new challenges to inspectors. Composite inspection often requires scanning of large areas for subsurface damage. This can be time-consuming and may require intricate mapping of the surface when damage is detected mapping and interpretation of the inspected area.

Composite sandwich panels with honeycomb cores are widely used in aircraft as secondary structures and control surfaces for rudder skin panels, spoilers, flaps, engine cowlings, landing gear doors, and body fairings. When a honeycomb structure is crushed or damaged, the damaged area may be removed and repaired with patches of similar layers of material bonded in place at an airline composite shop. Repairs are occasionally performed aboard aircraft and cured without the benefit of an autoclave, which may introduce more porosity than typically found in undamaged structures. A primary maintenance concern is how to determine whether these repairs are structurally sound.

Because traditional ultrasonic inspection techniques are not as effective on composites, the FAA funded Iowa State University, through the FAA Airworthiness Assurance Center of Excellence, to develop a nondestructive inspection technique for composite structures. Researchers developed a prototype air-coupled ultrasonic system, comprised of a computer and scanning equipment, for assessing composite damage and repairs. This is a noncontact ultrasonic technique in which air acts as a coupling medium between the ultrasonic transducer surface and the object under examination. Hence, in contrast to conventional techniques, no coupling gel or immersion in liquid is required.

Field tests of the new system proved successful. For example, researchers used the system to map the extent of damage to rotors on a Blackhawk helicopter at the Iowa Army National Guard Unit. They also conducted successful tests on a set of 42 honeycomb panels containing engineered flaws. This work marks the first demonstration of a non-contacting, non-contaminating air-coupled ultrasonic inspection tool in the field. Efforts are currently underway to license the technology and transfer it into the commercial sector.

Creating Flame Retardant Composites

The use of composite structures in both commercial and general aviation aircraft is increasing because of advantages such as lower weight, better fatigue performance, no corrosion, and better design flexibility. The new Airbus 380 and 350 for example, are expected to have over 20 percent of the structural weight in composites, including a carbon fiber reinforced epoxy wing. About 50 percent of the structural weight of the new Boeing 787 will be composites, making it the first large commercial airliner with a composite fuselage and wings. Although currently no fire resistance or flammability requirements exist for exterior polymer composite structures on airplanes, aircraft manufacturers must demonstrate that those composites provide equivalent safety to the current material (aluminum alloy).

Polymer composites can be flammable, so halogen (bromine and chlorine) containing flame retardant chemicals are normally added to reduce their flammability. However, halogen-containing flame retardants are being phased out all over the world because of environmental concerns, so FAA researchers are now working to identify new, non-halogen, environmentally-friendly strategies for reducing the fire hazard of polymer aerospace composites. To this end, use of epoxy resins and/or curing agents containing phosphorus, which is an environmentally-acceptable alternative to halogens, is being incorporated into existing aerospace epoxy formulations at low levels to provide low flammability structural composites with little or no compromise in processing, handling, and mechanical properties. Working with the FAA, NASA researchers synthesized epoxy resins and their curing agents containing phosphorus, characterized the phosphorus-containing epoxy formulations (resin and curing agent) by thermal analysis and flame tests, and measured their mechanical properties. NASA showed that the fracture toughness and compressive strength of several cured formulations showed no detrimental effect due to phosphorus content.

At the FAA, researchers used fire calorimetry and microscale combustion calorimetry to measure the flammability of the compounds. They observed a three-fold reduction in flammability for the phosphate epoxies, which contained the most phosphorus-oxygen chemical bonds. However, testing indicated that phosphorus in the compounds tested had no significant effect on flame chemistry. Instead, researchers attributed flammability reduction to the creation of a protective layer of char catalyzed by the phosphorus on the surface of the composite. The activity of phosphorus as a char catalyst increased with the number of phosphorus-oxygen bonds in the curing agent or epoxide, indicating that the catalyst for char formation is a phosphorus oxide or a phosphorus acid.

The work will be published in the journal *Polymer (*P.M. Hergenrother, C.M. Thompson, J.G. Smith Jr., J.W. Connell, J.A. Hinkley, R.E. Lyon, and R. Moulton, "Flame Retardant Aircraft Epoxy Resins Containing Phosphorus" *Polymer* 46, 5012-5024).

Licensing the Microscale Combustion Calorimeter

In a fire, the temperature at which a combustible material ignites (the ignition temperature), the rate of mass loss as the material subsequently burns (the burning rate), the rate at which the material releases heat in flaming combustion (heat release rate), and the maximum amount of heat that can be released by burning (heat of combustion) are the primary indicators of the material's hazard to life and property. The time available for passengers to escape from a fire in an enclosure such as an airplane cabin is determined by the growth rate of the fire. The fire growth rate increases with the ignitability and the heat release rate (HRR) of the materials in the enclosure. Resistance to ignition can be defined as the minimum (critical) heat flux or fire size below which the material will not burn. The critical heat flux (CHF) is related to the ignition temperature of the material (T_{ign}) as $CHF = \sigma T^4_{ign}$ where $\sigma = 5.7\ W/m^2\text{-}K^4$ is the Boltzmann constant. HRR is the product of the mass loss rate (MLR) or burning rate and the heat of combustion of the material (HOC): HRR = MLR x HOC.

In practice (i.e., in fire calorimeters), mass loss rate and heat release rate are measured continuously during the test by weighing the sample and measuring the amount of oxygen consumed by combustion, respectively. At the present time these fire hazard indicators, ignition temperature, heat release rate, and heat of combustion, are measured using procedures published by the American Society for Testing and Materials (ASTM) in at least three separate devices requiring at least one kilogram of material to complete all of the tests. Consequently, an instrument and method that measures ignition temperature, burning rate, heat release rate, and heat of combustion in a single, rapid, and quantitative test under fire-like conditions using a small amount (milligrams) of substance is of theoretical and practical importance to fire protection engineers and materials scientists.

The FAA filed an application for a new patent with the Patent and Trademark Office in December 2005 for a Flammability Tester. The Flammability Tester combines methods of thermal analysis and fire calorimetry in a single device that simultaneously measures multiple flammability parameters (HRR, HOC, and T_{ign}) of combustible materials using small samples. The method and apparatus is useful for quickly and accurately testing milligram and larger samples of combustible materials.

On January 18, 2005, the FAA licensed The Govmark Organization, Inc., Farmingdale, New York to manufacture and sell the Flammability Tester. On March 11, 2005, the FAA also licensed Fire Testing Technology, Ltd., in the United Kingdom, to manufacture and sell the Flammability Tester.

Evaluating the Flammability of Aircraft Electrical Wiring

Over the years, a number of aircraft wire insulation materials have been used throughout the aircraft. The composition of the wire insulation is dependent upon the wire location (environmental conditions) and its purpose. Examples of common wire insulation materials include aromatic polyimide, and fluoropolymer insulation, such as ethylene tetrafluoroethylene, polyvinyl chloride/nylon, and crosslinked-polyalkene. As technology has progressed, improvements in aircraft wiring have been made. Some of these improvements include arc propagation resistance, a decrease in smoke production, and better flammability properties.

The FAA issued its first flammability test requirement for electrical wiring in 1972, mandating, among other things that insulation on electrical wire or cable installed in any area of the fuselage must be self-extinguishing when subjected to what is called the 60-degree test. The 60-degree Bunsen burner test determines the resistance of electrical wire insulation to flame. The pass/fail criteria are based on the burn length, after-flame time, and drip-flame time. The FAA is now examining the currency of this flammability test requirement in light of the advent of new wiring and insulation materials and manufacturing processes to ensure the maximum safety for travelers.

To test the adequacy of the flammability requirement, researchers subjected samples of electrical wiring and electrical wiring insulation to the standard flammability test. They tested twelve specimens, and all but two passed the test. The 60-degree test did not discriminate very well between the performances of different materials. The difference in burn length for the best and the worst materials proved minimal.

In a second phase of testing, researchers evaluated five of the original twelve types of wire and cable, using a second type of flammability test. Researchers found the Polytetrafluoroethylene (PTFE)/polyimide/PTFE construction to be the overall best performer. Another round of tests confirmed these results.

Test results showed that the 60-degree single wire Bunsen burner flammability test might not be adequate to qualify wire when bundled and subjected to a severe ignition source. The FAA is currently expanding its research to upgrade the fire test criteria for electrical wiring and materials in other hidden areas, such as the attic above the cabin ceiling, areas beneath the floor, and areas in or around the lavatories. The test results are documented in *An Evaluation of the Flammability of Aircraft Wiring* (Technical Note, DOT/FAA/AR-TN04/32), which can be found on-line at http://www.fire.tc.faa.gov/pdf/TN04-32.pdf.

Studying In-Flight Flammability and Fuel Tank Inerting

Recent FAA research has illustrated that fuel tank inerting could be practical in the commercial fleet, thus reducing the risk of fuel tank explosions, if air separation modules could be used effectively in an inert gas generation system. Fuel tank inerting is accomplished by displacing the air in the existing empty tank space above the fuel (ullage) with nitrogen or nitrogen-enriched air generated by an onboard inert gas generation system. The FAA fuel tank inerting initiative focuses on center wing or body style tanks in the commercial transport airplane fleet. These tanks are frequently not used by the aircraft operators, and are likely to be empty on most domestic flight operations.

To demonstrate the use of hollow-fiber membrane air separation modules, the FAA, with the assistance of several aerospace companies, developed a prototype onboard inert gas generation system that uses aircraft bleed air to generate nitrogen-enriched air at varying flows and purities during a commercial airplane flight cycle. Additionally, the FAA developed models and experimental methods to predict oxygen levels and the progression of flammability in an aircraft fuel tank ullage throughout a typical flight cycle.

In conjunction with NASA aircraft operations personnel, FAA researchers conducted a series of ground and flight tests to evaluate the FAA inerting system and examine the flammability of both the center wing and one inboard wing fuel tank. The inerting system was mounted in the pack bay of NASA's Boeing 747 SCA, which is used for transporting the Space Shuttle Orbiter. During testing, researchers used special instrumentation to measure aircraft flight parameters, as well as fuel tank oxygen concentration and flammability, to understand better the ability of the FAA inerting system to reduce the flammability exposure of the center wing tank of a commercial transport airplane.

Test results prove the viability of the FAA inerting system, validating the primary research assumptions. Flammability measurements from both the center wing tank and the wing tank showed trends consistent with experimental and

computational analysis previously performed and allowed for the potential improvement of ullage flammability models. A description of the flight test program and findings are contained in *Evaluation of Fuel Tank Flammability and the FAA Inerting System on the NASA 747 SCA* (DOT/FAA/AR-04/41), authored by Mike Burns, William Cavage, Robert Morrison, and Steven Summer. The report is available on-line at http://www.fire.tc.faa.gov/pdf/05-25.pdf.

In December 2005, as a result of this research, the FAA issued a notice of proposed rulemaking for new rules. That would require operators and manufacturers of transport category aircraft to take steps, that in conjunction with other required actions, should greatly reduce the chances of a catastrophic fuel tank explosion.

Improving the Fire Safety of Insulation Material

The FAA recently proposed an Airworthiness Directive (AD) that would require U.S. airlines to remove thermal acoustic insulation blankets made of a Mylar® film called AN-26 from over 800 of their transport aircraft. Service experience and tests conducted by FAA fire safety researchers prompted the proposed AD. The tests demonstrated that the film consistently could be ignited by an electrical arc and could cause a fire aboard an aircraft.

Aircraft insulation blankets are used primarily to protect passengers and crew from engine noise and, at high altitudes, from frigid temperatures. They are typically composed of a batting material, generically referred to as fiberglass, with a covering of film that both contains the batting and resists the penetration of moisture. Metallized polyethyleneteraphthalate (MPET) and AN–26 are specific choices of films that aviation manufacturers have used as coverings.

Based on in-service experience in the mid-1990s, FAA researchers began investigating the adequacy of the existing Bunsen burner flammability criteria for testing thermal acoustic insulation. Those tests alerted the FAA to the need for a new certification standard, but any such standard would have to be based on a test method capable of screening out materials considered too hazardous for future installation.

While developing the new test standard, FAA fire researchers also established criteria to determine whether or not existing materials could safely remain in service. A review of the service history, and subjecting AN–26 to a variety of tests, revealed that even though the material met the standards in place at the time of original certification in 1981, this type of insulation material could result in a fire when subjected to electrical arcing and sparks. In cooperation with industry, the FAA used the insulation blankets' response to electrical arcing and spark testing as the basis for identifying the unsafe condition with MPET, and determined that these same safety criteria were applicable to AN–26. Additional research data have shown that contamination, such as dust, lint, grease, corrosion-inhibiting compounds, can increase susceptibility to ignition and flame propagation. As a result of this research, the FAA has proposed adopting the new airworthiness directive for certain Boeing transport category airplanes. The proposed AD would require replacing any insulation blanket constructed of polyethylene teraphthalate (PET) film, ORCON Orcofilm AN–26 with a new insulation blanket.

Because of the large cost of removing AN26 (estimated to be 400 million dollars for the U.S. fleet), the FAA conducted additional work to evaluate alternate means of compliance for the proposed AD. Researchers have already evaluated a fire blocking cover and a spray-on fire retardant, and they will continue to conduct tests to ensure that any approved alternate means of compliance meets the intent of the proposed AD.

Developing New Fire Test Methods

In 2003, the FAA passed a new rule pertaining to the flammability of thermal acoustic insulation used in transport category aircraft. The rule established two new tests – the first measures a material's capability to resist flame spread from a small ignition source, and the second determines the ability of a material to resist penetration or burn through from an external fuel fire. A radiant panel is required to conduct the flame spread test, while an oil-fired burner is used to simulate the external fire in the burnthrough test. Both of these tests are significantly better than the previous test method used to qualify insulation materials.

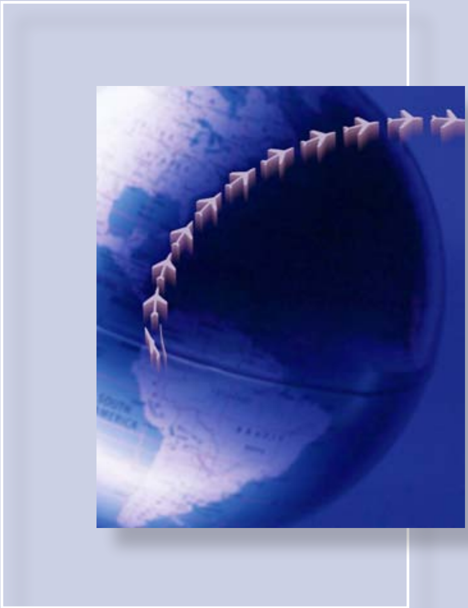
Although researchers have developed and refined these new tests over the past two years, many details still need to be addressed with regard to the conduct of these tests and the actual installation of insulation blankets in an aircraft. In terms of flame propagation, for example, many components of the blanket system, such as tape and "hook and loop" fasteners must also be tested since they are considered part of the blanket system and affect whether or not the material will propagate a fire. To ensure that all blanket components are properly tested, the FAA recently developed advisory circulars for both new test methods based on results from the latest research. The radiant panel advisory circular (AC 25.856-1) describes the test methodology and pass/fail criteria for evaluating the flammability of insulation blankets containing sub-components, such as thread, tape, and hook and loop. Tapes, for example, are used during initial production and also in making repairs to an in-service aircraft. Since it is not practical to test each possible configuration of tape and film/batting material, researchers have developed a simplified process using strips of tape. The advisory circular also requires testing for structural damping materials. For example, although small aluminum sheets bonded directly to the airplane skin are not considered insulation, materials that include a layer of foam or other material sandwiched between the skin and thin aluminum sheets should be tested.

The burnthrough advisory circular (AC 25.856-2) describes the appropriate methods of installing the insulation in an aircraft. Insulation materials can be classified into three basic categories: batting systems, barrier systems, and encapsulating systems. The advisory circular describes each system type and provides schematic examples of each in an appendix. In addition, it highlights critical installation areas, such as blanket overlap at frame members, horizontal blanket overlap, penetrations, and types of installation hardware. It includes a detailed test methodology for evaluating the burnthrough resistance of two horizontally overlapped blankets, and describes the appropriate test methodology for evaluating system performance in the event that an alternative approach is desired. This methodology includes a description of the test apparatus modifications necessary to fully evaluate any unconventional approach.

An electronic version of the radiant panel advisory circular can be found at http://www.airweb.faa.gov/rgl. When published, the burnthrough advisory circular will also be posted on this site.

Ensuring International Aircraft Fire and Cabin Safety Research Cooperation

The Cabin Safety Research Technical Group, comprised of representatives from the major aviation authorities throughout the world, including the FAA, sponsored the Fourth Triennial International Aircraft Fire and Cabin Safety Research Conference in Lisbon, Portugal, on November 15-18, 2004. The fourth in a series of triennial conferences to inform the aviation community about recent, ongoing, and planned research activities in aircraft fire and cabin safety, this is the only technical conference devoted exclusively to fire and cabin safety research in civil transport aircraft. Approximately 350 people attended the sessions on materials fire safety, systems fire safety, evacuation, crash dynamics, and operational issues.



The conference fire safety sessions focused on fuel tank inerting, fuel flammability, thermal acoustic insulation flammability, and hidden fire safety. Other presentations included halon replacement (halon production was banned because it is an ozone depleting agent), smoke and fire detectors (current cargo detectors exhibit very high false alarm rates), and ultra-fire resistant materials. Sessions on aircraft evacuation covered a broad range of research activities. A major concern is evacuation from the new, high-capacity Airbus 380, which will have an equal number of passengers on the upper and lower decks. An operational issues session focused on passenger performance and awareness. A crash dynamics session covered modeling and crash testing. Attendees discussed passenger protection, the development of neck injury criteria for occupants in side-facing seats, and simplifying the aircraft seat dynamic test requirements.

To make further improvements in aircraft fire and cabin safety, it is essential that stakeholders work together to seek practical and cost effective solutions. Information on the Cabin Safety Research Technical Group and the proceedings of all four conferences is available on-line at www.fire.tc.faa.gov.

Airport Technology

Improving Aircraft Rescue and Fire Fighting

For over 13 years, FAA Aircraft Rescue and Fire Fighting researchers have relied on their High Performance Research Vehicle, an Emergency One Titan 4x4 fire fighting vehicle built and procured in 1992, to achieve significant safety advances. For example, under an Interagency Agreement between the FAA and the U.S. Air Force Research Laboratory, researchers developed fire and rescue innovations, including: the Driver's Enhanced Vision System; the Snozzle™ High Reach Extendible Turret; High Reach Extendible Turrets with aircraft skin penetrating devices; the Rhino™ multi position high performance bumper turret; vehicle suspension enhancements; and the lateral G-force indicator for vehicle stability.

With the upcoming introduction of the new Airbus 380 aircraft in 2006, researchers anticipate the need for extensive live fire testing to develop standards for fire protection for the new aircraft, which will carry twice the number of passengers and twice the amount of fuel as most current passenger jets. The size of the new large aircraft and the need for more sophisticated test and development methods led the FAA to acquire a new state-of-the-art research vehicle. With final specifications developed by FAA researchers, the new aircraft rescue and fire fighting vehicle is significantly larger than the older model with room for up to 6,000 pounds of additional installed equipment, such as the next generation elevated boom. It has a water tank capacity of 2,500 gallons, dual foam tanks to carry two fire fighting agents, and an electronic foam proportioning system for better control of foam injection and better monitoring of the tracking agent used in testing. The vehicle also carries two complementary agents, Halotron and dry chemical. For optimum vehicle handling and tire wear, the vehicle has rear wheel steering capabilities.

In early August 2005, researchers conducted pre-delivery testing and inspection at the Oshkosh Truck Corporation's Test and Development Labs. There they put the vehicle through all testing procedures specified for prototype vehicle designs in FAA Advisory Circular 150/5220-10C, "Guide Specification for Water/Foam Aircraft Rescue and Fire Fighting Vehicles." This series of tests included both static and dynamic testing of the vehicle's stability, acceleration, braking, steering, and pump, and roll capabilities. The new vehicle met all criteria and the FAA accepted it for delivery.

Creating the North American Bird Strike Advisory System Strategic Plan

Bird strikes continue to represent a significant safety risk to all aircraft. On the civilian side, over 6,000 bird strikes are now reported annually to the FAA National Wildlife Strike Database. Because they also represent a similar risk to military aircraft and international air traffic, the FAA, U.S. Air Force, and Transport Canada have joined forces to develop a North American Bird Strike Advisory System. When fully operational, the North American Bird Strike Advisory System, integrating state-of-the-art technologies such as radar detection and the use of Geographic Information Systems, will provide on-line advisories to prevent bird strikes.

As the first step towards realizing this system, the three agencies have a drafted a strategic plan that highlights the many advantages of an integrated and consolidated bird strike advisory system. One such advantage is the improvement in the accuracy and fidelity of bird avoidance information provided to users in the aviation community. Another advantage of the proposed system is the use of data from new and existing radar and other systems to enhance bird activity reporting. A key element of the plan is the development of a robust communications infrastructure and network to enhance the timeliness and scope of bird advisory information.

This draft Strategic Plan is the initial step in a process of consolidating and integrating the various United States and Canadian civil and military efforts to develop and implement a North American Bird Strike Advisory System. When implemented, the plan will represent a critical first step leading to the realization of a North American Bird Strike Advisory System that will help protect aviators and aircraft from the deadly and costly effects of bird hazards.

Testing the Ability of Radars to Detect Foreign Object Debris

Foreign object debris (FOD) is defined as any substance alien to the vehicle or system that can potentially cause damage. FOD can result from the manufacture or maintenance of aircraft and from the loss of parts from aircraft, pavement cracking, wildlife, ice and salt accumulation, and construction debris. The critical need for FOD detection and removal was clearly demonstrated in the loss of the Concorde in 2000.

To enhance airport safety, FAA researchers evaluated an experimental radar for the detection of FOD on runways. As part of the evaluation, they conducted tests over a two-week period at New York's John F. Kennedy International Airport in January 2005 to assess the radar's ability to detect FOD, to recognize FOD amongst other items, and to precisely locate FOD on a runway. During the tests, researchers placed FOD items on the runways at locations, and recorded known placement locations using Global Positioning System (GPS) linked to a Geographic Information System (GIS). Radar return data was subsequently entered in the GIS system. The GIS system allowed for exact comparisons between known placed FOD items and radar processed FOD target returns.

These preliminary tests proved the potential of the radar to detect and locate FOD in clear dry weather and winter like conditions. Additional tests are planned to evaluate the performance of the radar under wet weather conditions.

The analysis of the tests and a preliminary evaluation of the radar, *Evaluation of the Tarsier FOD Detection Radar,* will soon be published and made available at http://www.airtech.tc.faa.gov/safety/downloads/.

Developing Obstruction Lighting Standards for Wind Turbine Farms

As a result of a U.S. Department of Energy mandate that renewable energy sources provide six percent of the nation's electricity by the year 2020, wind turbines are now being used in 32 of the 50 states in U.S., with predictions that turbines will soon be operating in all 50 states. This renewed interest in wind energy has resulted in new, large turbines capable of generating large amounts of energy. A single turbine, 442 feet tall from the tip of the blade to the ground, generates well over 5-million kilowatt-hours per year, enough to power more than 500 households. Some sites already in operation have over 200 turbines spread over 20 miles on top of mountain ranges.

Because of the size and number of these turbines, the FAA considers them air navigation obstructions. For anything over 200 feet high, Federal Air Regulations require these obstructions to air traffic be illuminated with the appropriate FAA approved flashing red, flashing white, or steady burning red light lighting. Although FAA Advisory Circular 70/7460-1K, Obstruction Lighting and Marking, includes some provisions for lighting or marking a single wind turbine, it does not provide guidance for lighting a large group, or farm, of wind turbines.

FAA researchers recently undertook an effort to develop obstruction lighting standards for wind turbine farms that would ensure pilots could easily see, identify, and avoid turbines and to minimize any effects of those lights on the surrounding community or wildlife. After an initial investigation of eleven wind turbine farms, researchers documented current light installation, how those lights appeared from the air during both daytime and nighttime conditions, and how the surrounding community perceived the lights. They documented their findings and recommended that obstructions in close proximity to each other, as in a tower, bridge, or even wind turbine sites, should be treated as though they are one large obstruction. The recommended flashing lighting pattern would warn pilots that the obstruction was a single, very large structure that should be avoided.

To validate these recommendations, the FAA established a test-site in Lawton, Oklahoma, with 43 wind turbines situated along a mesa in two predominant rows. In the lighting plan used for the test site, only 14 turbines were lit, versus the 26 that would have been required under the current guidance. Researchers conducted test flights, and through repeated evaluations confirmed that the proposed lighting configuration provided sufficient guidance to approaching aircraft. Researchers will publish the results of this evaluation in an FAA technical note, which will recommend new lighting standards for illuminating wind turbine farms as obstructions.

Alternating Yellow/Green Taxiway Centerline Lights to Enhance Runway Safety

FAA Advisory Circular (AC 150/5340-30), "Design and Installation Details for Airport Visual Aids," provides airports with guidance for lighting exit taxiways with color-coded alternating yellow and green fixtures to warn pilots and vehicle drivers that they are within the runway environment. Upon suggestions from industry, FAA researchers examined the feasibility of changing from the existing concept of alternating yellow and green taxiway centerline lights -to, using the same color coding in the reverse direction as a warning that one is approaching to the runway environment from an intersecting taxiway. A lighting configuration such as this could act as an enhancement to the hold position area, helping to reduce runway incursions. It could be applied to any airport with existing taxiway centerline fixtures with minimum cost.

To study this theory, researchers temporarily constructed a curved taxiway entrance lighting configuration, using standard FAA approved taxiway lighting fixtures, at the FAA's William J. Hughes Technical Center. The simulated taxiway lighting configuration included the following characteristics:

- A lead-in segment of solid green colored centerline lights for a distance of 200 feet prior to the hold line location (the beginning of the runway environment).
- A continuing segment of alternating yellow and green taxiway lights along the straight and curved section of the taxiway/runway entrance to the point of tangency with the runway centerline.
- All spacing and alignment was in accordance with the appropriate FAA Advisory Circular.
- All fixtures were standard FAA approved L-852 taxiway lights, with standard lamps and filters.

Those helping to test the configuration viewed the lighting configuration under the existing weather and ambient light conditions. Individual subjects then drove in ground vehicles, at typical aircraft taxi speeds, through the display. They stopped the vehicle at the simulated hold position, as though waiting for a clearance, and then drove along the curved, color-coded taxiway lights. From this study, researchers proved that the concept of illuminating the runway environment area with alternating yellow and green centerline lights would be a cost-efficient way to improve safety at those airports that have existing taxiway centerline lights.

Improving Aircraft Landing Lights

FAA researchers investigated the potential safety advantages of standardizing aircraft landing lights in the airport environment. Specifically, they explored the procedural use of landing lights to let other pilots know which aircraft had clearance to depart. Thirty-two pilots participated in the study as either the Captain or First Officer of a Boeing 747-400 simulator crew. Each crew flew either a set of 16 scenarios in an environment with a standardized use of landing lights or scenarios using current practices. In some of the scenarios, a rogue aircraft made an error that caused a runway incursion that could have resulted in an accident if not detected by the subject crews.

The research team conducted multidimensional measures of runway incursion severity and situation awareness after each scenario. In general, the pattern of results suggest that standardizing the use of aircraft landing lights to indicate that aircraft were cleared to depart prevented or reduced the severity of runway incursions or accidents and increased pilot situational awareness. Further studies are recommended to determine the effects of other factors such as consistency, conspicuity, and the effects of the message on other human system elements. Evaluating alternatives such as pulse lighting and the potential value of cues to air traffic control may reveal additional benefits.

Evaluating Runway Status Lights

The Runway Status Lights system consists of an array of lights called Runway Entrance Lights placed at runway/taxiway intersections to warn pilots and vehicle operators that a runway is unsafe to enter. Additional lights called take-off hold lights are being evaluated. These lights are placed on the runway from the departure positions and hold location and inform pilots that is unsafe to begin a departure. The Runway Status Lights System works in conjunction with ASDE-X, ASDE-3, ASR-9, and AMASS systems as part of a layered defense against surface accidents. The operational evaluation of the Runway Entrance Lights at Dallas Fort Worth Airport has been expanded to include the evaluation of the take-off hold lights as well. The FAA is also planning to extend the evaluation to additional airports.

Preventing Runway Incursions

FAA researchers are evaluating the potential of inductive loop technology to improve runway safety and to monitor airport surface movement at the Gulfport-Biloxi airport. The Runway Obstruction Warning System is based on technology used worldwide to control the flow of vehicles at traffic lights. It consists of a network of sensors embedded in/near runways and taxiways that can be configured to be monitored in the tower and/or control runway lights visible to flight crews.

As a result of demonstrations conducted at the Gulfport-Biloxi airport, researchers conducted a system engineering feasibility study to identify the specific functional and implementation changes required to transition from the prototype runway obstruction warning system to a national airspace system-compatible technology insertion candidate. Initial indications from the study show that such a system may be effective in the tower environment.

Researchers demonstrated a redesigned system in July 2005. Analysis of the demonstration results indicates the new prototype works better, but still has a number of anomalies. Planning and activities are underway to implement a number of recommendations from the study, and develop solutions for the anomalies, and recover from the effects of Hurricane Katrina.

Conducting Rigid Pavement Full-Scale Traffic Tests

Traffic tests involving full-scale simulated aircraft gear loads are essential to developing the airport pavement thickness design procedures for the next generation of heavy civil transport aircraft. The FAA National Airport Pavement Test Facility is the world's only facility capable of performing controlled, full-scale traffic tests to failure on airport pavements subjected to realistic gear loads. In December 2004, FAA researchers successfully completed a series of traffic tests on three rigid (concrete) pavement test items, designated as CC2 (for Construction Cycle 2).

All three test items included a 12-inch thick concrete surface, consisting of 15 x 15 foot slabs joined by dowels in both directions. The items had different structural designs to compare the performance of different foundation types. The three items included: a conventional structure, with the concrete slab supported by a crushed aggregate subbase; a concrete slab supported directly on the clay subgrade (no base); and a stabilized (econocrete) base between the concrete slabs and the crushed aggregate subbase. Researchers subjected the test items to two lanes of repeated traffic, with the facility's load carriages programmed to simulate the normal lateral distribution of traffic (wander) on an airport taxiway. Except on one test item, the north load carriage applied a six-wheel gear load (three dual axles), similar to a Boeing 777, while the south carriage applied a 4-wheel gear. On one test item, both lanes received 4-wheel traffic, with different wander patterns. In all cases, the per-tire load was 55,000 pounds.

Researchers monitored the pavement test items for the onset and progress of cracks, which are an indicator of pavement performance. They conducted pavement performance monitoring at four levels: visual surveys using standard field inspection procedures; nondestructive testing using heavy-weight deflectometers and other devices; destructive testing of core samples; and embedded sensor monitoring. The research team used in-situ strain gages to detect the formation of cracks before they became visible from the surface. They recorded pavement condition using the Structural Condition Index (SCI), an index of rigid pavement performance, which varies between 0 and 100, and depends on the number, type and severity of observed cracks and other distresses. A SCI value of zero corresponds to complete loss of structural integrity.

The total number of load passes varied by test item, from 5,400 to 31,000 passes. Longitudinal cracks began to appear on the outer slabs of the test items after several hundred passes. Researchers continued trafficking the test items until full structural failure, characterized by extensive cracking, and significant loss of bearing capacity, occurred. Analysis of the test data has already yielded a number of significant conclusions. For example, the current design model assumes that the deterioration of SCI is a simple logarithmic function of traffic. The CC2 tests demonstrated that this relationship is valid for stabilized base as well as conventional structures. Furthermore, tests on three different supports (conventional, slab on grade, stabilized base) confirmed that the quality of the base has a specific, quantifiable effect on the durability of the pavement after the initial crack forms. This data, in combination with data from earlier full-scale tests, is being used to update the FAA's thickness design standards for concrete pavements.

Evaluating Ultra-Thin Whitetopping for General Aviation Airport Pavements

The FAA allows conventional concrete overlays with a minimum thickness of six inches to serve aircraft between 12,500 and 30,000 lbs. and five inches for aircraft weighing less than 12,500 lbs. Thinner concrete overlay slabs (known as ultra-thin whitetopping or UTW) could theoretically be justified for smaller aircraft on the basis of a structural analysis, if there is a strong and permanent bond between the new concrete overlay and the existing asphalt surface. UTW has been used extensively to rehabilitate highway pavements since the 1970s, but has only been used at three airports in the United States: Savannah-Hardin County, Tennessee; New Smyrna Beach, Florida; and Spirit of St. Louis Airport, Missouri.

To assess the viability of using UTW for general aviation airport pavement rehabilitation, the FAA funded the Innovative Pavement Research Foundation to conduct a research project called, "Innovative Rehabilitation of Pavement for Light Load Aircraft." The Innovative Pavement Research Foundation is a nonprofit research foundation sponsored by the American Concrete Pavement Association and Portland Cement Association to conduct research to improve the design, construction, and maintenance of concrete airport pavements. The project consisted of a field evaluation and a laboratory study. For the field evaluation, researchers studied the three general aviation airports currently using UTW. The airport field survey identified some locations where heavy loads (e.g., from fuel trucks) had apparently led to debonding and cracking in the UTW area.

For the laboratory work, researchers evaluated the concrete-asphalt bond. That bond, if properly constructed, should survive accelerated cycles of freeze/thaw and wet/dry, simulating what a pavement might experience in the field. Failure of the bond, however, due to poor construction practices or to environmental cycling over time, could lead to loosening of concrete pieces and create a foreign object debris risk. Results of the laboratory testing proved somewhat surprising. Neither the freeze/thaw nor the wet/dry exposure cycles caused significant deterioration in the UTW bond, and researchers described the bond retention at the concrete/asphalt interface as excellent. The tests, however, did identify a potential failure location in the surface of the asphalt layer, which could be a concern if overlaying asphalt of unknown quality.

A final report of this study is available on-line at http://iprf.org/products/IPRF-01-G-002-3-Final%20Report.pdf.

Creating the Airport Cooperative Research Program (ACRP)

In September 2005, the Secretary of Transportation signed a Memorandum of Agreement implementing the ACRP. The ACRP is sponsored by the FAA , acting through its Transportation Research Board (TRB), and managed by the National Academies. Congress appropriated $3 million in FY 2005 and $10 million in FY 2006 to the FAA for ACRP research projects.

The ACRP will carry out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. The ACRP will undertake research and other technical activities in a variety of airport subject areas including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration.

The primary participants in the ACRP include representation from the FAA, airport operating agencies, Airports Council International - North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), the Air Transport Association (ATA), and TRB.

The ACRP will produce a series of research reports for use by airport operators, local agencies, FAA, and other interested parties.

Air Traffic Management

Demonstrating the Small Aircraft Transportation System Concept

FAA and NASA researchers, along with local airports and aviation authorities, concluded the five-year public/private research program on the Small Aircraft Transportation System (SATS). SATS is a collaborative research effort between NASA, FAA, and industry focused on increasing public access and mobility within the national airspace system. It is designed to facilitate transportation between small general aviation airports using small aircraft as an alternative to traditional airline travel.

Project participants successfully concluded a proof of concept demonstration of four operating capabilities in Danville, Virginia, in June 2005. The four capabilities included: higher volume operations at nontowered, nonradar airports; lower landing minima; single pilot performance; and integration of SATS operations into the national airspace system. When implemented, these operating capabilities will enable point to point, on demand travel between more than 5,400 existing small airports.

Testing the Surface Traffic Management System

FAA and NASA researchers successfully completed the initial surface traffic management system research at the Memphis International Airport, demonstrating that this technology could safely increase airport capacity and efficiency using traffic management technologies. The surface management system is a decision support tool that will help controllers, traffic managers, and airspace system users manage the movements of aircraft on the surface of busy airports, improving capacity, efficiency, and flexibility. The system presents a real-time map display of the airport layout, aircraft, taxiways, runways and gates. With the click of a mouse, individual aircraft can be targeted and pertinent information about the flight's arrival and departure appears on a computer screen. The technology predicts arrival time, touchdown, and taxi time to the gate.

After successful tests, Memphis International Airport is now operating the system for the FAA under a cooperative research and development agreement. FAA and NASA researchers continue to refine surface management system functions, including developing more efficient traffic flow management functions. As part of a continuing surface investigation effort, FAA researchers installed the system at Louisville, Kentucky, for use by UPS ramp controllers. The surface traffic management system currently provides UPS ramp controllers with a tactical display of aircraft, both on the surface and in the vicinity of the airport, and serves UPS as a vital tool in efficient ramp management for unloading, loading, and refueling. Enhancements from the second phase of research will be installed and tested at airports other than those already using the SMS.

Developing the Traffic Management Advisor Multi-Center

The Traffic Management Advisory-Multi-Center (TMA-MC) system is an extension of the Single-Center TMA Decision Support Tool in current use at more than half of the FAA Air Route Traffic Control Centers. The FAA and NASA are developing TMA-MC to enable time-based scheduling of arrivals to airports in the complex airspace of the Northeastern United States. High traffic congestion, multiple merging routes, narrow airspace sectors, and terminal airspace fed by more than one Center characterize this airspace.

During FY 2005 researchers conducted an operational field evaluation of the system to assess potential benefits. Researchers assessed the system's performance using metrics that compared the operational delay at Philadelphia Airport while using TMA-MC against the delay under similar weather and demand conditions without the tool. TMA-MC proved successful in that operational trial – average delays at Philadelphia were significantly lower using TMA-MC as compared with the average delay in each of six non-TMA-MC control periods.

Evaluating the Digital Airport Map Database

During FY 2005, the certification process was begun and work was done on the digital airport map creation and maintenance process. The production team is currently awaiting an investment decision by the FAA to continue re-processing the original 82 maps and expand the database. This database is intended to be used in certified avionics applications, such as surface moving maps to enhance pilot and vehicle operator situational awareness.

Aviation Weather

Improving Aviation Weather Forecasts

One of the key ways to improve aviation safety and capacity is to provide better forecasts of aviation weather phenomena. The FAA Aviation Weather Research Program has sizeable research efforts in forecasting meteorological phenomena that pose problems for aviation, including: convective weather; aircraft icing (both in-flight and on ground); low ceiling and visibility oceanic weather; and turbulence. Recognizing that data quality can also be affected by the nature and quality of the meteorological sensors, the FAA also invests in new sensor development and radar technology. Scientists and engineers from the National Center for Atmospheric Research, Massachusetts Institute of Technology Lincoln Laboratory, and the National Oceanic and Atmospheric Administration (NOAA) Global Systems Division, National Severe Storms Laboratory, and Aviation Weather Center collaborate to provide the best technical solutions for aviation.

The Aviation Weather Research Program makes use of several government platforms to deliver its products to end users, via experimental prototypes or via formal government technology transfer efforts. These platforms include:

- FAA Integrated Terminal Weather System (ITWS), which operates four prototypes demonstrating new products, and 11 operational systems at key terminals around the country. ITWS dedicated access is available to the towers, terminal radar approach control facilities, air route traffic control centers, and the Air Traffic Control System Command Center.
- FAA Enroute Weather and Radar Processor (WARP) system, present in all enroute air traffic control facilities, provides weather products for the enroute controllers' displays.
- Aviation Digital Data Service (ADDS), specifically developed by the FAA to provide public access to aviation weather data and products, also serves as an approved site for general aviation pilot weather briefings.

Providing Weather Information on the Internet

For public dissemination of weather information, the FAA developed the Aviation Digital Data Service, available 24-hours a day on the Internet (http://adds.aviationweather.gov). Operated by the National Weather Service, this aviation information allows pilots, airline dispatchers, and other aviation users easy access to up-to-date weather data and products in user-friendly graphical and text formats. By providing pilots and dispatchers easy access to the forecast weather conditions, the Aviation Digital Data Service facilitates flight planning and minimizes the time required to change the route of flight when needed.

The Aviation Digital Data Service integrates existing tools, such as the current icing potential, forecast icing potential, graphical turbulence guidance, and the national convective weather forecast, to bring text, digital and graphical analyses, and observations of the latest weather developments to a variety of users. An important feature of the Aviation Digital Data Service is the flight path tool, which employs user-friendly graphics to display thunderstorms, icing, turbulence, and other aviation weather hazards, for all flight altitudes, along a chosen route of flight selected by the user.

FAA-funded researchers recently added new functionality to the flight path tool, making it even easier for users to plan routes to avoid dangerous weather. The original flight path tool gained popularity because it displayed complex three-dimensional gridded data, like icing or turbulence, with the observed and forecasted weather conditions provided in pilot briefings and other traditionally-used observation and forecast reports. Using the on-line program, a user can "click" on a route of flight within the continental U.S. and view these products in the vertical dimension along that route.

Forecasting Turbulence

Turbulence accounts for 65 percent of all weather-related injuries, while only 35 percent of turbulence is forecasted. Because observations and forecasts are not accurate enough to pinpoint the location, time, and intensity of turbulence, FAA-funded researchers created the Graphical Turbulence Guidance product. This tool produces easy-to-interpret depictions of turbulence. It is available on the web-based Aviation Digital Data System, allowing anyone with an Internet connection access to the display, which shows relative turbulence intensities at user-selected altitudes.

Using input from several numerical weather prediction models, the Graphical Turbulence Guidance tool refines turbulence assessments by comparing the models with current pilot reports of turbulence. It produces turbulence forecasts out to twelve hours and clear-air turbulence forecasts for altitudes above 20,000 feet. Recently, a new Graphical Turbulence Guidance product for altitudes above 10,000 feet received FAA and National Weather Service endorsement through the Aviation Weather Technology Transfer Board. With the Board's endorsement, researchers entered into the final phase of research needed to advance the product to operational status. During this experimental research phase, users are allowed to view the product (versus a limited controlled group in the early research phase) and provide feedback, which the researchers use to refine and validate the product before requesting an operational decision from the Board. This is one more step toward a fully-developed, advanced Graphical Turbulence Guidance tool, which will provide forecasts for all altitudes and will have the capability to forecast mountain-wave and convectively-induced (regions involving thunderstorm activity) turbulence.

To meet the short-term need of pilots to obtain sufficient warning of turbulence ahead to alert passengers and crew or to take evasive action, FAA researchers are developing a turbulence detection tool. The research team conducted a real-time regional demonstration last summer that combined the outputs of 16 NEXRAD radars located in the upper Midwest region. Researchers created a three-dimensional image (mosaic) of detected turbulent conditions from these combined data sets. During the test, a commercial vendor sent the image, including a customized map of the flight region, via an uplink to the cockpit of the demonstration partner's aircraft. The detection product produced turbulence intensities in the form of a metric, the eddy dissipation rate. The eddy dissipation rate is a measure of the actual atmospheric conditions since it does not include pilot induced actions or the aircraft's response. This metric, combined with the radar information, provides a 15-minute look ahead of in-cloud aviation hazards, emphasizing convectively-induced turbulence. Once the turbulence detection product is approved for operational use, the FAA plans to install it on all operational NEXRADs (anticipated in FY 2008). The eddy dissipation rate data could then be incorporated into existing aviation decision support systems to provide convectively-induced turbulence nowcasts to the aviation community.

Ensuring Safety in Winter Weather

The Weather Support to Decision Making (WSDM) System, developed with FAA funding, is currently operational at the Minneapolis-St. Paul International Airport as well as Denver International Airport. The system uses Doppler radar, surface weather data, and snow gauges to determine precipitation type, temperature, wind speed and direction, and the liquid water equivalent of snow. The system produces real time, short-term forecasts in the terminal area to support aircraft deicing and terminal management of runways during winter storm conditions. In a recent upgrade to the system, researchers completed development of a freezing drizzle detection product. Freezing drizzle conditions experienced at Denver International Airport during the past two winters resulted in more than two million dollars of engine damage as well as additional costs due to damaged aircraft taken out of service. With the upgrade installed, the WSDM system correctly diagnosed a freezing drizzle event this past January at the Denver airport. Since implementing the drizzle detection product and changing engine run-up procedures (sheds ice buildup on engine fan blades), the airlines have reported no further engine damage as a result of freezing drizzle.

Forecasting Oceanic Weather

Lack of data on oceanic routes results in unnecessary rerouting or encounters with hazardous weather. To address this need, FAA-funded researchers developed an Oceanic Cloud Top Height product to provide pilots with an automated graphical display showing areas of convection relative to the aircraft's flight path and altitude. Having this information allows pilots to avoid dangerous convection and turbulence conditions that occur around clouds along their oceanic routes. In May, after providing technical presentations to the joint FAA/National Weather Service Aviation Weather Technology Transfer Board, the Board approved the product to enter the experimental phase of research. The team will use this phase to refine the product prior to seeking an operational decision. The team also demonstrated the feasibility of using an automated uplink of this product to select commercial aircraft this year.

Improving Safety with National Ceiling & Visibility Tools

Low cloud ceilings and poor visibility conditions are safety hazards for all types of aviation. In fact, in the continental United States, 72 percent of ceiling and visibility related accidents result in fatalities. To mitigate these types of accidents, FAA-funded researchers created a National Ceiling and Visibility Analysis product that provides users in the lower 48 states an automated graphical display showing current ceiling, visibility, and flight category conditions along their route of flight. The joint FAA/National Weather Service Aviation Weather Technology Transfer Board has approved this product for experimental use. During the experimental stage, all users can view the product and provide feedback on its performance, allowing the researchers to make necessary refinements before seeking the product's operational release from the Aviation Weather Technology Transfer Board.

Ceiling and visibility conditions are also a major concern within Alaska. Data indicate that 55 percent of ceiling and visibility-related Alaskan accidents result in fatalities. The FAA continues to make progress on the National Ceiling and Visibility Alaskan Analysis product, which is now in the testing phase of its research. In addition, a companion product, the National Ceiling and Visibility Alaska Forecast product, has received approval from FAA and the National Weather Service to enter the testing phase of research. The test phase means that limited users can see the product and provide input into the development process. When fully developed, the Alaskan forecast product will provide users with an automated graphic display containing forecasts from 1 to 12 hours of ceiling, visibility, and flight category conditions.

Mitigating the Effects of Convective Weather

The FAA has a multifaceted research program designed to mitigate convective weather delays and improve safety near thunderstorms. The largest research project is geared toward providing aviation-oriented convective weather depictions and forecasts on the tactical (0-2 hour) time scales. Multiple radar data sources, satellite imagery, surface observations and numerical model data are combined using fuzzy logic techniques to produce high resolution forecasts. Thunderstorm growth and decay trends are provided as a product overlay and incorporated, along with initiation evidence, internally into the forecast storm evolution. A smaller but very significant research component is geared toward improving strategic (2-6 hour) forecasts of convective weather. The fuzzy logic forecast technology is coupled with numerical weather predictions and climatology to produce a blended 0-6 hour forecast. Improving these probabilistic strategic forecasts is crucial to enabling more effective traffic flow planning. Experimental tools are made available on FAA operational weather and air traffic control systems and the National Weather Service-operated Aviation Digital Data Service, allowing FAA air traffic specialists, airline dispatchers, and pilots to use experimental products and provide feedback leads to critical tool refinements. In the future, researchers hope to integrate these new tools into the automated traffic flow management decision support systems and cockpit data link technology.

In fiscal year 2005, researchers demonstrated several capabilities, including a 0-2 hour Echo Tops Forecast product, which improves situational awareness between the terminal radar approach control facility and en route managers. It allows them to keep routes open longer, reroute traffic earlier/close impacted routes sooner, thereby minimizing cost and impact to airlines. They also extended the convective forecast out to 6 hours and introduced a probabilistic forecasting capability, requested by the operational user community. In addition they demonstrated techniques to forecast new growth of thunderstorms, the growth of which can greatly disrupt traffic flow and capacity.

Researchers conducted a demonstration in the Chicago area. As a result, researchers found a new means of detecting surface effects on convection. A second demonstration occurred in the Dallas-Fort. Worth region where a meteorologist at the Center Weather Service unit (a position within the air route traffic control center) helped test the 1-hour automated forecast of storm initiation. The meteorologist supplied value-added enhancements to the automated output.

Avoiding In-flight Icing Conditions

The formation of even a thin coat of ice on an aircraft surface can seriously impact an airplane's ability to fly by increasing drag, decreasing lift, and increasing aircraft weight. In many cases, the build-up of ice is so rapid that the pilot does not have enough time to take corrective action. National Transportation Safety Board records indicate that in-flight icing causes more than 25 accidents annually, with over half of these resulting in fatalities and destroyed aircraft. This equates to $100 million in injuries, fatalities, and aircraft damage each year.

To address this problem, FAA researchers developed the Current and Forecast Icing Potential products to alert users to areas of in-flight icing, by displaying graphically the likelihood that icing will occur along their route of flight. The Aviation Weather Technology Transfer Board approved an upgrade to the Current Icing Potential product for operational use. The upgrade provides a more detailed look, at greater spatial resolution, of icing conditions. Users can now see the finer details of weather structure contributing to potentially hazardous icing conditions, providing a more accurate depiction of the icing hazard. This improvement allows pilots to devise flight plans that more effectively avoid these regions and thus enhances safety.

Assessing Quality

Because verification is critical to providing reliable information for improved weather forecasts, FAA-sponsored researchers are developing verification techniques and tools that allow forecasters, and developers to generate and display statistical information in near real time. To enhance verification efforts, researchers are developing a Real-Time Verification System as a tool for assessing the quality of weather forecasts (http://www-ad.fsl.noaa.gov/fvb/rtvs/). The system is designed to provide a statistical baseline for weather forecasts and model-based guidance products, and to support real-time forecast operations, model-based algorithm development, and case study assessments. More importantly, it provides verification of research and operational weather products in real time via the Internet. This allows an aviation decision-maker to know how well a product is performing.

A flexible easy-to-use web-based graphical user interface allows quick data access. Users can compare various forecast lengths and issue times, over a user-defined time period and geographical area, for a variety of forecast models and algorithms. System users include aviation researchers, the National Weather Service's Aviation Weather Center, the FAA Air Traffic Control System Command Center, the FAA/National Weather Service Aviation Weather Technology Transfer Board, and several airline dispatch centers. On June 30, researchers installed the system as a prototype at the National Weather Service Headquarters in Silver Spring, Maryland. This prototype is a major milestone in achieving full operational verification capability. It is anticipated that the system will be fully operational in early 2006.

Enhancing Weather Models

The Rapid Update Cycle is an operational weather prediction system comprised primarily of a numerical forecast model and an analysis system to initialize the model. Funded by the FAA, National Oceanic and Atmospheric Administration researchers developed the model to provide frequently-updated short-range weather forecasts.

Researchers have now updated the model to provide higher resolution graphics and assimilation of additional weather information, including improved moisture analysis and improved cloud/precipitation physics, to increase forecast accuracy. Called RUC 13 because of its 13-kilometer resolution, the model provides improved aviation and surface forecasts of interest to aviation as well as the general public. The RUC 13's output is used as input for FAA-developed aviation-weather applications that produce weather forecasts.

Testing the Phased Array Radar

FAA researchers, in partnership with the Department of Defense, Office of Naval Research, National Oceanic and Atmospheric Administration, National Severe Storms Laboratory, Oklahoma State Regents for Higher Education, University of Oklahoma School of Meteorology and Engineering, and Lockheed Martin, are conducting research and testing of the Phased Array Radar Technology to improve airport and aircraft tracking and weather information for civilian use. In fiscal year 2005, the Office of the Federal Coordinator for Meteorology established the Phased Array Radar Joint Action Group tasked with completing the "Federal Research and Development Needs and Priorities for Phased Array Radar." The purpose of this document is to establish the need for multiagency research in phased array technology.

Researchers installed the track processor at the National Weather Radar Testbed, located at the National Severe Storms Laboratory in Norman, Oklahoma, in September 2005. The processor enables dual use capabilities – tracking aircraft while simultaneously gathering meteorological data.

The FAA also began a research project with the Massachusetts Institute of Technology Lincoln Laboratory to assess the feasibility of developing low cost transmit/receive modules. The studies showed that low cost modules are feasible, that the technology and manufacturing to support them is greater than anticipated, and that phased array radar technology is becoming affordable for civilian use. Additional studies are underway to develop a phased array system architecture.

Commercial Space

Enhancing Flight Safety Systems

The FAA Office of Commercial Space Transportation completed a follow-on study to its earlier report on non-traditional flight safety systems. Conventional flight safety systems minimize the threat to public safety and property posed by a malfunctioning launch vehicle. Non-traditional versions include fully autonomous and semiautonomous systems that interface with pilots and/or ground controllers. Because the FAA anticipates the application of these methods to spacecraft safety and health monitoring systems in the near future, proper regulation of these systems is essential to maintaining a consistent level of safety at a variety of ranges and spaceports.

In its earlier study, researchers developed a verification framework for the regulatory approval of nontraditional systems. In an effort to gauge the effectiveness of this methodology, researchers recently applied it to an autonomous flight safety system currently being developed and tested by NASA at its Wallops Flight Facility. Because this program is still evolving, researchers based their evaluation on early research data in combination with results from completed tests. The results and lessons learned during this trial yielded valuable initial insights into possible approaches to creating valid new regulations.

Mitigating Radio Frequency Blackouts

During the critical reentry phase of flight, space vehicles can suffer severe degradation or total loss of voice and data communications because of high temperature plasmas. A study assessing the radio frequency blackout phenomena caused by plasma generation has been completed. It evaluates the known methods for mitigating this condition that might be applicable to prospective reentering commercial space vehicles. In particular, the methods demonstrate the ability to predict the ionized flow field to identify the altitude of blackout onset.

Researchers studied four mitigation methods under active and passive classes. The passive methods, such as aerodynamic shaping and use of high frequencies, show the most potential. By avoiding a temporary loss of signal strength, these methods may make continued communications possible with reentering craft. They also may meet the cost effectiveness requirements imposed upon commercial reusable launch vehicles. Researchers will continue to identify specific frequency bands that are suitable for communications in the presence of plasma shielding.

Analyzing Debris Risk

The FAA often uses computer-based models to develop public casualty expectations associated with launch accidents. In addition, the FAA uses the model to help establish insurance requirements and liability limits.

To ensure safety of commercial launches, FAA researchers tested how well the current computer model could calculate the hazards to victims inside of buildings struck by falling debris. During the tests, researchers compared results from the model with actual damage data from exploded inhabited buildings. Sources of the historical data included the Khobar Towers bombing, the World War II bombing of London, the Oklahoma City bombing, and the SCUD missile attacks on Israel. Researchers have completed the Khobar Towers data comparisons. The data suggest that the FAA model is not as conservative as some had suspected. Completion of the project, slated for early next year, should provide a better basis for predicting debris-related casualties resulting from launch accidents.

Identifying Weather Delays

Postponing or canceling a commercial launch directly affects operational costs, which often exceed millions of dollars. To better understand the effects of weather on Expendable Launch Vehicle launches, researchers looked at data from over 300 launches from 1988-2005 at the Eastern Range at Cape Canaveral, Florida, and the Western Range at Vandenberg Air Force Base, California. In addition, several launches from the Kodiak Launch Complex in Kodiak, Alaska, were reviewed to determine trends and predict problematic weather for future launch operations. They categorized data into weather delays or scrubs as a result of lightning launch commit criteria, range safety, or user weather constraints. When research is completed, the published results will help commercial launch operators make sound decisions regarding launch operations and planning. The outcome will highlight new methodologies and help identify additional studies to aid commercial operations in the future.

Evaluating Reconfigurable Control Allocations for Reusable Launch Vehicles

Control surface degradation or actuator failure may pose a significant safety threat to reusable launch vehicles. To enhance safety and reliability of these vehicles, the FAA initiated a study to evaluate advanced guidance and control methods to compensate for control surface damage or failure. In particular, researchers wanted to know if alternative actuators and a reconfigured adaptive control strategy might help improve the management of emergency situations. Such a system would modify the guidance laws in response to real-time equipment conditions, resulting in changes to flight control strategies.

Researchers found that the most desirable solution would be for the control algorithms to adapt to changing conditions using available control surfaces and other actuators. They developed the concept of an executive reconfiguration control scheme that is independent of the physical hardware layer. A critical aspect of the system would be the ability to distribute control responsibility among available actuators in a reconfigured mode with a new management strategy that would adjust the flight profile to reflect the modified goal. Such a hierarchical scheme has the advantage of being design and device independent and, therefore, applicable to all generic reusable launch vehicle physical equipment types.

Environment & Energy

Developing a Suite of Analytical Tools

Because aviation noise and emissions are highly interrelated phenomena that must be understood and mitigated together, FAA and NASA researchers are developing an integrated suite of analytical tools, the Environmental Design Space (EDS), Aviation Environmental Design Tool (AEDT), and the Aviation environmental Portfolio Management Tool (APMT). Each tool in the suite provides a key component of a valuable integrated decision making capability. EDS generates performance and cost data on source noise and exhaust emissions. AEDT computes and identifies interrelationships between noise and various emissions at the local, regional, and global levels. APMT computes the economic impact and assesses the cost-benefit of mitigation strategies. Individually these tools provide critical data, but as an integrated set they can help government and industry undertake operations and projects that more effectively control aviation noise and emissions. The toolset also will help the aviation community educate the public about how aviation noise and emissions, in combination, affect local, regional, and global communities.

Last year, on behalf of the FAA and NASA, the National Research Council's Transportation Research Board began an assessment of the proposed tool suite. The Board conducted three workshops to analyze the required capabilities of the new toolset, and assess existing tools and their integrated potential. The FAA and NASA used the input from those meetings to refine the conceptual foundation and formulate a comprehensive work plan. In March 2005, the agencies launched their full-fledged development effort.

Member universities of the FAA/NASA/Transport Canada-sponsored Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) are developing the EDS and APMT modules. They completed version 0.0 of the EDS module and are now validating and refining it. They also completed comprehensive requirements and architecture studies for APMT and are now engaged in developing version 0.0. Led by Volpe National Transportation Systems Center, a team including the ATAC Corporation, CSSI, Inc., and Wyle Laboratories is developing the AEDT module. They have completed prototypes of that system's components and are collaborating with the EDS and APMT development team to ensure the various modules function as an integrated tool suite.

Although this research and development work will last a decade, some capabilities will come on-line between 2006 and 2009 – in time to influence the seventh and eighth meetings of the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP). The integrated tools will help to inform regulatory decisions that have historically incurred $10 billion to implement in mitigation costs to government and industry.

PARTNERing for Excellence

The PARTNER Center of Excellence, sponsored by the FAA, NASA, and Transport Canada, and directed by the Massachusetts Institute of Technology (MIT) has seen considerable growth in its two-year history. PARTNER recently welcomed York University of Toronto, Canada, and the Georgia Institute of Technology to its team – which, in addition to MIT, also includes Boise State University, Florida International University, the Pennsylvania State University, Purdue University, Stanford University, the University of Central Florida, and the University of Missouri – Rolla. The addition of York University reflects the Center's goal to expand internationally and also supports a key element of the Center's research strategy – to expand its capabilities in the area of climate change impacts from aviation. The addition of Georgia Tech reflects the growth in the Center's activities in modeling.

In the past year, the Center also added two members to its Advisory Board: Airbus and Bombardier. The Advisory Board, comprising a broad range of stakeholders, serves as the principal point of contact for establishing collaborative research programs with industry and is the primary mechanism for ensuring that research is aligned with national and international needs.

The FAA has identified six of the Center's research efforts as "highly influential." The Office of Management and Budget (OMB) requires the agency to give this designation to any research effort it considers to have a potential impact of more than $500 million in any one year on the public or private sectors, or if the work is novel, controversial, or precedent-setting. PARTNER research efforts – on climate impact of aviation, particulate matter and hazardous air pollutants, noise metrics, supersonic transport acceptability criteria, and monetization of aviation environmental impacts of aviation to inform policies and regulatory actions, both nationally and internationally – clearly meet these criteria. Once PARTNER research undergoes a formal peer review process, the FAA expects the research results to influence greatly the aviation enterprise and the general public.

Studying Airport Encroachment and Land Use

A PARTNER researcher team, led by Purdue University and Florida International University, is researching issues of airport encroachment and land use. The Management and Airport Controls project is studying development around Denver International, Fort Lauderdale International, and Orlando-Sanford International airports. The team is working closely with airport administrators, civic leaders, and aviation organizations to collect data on the most prominent encroachment issues. Researchers are using census and image analyses from 1970 to 2000 to evaluate demographic trends and socioeconomic factors in areas adjacent to the study airports. The study will reveal trends and provide lists of indicators to predict where and why population expansion will occur and help to prevent its encroachment near airports.

In the fall of 2006, the team will present a final report of its findings and recommendations to help inform future policy. This research has been given the OMB designation "influential," as the findings are expected to have a clear and substantial impact on important public policies or private sector decisions of high public interest.

Furthering Knowledge Through Quiet Technology Demonstrator 2

The Agency continues to support research into new noise reduction technologies through participation in NASA's Quiet Aircraft Technology Project. The goal of this program is to reduce perceived aircraft noise by 50 percent in 10 years, using 1997 levels as the baseline. As part of this effort, FAA, NASA, and aerospace industry partners recently flight tested new, jointly developed noise reduction technologies. During the three-week flight test program, Quiet Technology Demonstrator 2, researchers used a Boeing 777 to validate the benefits of several new noise reduction technologies, including two improved chevron designs on the engine nacelle, and a cover that fits on the landing gear.

Chevrons are scalloped or serrated edges already used on some newer jet engines. They modify the exhaust flow to reduce the jet noise levels. One improved chevron design includes asymmetrical scallops around the engine.
The new design tailors the chevrons to take into account the air flow and acoustic differences that occur when the engine is installed on the aircraft. Laboratory tests show the advanced chevron shape will reduce jet noise as much as four decibels during takeoff and when flying at cruise altitude. Results of the flight tests may lead to changes in aircraft configurations, future airplane engine and landing gear designs.

NASA research has shown that when landing, air rushing past a conventional landing gear is almost as loud as engine noise. To address this problem, the landing gear cover tested during the Quiet Technology Demonstrator 2 flight test is a toboggan-like cover for the aircraft's main landing gear. The cover streamlines the landing gear and makes it less noisy. The cover had previously been tested in a wind tunnel on a 26 percent scale model of the landing gear. The covered gear concept could reduce landing noise by another three decibels.

Mitigating Sonic Boom

The FAA and NASA have initiated a project, through PARTNER, to understand the impact of sonic boom phenomena. The project team is led by Pennsylvania State University and Purdue University. Its objectives are to assess applicability of existing noise metrics to sonic boom, determine annoyance associated with supersonic jets, and provide guidance for designing supersonic jets that will minimize the impact of sonic boom.

This research project began in April 2005. The project team has surveyed existing sonic boom simulators to compare their abilities to duplicate sonic boom sounds and has begun to use the devices to assess human perceptions of the simulated sounds.

The team is using a mobile Gulfstream simulator. Comparisons of the Gulfstream with the NASA Langley and Lockheed-Martin simulators and real booms are being conducted at NASA Langley Research Center in Hampton, Virginia, NASA Dryden Flight Research Center, near Palmdale, California, and at Lockheed-Martin Aeronautics in Palmdale, California.

Once testing is completed, the researchers will evaluate the results from the three simulators against one another to compare the realistic and reproducible qualities of their output. Based on the findings from these tests, the project team will agree on requirements for sonic boom simulators. If they deem the realism in one or more of the simulators acceptable, the team will conduct subjective tests. Based on these tests, preliminary acceptance metrics would be defined by the end of 2006. This would guide development of a demonstration aircraft.

The researchers are also studying representative atmospheric turbulence filter functions by means of glider and ground waveforms derived from the shaped sonic boom demonstrator field measurements. They performed the demonstrator flights using a modified F-5E aircraft with flat-top front shock shaping only. The project's industrial partners will collaborate in a detailed analysis of the waveforms collected in those studies to create waveforms, of a shaped boom design, that have been propagated through realistic atmospheric effects. This will help design aircraft that will take into account realistic sonic boom impact.

Understanding Low Frequency Noise

Citizens ultimately determine when the noise associated with aviation is at an acceptable level. Researchers understand, however, that they need to determine a scientifically-based metric to assess the human impact of aircraft noise. In its search for such a metric, the FAA is funding the PARTNER Center of Excellence to study low frequency noise. The study encompasses many factors, including the noise source level and its spectrum, atmospheric propagation, the impact on homes in the form of noise, vibration and rattle, subjective perception and annoyance, and the ability of metric calculations to predict the physical and perceived impact.

The researchers are exploring new ways to measure and predict the annoyance people feel when faced with low frequency noise. The research team members come from

Pennsylvania State University, Purdue University, the University of Central Florida, the Boeing Company, GE Aircraft Engines, Rannoch Corporation, the Volpe National Transportation Systems Center, and Wyle Laboratories.

In the past year, the team conducted a low frequency noise study at Washington Dulles International Airport together with a NASA/Volpe assessment of "start of takeoff roll" source noise. They logged over 500 recordings of thrust reverser and sideline on-acceleration source noise, 41 hours of impact assessments involving residences of different construction types, and concurrent profiles of combined meteorological, wind, and temperature data. They also collected source noise recordings at the houses and runway locations using high quality microphones, and then labeled acoustic signatures for each of the various types of participating aircraft.

The signature recordings form a database that is being used in psychoacoustic testing. Juries of human subjects are reacting to the recordings, with specific emphasis on their perceptions of low frequency noise. This research may have implications on airport operations and future aircraft design and regulations. Eventually, it may identify acceptance metrics for low frequency noise and lead to action and technology development to mitigate the impacts of this type of noise.

Developing Emissions Profiles

Under the National Particulate Matters (PM) Roadmap, the FAA has partnered with NASA and the aviation community to test selected commercial aircraft under field conditions and develop accurate emissions profiles for aircraft engines in current use. The participants agreed to an element of anonymity to avoid sensitive issues of security procedures and handling of proprietary data; hence, the tests have come to be called the "Una-Una" (unidentified airport, unidentified airline) study. This study focused on particulate matter emissions. The research team studied engines manufactured either by General Electric or Pratt & Whitney mounted on Boeing 757, Boeing 767, and McDonnell Douglas 88 aircraft. The test team included individuals from FAA, NASA, the National Oceanic and Atmospheric Administration, Volpe National Transportation Systems Center, University of Central Florida, University of Missouri-Rolla, and Aerodyne Research, Inc.

During Phase 1 of the test, researchers held the aircraft immobile on the ground with their engines operating at various power settings. They measured emissions at engine exit nozzle and at downstream locations. Because the engines came from different manufacturers – and thus may have different rated thrust and depend on different emissions technologies – the study also provided an opportunity for a broader evaluation of particulate emissions than previously available. In Phase 2, researchers performed advected emissions measurements near the start of the runway, where aircraft generally begin takeoff operations. Although they initially collected samples from directly behind the engine, they subsequently tried to capture the exhaust plume as it moved a short distance downwind from a single aircraft, or under some runway conditions, from multiple aircraft.

In addition to gathering extensive information on the level of particulate matter emitted under a range of power settings, the research team is working to answer critical questions about the physical and chemical properties of aircraft particulate matter, such as particle count, size distribution, particle composition, and black carbon mass. The researchers also evaluated different types of measurement equipment to determine how well these instruments measured various particulate matter characteristics. Initial indications show, for example, that NOAA's Light Detection and Ranging (LIDAR) technology failed to measure particles of less than 100 nanometers, while the Aerodyne and University of Missouri – Rolla systems successfully provided accurate measurement. These results will allow comparison with the measurements based on other technologies. Such information could prove relevant to a new standardized particulate matter test protocol being developed by the Society of Automotive Engineers (SAE).

The test team is drawing generalizations from the data and getting their findings peer reviewed for publication. They will conduct additional research on lessons learned and answer research questions about particulate matter aging and its subsequent transformation downstream during the next airport study conducted in October 2005 in Cleveland, Ohio.

Creating the Particulate Roadmap

Regulatory and health agencies in the United States and other countries have found that exposure to particulates from a variety of sources, including aviation, may be hazardous to human health. These emissions may also adversely affect global climate. Although aviation is a known source of particulate emissions, there is little information on the characteristics of these emissions. To collect accurate and reliable scientific data on the characteristics of aviation emissions (rate of occurrence, particle size distribution, number density, composition, behavior in the environment, etc.), the FAA, NASA, DoD, the Environmental Protection Agency, engine and aircraft manufacturers, airports and airlines, and other stakeholders joined forces to develop a unified R&D and regulatory "Particulate Roadmap."

This roadmap will help researchers understand and quantify aircraft particulate matter emissions in relation to other sources. It will also help them determine how particles are composed, formed, grown, and transported. The resulting long-range action plan will guide aviation technology development.

Significant progress continues to be made in defining all the work elements necessary to achieve the project goals as defined in the mission statement. To ensure continued progress, the interagency Joint Planning and Development Office and its Environment Integrated Product Team will include this work in their research roadmap.

Designing Air Quality Standards

Airports are required to demonstrate compliance with the National Ambient Air Quality Standards (NAAQS) to ensure that particulate matter emitted by aircraft operated at their facilities does not exceed the size allowed by their applicable version of the standards. Until hard data becomes available, the FAA has developed a way to estimate the levels of particulate matter emissions attributable to a particular aircraft. Known as the First Order Approximation (FOA), this mathematical formula correlates the "smoke number" that is reported in the aircraft's original certification process with the generalized mass emission rates of non-volatile particulate matter emissions. The FOA methodology also draws on limited data from other sources.

Over 70 U.S. and international government, academic, and industry professionals have peer reviewed the initial development of the FOA. Feedback has been essential in the steps the FAA has taken to improve usefulness of the methodology. With each improvement, the FOA is returned to the peer review group for another evaluation and comment. Important contributors to these reviews include participants in the National PM Roadmap, researchers from PARTNER, and members of Working Group 3 of the International Civil Aviation Organization's Committee on Aviation Environmental Protection.

In August 2005, the FAA released version 4.3 of the Emissions Dispersion Modeling System, the latest version of the FOA methodology to estimate particulate matter mass emissions from aircraft engines, including emissions associated with downwind concentrations. For the first time in the evolution of modeling system, it can be used to demonstrate compliance with particulate matter national ambient air quality standards for airport emission sources.

The FOA will continually be improved as the science of particulate matter emissions from aircraft engines matures. Although it ultimately will become obsolete as verified indices of these emission emerge, the FOA fills an immediate need to estimate aircraft particulate matter emissions for compliance purposes.

Studying the Effects of Aviation on the Global Atmosphere

Aviation emissions contribute to climate change from factors such as greenhouse gas emissions, condensation trails (contrails), and enhanced cirrus clouds. Contrails are line-shaped clouds composed of ice particles, which are visible behind jet aircraft, typically at cruise altitudes in the upper atmosphere. Depending on the temperature and the amount of moisture in the air at the aircraft altitude, contrails evaporate quickly (if the humidity is low) or persist and grow (if the humidity is high).

Based on analysis of current meteorological data and on assumptions about future air traffic growth and technological advances, persistent contrail cover is expected to increase between now and the year 2050. Though contrails have been produced by jet aviation since its earliest days, focus on contrails has increased with the growing concern over climate change. It is currently estimated that regions of the atmosphere with sufficient humidity to support the formation of persistent contrails cover about 16 percent of the Earth's surface. If air traffic in these regions increases in the future, persistent line-shaped contrail cover will also increase.

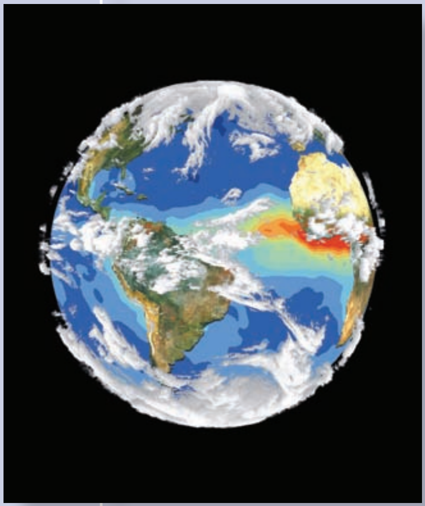
In 1999, the Intergovernmental Panel on Climate Change (IPCC) published a "Special Report on Aviation and the Global Atmosphere." The 1999 report comprised a complete and thorough documentation of the state of understanding at that time of how emissions at cruise altitudes affect the atmosphere. A much used resource, the contents of that report have guided the ensuing research and have begun to influence international policy making. The momentum brought by the development of the 1999 IPCC report was not maintained; yet, the active research groups have made a number of significant advances in the intervening years. Recently, PARTNER developed a report to summarize some key insights that have emerged over the past five years and identified further research needed. As a result, PARTNER also is now conducting new research efforts to address key uncertainties, including investigating relationships between aircraft parameters (controllable inputs) and the properties of the condensation trails (contrails) generated by aircraft under a variety of atmospheric conditions. This research will be critical to the deliberations of the International Civil Aviation Organization's Committee on Aviation Environmental Protection.

Measuring Aviation's Greenhouse Gases

The World Meteorological Organization (WMO) and the United Nations Environment Programme established the Intergovernmental Panel on Climate Change to assess scientific, technical, and socioeconomic information relevant to the understanding of human-induced climate change, potential impacts of climate change and options for mitigation and adaptation.

The FAA's Chief Scientific and Technical Advisor for Environment is working with the Panel to revise the Guidelines for National Greenhouse Gas Inventories. The new guidelines, which will be published in 2006, stress harmonization with other sectors of the economy, introduce new scientific and technical material, and incorporate input from the International Civil Aviation Organization's Committee on Aviation Environmental Protection. A key feature is a new methodology for computing inventories bases on newly available models such as the FAA-developed System for Assessing Aviation's Global Emissions.

The draft guidelines will be ready for government consideration in early 2006. When published, they should be influential for years to come as countries seek to manage their greenhouse emissions.



Rewarding Research

This year, the PARTNER Center of Excellence announced two winners of the 1st Annual Joseph A. Hartman Student Paper Competition. Named to honor one of the Center's founders, the contest awarded cash prizes of $2,000 to co-winners Nicolas Antoine and Nhut Tan Ho.

PARTNER honored Dr. Antoine, formerly of Stanford University and now at Airbus, for his paper, "Aircraft Optimization for Minimal Environmental Impact." This study looks at the feasibility of integrating noise and emissions objectives into the conceptual design stage of new aircraft. His approach allows early quantitative analyses of trade-offs between environmental performance end operating costs. It also could impact the long-term design of the next generation of commercial aircraft.

Formerly of MIT and now at California State University, Northridge, Dr. Ho, was honored for his "Design of Aircraft Noise Abatement Approach Procedures for Near-Term Implementation." This research considers the installation of the Continuous Decent Approach (CDA) paradigm in commercial airports. While CDA clearly can reduce emissions as well as the noise affecting surrounding communities, its implementation may pose new challenges for air traffic control. This paper looks at many of these problems and suggests ways to overcome them.

The judges also awarded an "Honorable Mention" and a cash prize of $200 each to three students from the Pennsylvania State University:

- Peter Shapiro: "Subjective Response to Low-Frequency Aircraft Noise;"
- Erin Horan: "Vibration and Rattle Impact Due to Low Frequency Noise Investigated at Dulles Airport;" and
- Remy Gutierrez: "Investigation into Low-Frequency Airplane Source Noise Directivity Along Runway Sideline During Start of Take-off Roll and Thrust Reverser Engagement."

Each of these papers relates to a larger project to quantify and define issues associated with aircraft low-frequency noise.

Nicholas A. Jaggers, a PARTNER student at Purdue University, took second prize in the FAA Centers of Excellence Joint Annual Meeting Student Poster Contest for his entry, “Research to Examine Population Encroachment on Airport Operating Areas.”

The FAA also named Stephen P. Lukachko, a doctoral student in Aeronautics and Astronautics at MIT, “Student of the Year” for the FAA Centers of Excellence. He has developed an accounting framework to assess uncertainties and trade-offs of environmental impacts of commercial air transport.

Human Factors & Aeromedical

Following user feedback, human factors specialists revised the Human Factors Awareness Course. In addition, they finalized the evaluation components of the training course, providing a set of quizzes (one for each module), a pre-test, and a post test. Users can now print a course certificate of completion.

Improving Tower Siting/Visibility

In an average year, the FAA starts construction on seven airport traffic control towers (ATCT). Towers recently constructed or currently being built range in height from 65 to 300 feet tall and cost from $11 to $80 million. These costs depend on several factors, such as the size of the base facility, whether there is a colocated terminal radar control facility, the equipment integrated in the tower, and the surrounding security requirements. But a major factor is the tower height and location. Each new tower costs millions of dollars to construct – approximately $40,000 per foot of height.

In the past, tower siting (height and location) decisions were based on the FAA's Airport Tower Siting Criteria (FAA Order 6480.4), issued in 1972. As part of efforts to update and revise that order, researchers collaborated with engineers and air traffic control specialists to develop, test, and validate a set of human performance metrics for assessing the impact of tower height on air traffic control tower specialist performance. After analyzing a number of methods to address object obscuration, object discrimination, line-of-sight angle of incidence (look-down angle), two-point lateral discrimination, and tower cab design human factors considerations, researchers developed a web-based tool to assist tower planners and construction engineers.

Sharing Human Factors Knowledge

The Human Factors Workbench provides FAA employees, system developers, human factors researchers, and human factors practitioners easy access to human factors information that supports aviation-related activities. By providing free on-line access (http://www.hf.faa.gov/Portal/default.aspx) to information, the toolbox promotes knowledge sharing, allowing users to access: system development and process descriptions; more than 100 human factors tools; the Human Factors Awareness training course; and more than 1,600 publications, studies, and other papers assembled into a searchable database. Creation of the Human Factors Workbench promotes the sharing of knowledge about human factors best practices, and helps acquisition professionals, the FAA workforce, and associated participants, accomplish FAA objectives for the national airspace system. The Human Factors Workbench promotes use of important information related to solving human-system performance challenges in the aviation community.

The FAA recently added new reports to the library and enhanced its search capability. Researchers also expanded the toolbox and updated some existing tools to reflect changes in the FAA Acquisition Management System.

The ATC Visibility Tool allows the user to manipulate basic or advanced visibility parameters to measure the effects on an observer's ability to acquire an object visually. It also defines the minimum line-of-sight angle of incidence required for airport traffic control tower specialists to perform their necessary separation task. Users simply input an object, designate tower height and key point distance, select the outside illumination level, and the tool calculates minimum discrimination and slant angle (height) requirements. The tool is publicly available at http://www.hf.faa.gov/visibility.

As a result of this research, in June 2005, the FAA released for comment and interim use a revised ATCT siting policy that mandates the use of visibility performance measures. This research is having an immediate impact. It is not only enhancing safety by allowing researchers and engineers to find and resolve potential problems before tower construction begins, but it is also contributing to significant cost savings.

Designing the Future En Route Workstation

The expected 50 percent increase in air traffic by 2020 will require a dramatic change in how air traffic controllers work. To determine the feasibility of integrating automation functions in the tower that would allow controllers to handle additional traffic, researchers are examining ways to present and integrate information, measure controller operations, and ensure human factors considerations are reflected in the controller workstation of the future. The goal of this research project is to minimize the number of steps and amount of time an air traffic control specialist needs to either retrieve or input data into an automation system.

In one of the most complex person-in-the-loop simulation studies ever conducted at the FAA William J. Hughes Technical Center, researchers exposed controllers to three workstation concepts and three levels of traffic. The workstation concepts included a baseline condition (Display System Replacement, Traffic Management Advisor, User Request Evaluation Tool, and data link-digital communications), a generic future concept (identical Radar Controller and Radar Controller Associate workstations), and a specialized future concept (where the Radar and Radar Associate workstations reflected some specialization based on the function). The three traffic levels consisted of 21 (today's traffic), 28 (33 percent traffic increase), and 35 (66 percent traffic increase) aircraft under control. The experiment also included scenarios to address the effect of providing a conflict probe on the radar controller workstation and of upgrading the data-side display from a conventional configuration to one that includes a radar display with integrated automation functions. In addition, the study included scenarios to address the effect of providing data link-digital communications functionality by removing it from the available tools.

Data analysis continues on the project. The results of this research project may help increase controller productivity and enable the air traffic system to increase capacity through user-centered automation.

Determining the Benefits of the En Route Information Display System

The FAA plans to deploy a new system that will provide controllers real-time electronic access to weather data, aeronautical data, air traffic control procedures documents, Notices to Airmen, pilot reports, and other information. Prototype systems are currently being assessed at the Boston, Jacksonville, and Salt Lake Air Route Traffic Control Centers.

As part of efforts to develop the En Route Information Display System (ERIDS), a team of researchers is studying controller information needs. In particular, they are assessing the benefits of the new system from a controller perspective, focusing on potential workload reduction and convenience. To date, researchers have identified current paper sources of air traffic system information, determined how often controllers access this information, examined the time and motion required for a controller to access information, and studied the importance and currency of the information.

To determine the impact, workload cost, and benefits of ERIDS on the total system, baseline information was compared to performance data when using ERIDS. Radar controllers, radar associates, supervisors, and others took part in the study. The team also developed a test plan and began data collection efforts on the prototype systems in late 2005. In addition to this study, researchers are reviewing system hardware, evaluating integration into controller workstations and location of system hardware.

The FAA will use the results of this research to determine the human performance impact of the new system. This information will be an important input to the cost-benefit analysis prior to making a final decision on system acquisition and national deployment.

Developing a Modular Display Concept for Air Traffic Control Towers

Currently, each air traffic control facility is responsible for its own tower cab design. Lacking any central human factors design for tower displays and the arrangement of equipment within the tower cab, each tower is a unique facility that has evolved over time as a result of funding, traffic demand, and individual facility decisions. As a result, most tower cabs have a piecemeal design that places equipment where room is available without a clear understanding of controller information requirements.

To create a more efficient cab design, human factors researchers are developing a modular concept of air traffic control tower design. In support of this effort, they collected data that will help them understand tower controller work patterns and the information required to perform controller tasks, with emphasis on the interaction with tower cab systems. They also produced sketches of tower cab layouts, recording the type and placement of equipment relative to controller positions. They developed flow diagrams to identify controller tasks, task elements, communications and coordination, and the information required to support task goals for each position in the tower cab (e.g., local, ground, flight data, clearance delivery). The diagrams identify which information elements or sources can serve controller requirements across multiple tasks and between positions.

Once research is complete, the FAA will have a master concept for tower cab design that uses a modular approach to meet the tailored display needs for each tower.

Transforming a Safety Culture

To understand better and improve the organizational safety culture, human factors researchers began assessing the culture attributes of FAA Air Traffic Organization Technical Operations facilities.

The research team conducted a series of focus group sessions at the Seattle, St. Louis, and Potomac Terminal Radar Approach Control facilities. They selected these facilities because of their potential to provide a realistic sampling of work environments and job types without having to conduct a large-scale nationwide study. After interviewing participants, the team developed a safety culture survey instrument that is now ready to be tested.

To determine overall trends in the safety culture, researchers hope to conduct a longitudinal study—repeated measurements over a long period of time. A single survey would simply provide one data point, a snap-shot, which is an important starting point, but not nearly as useful as the long-term trend report.

Data from the study will provide an in-depth understanding of the baseline status of the organization’s safety culture. Once the baseline is established, subsequent measurements will allow the organization to assess the effectiveness of various interventions that may be implemented in the course of the culture change efforts.

Enhancing the Aircraft Certification Job Aid

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

FAA-funded researchers at Research Integrations, Inc., previously developed a PC-based software tool with three major databases addressing regulatory information, flight deck components, and human factors considerations. Early versions of the Job Aid addressed Part 25 Transport Category Aircraft displays, controls, and integrated flight deck systems such as the flight management system. Human factors researchers have added information on Part 25 integrated flight deck systems and summaries of Part 25 regulations for human factors considerations related to equipment, tasks and procedures, and testing assumptions. Additionally, human factors summaries of Part 23 Commuter Category Aircraft regulations and Advisory Circulars for human factors considerations related to displays, controls, and integrated flight deck systems are complete. A limited number of certification personnel continue to use the fielded version of the job aid in their jobs. They provide important feedback for future version enhancements.

Evaluating Electronic Flight Bags

Airlines are now introducing electronic flight bags into the flight deck, bringing with them many human factors challenges. The FAA defines an electronic flight bag as an electronic information management device used by crew members to obtain information currently provided in paper form. Although these devices may look like familiar equipment, the flight deck perspective of their flexible configurations and functionality sets them apart from traditional equipment.

Human factors research is needed to provide input for certification, operational approval, and training guidance, including input to Advisory Circulars, as well as to mitigate risks associated with implementation and integration on the flight deck. The focus of the current effort is to develop more practical aids for field evaluations of electronic flight bags by FAA field inspectors. Such tools will benefit the FAA, system designers, and operators by providing structure for human-factors evaluations. They will be customized for both aircraft certification specialists and Flight Standards inspectors.

Researchers continue to refine the Electronic Flight Bag Usability Assessment Tools, developed with FAA funds by the Volpe National Transportation Systems Center. In 2005, researchers refined the assessment tool for FAA Aircraft Certification specialists. They participated in workshops with the intended users, received feedback, and incorporated the results into the assessment tools. Additionally, working closely with FAA pilots and capitalizing on the products previously developed for aircraft certification, researchers developed an initial usability assessment checklist for inspectors.

Determining Effective Flight Symbology

New technology and electronic displays are becoming more common in the cockpit. Because display technology varies widely from manufacturer to manufacturer and device to device, researchers are working to determine what aeronautical chart symbology (airports, roads, railroads, terrain features, obstructions, etc.) most effectively presents moving maps and electronic chart displays. The goal of this work is to identify features of navigation symbology that are problematic when presented on electronic displays, and develop a method to design and evaluate symbology that takes into account the different media (e.g., paper vs. electronic) and platforms on which they will be displayed. FAA-funded researchers at the Volpe National Transportation Systems Center, have conducted two experiments.

They first tested the intuitiveness of navigation symbols that are constructed from feature rules (e.g., an outer circle implies that it is a "fly over" point). The second experiment identified stereotypes for the navigation symbols. Results from this research will help the FAA and industry establish standards for symbology. The researchers are currently working with the Society of Automotive Engineers (SAE) G-10 Aeronautical Charting Subcommittee in its efforts to update the recommended symbol set in SAE Aerospace Recommended Practice 5289. The subcommittee plans to use the results of these experiments for input to the recommended symbol set.

Understanding Human Error

For the past six years, the FAA has used the Human Factors Analysis and Classification System (HFACS) to examine human error associated with commercial and general aviation accidents. Designed by the military and modified for FAA use by FAA and University of Illinois researchers, HFACS is a theoretically based tool for investigating and analyzing human error associated with high-risk environments such as aviation. Researchers have proven that HFACS is a reliable tool to conduct human factors analysis of commercial and general aviation accidents.

The research team continues to conduct focused investigations of human error associated with a variety of aviation communities, including: commercial aviation; general aviation in Alaska versus the rest of the U.S.; helicopter emergency medical services; and aviation maintenance. To date, they have examined and classified over 25,000 accidents using the HFACS framework. This encompasses all civilian aviation accidents since 1990.

Researchers also have integrated HFACS and other traditional National Transportation Safety Board (NTSB) situational and demographic variables into a single, web-based database, which allows for human error examinations of the accident data. The data provide critical information in the development of "data-driven" interventions to prevent accidents. These interventions are catalogued into the human factors intervention matrix, which maps the causal categories outlined by HFACS to five human factors approaches to intervention – organizational/administrative, human/crew, technology/engineering, task/mission, and operational/physical intervention. The team also has completed a preliminary investigation of current FAA and proposed NTSB safety interventions using HFACS. Results from this effort will provide the baseline information necessary for assessment, modification, and/or development of future safety interventions.

Improving Human Factors in Aviation Maintenance

Attention to human factors issues in maintenance and engineering has become a cornerstone for ensuring continuing safety. To help achieve our safety goal, the FAA released *The Operator's Manual for Human Factors in Aviation Maintenance*. Written in response to industry requests for simplified instructions, the manual provides a short and concise listing of six key factors that will help ensure appropriate human factors input into any maintenance organization.

Available to the public, at no cost on the Internet (http://www.hf.faa.gov/opsmanual), the manual provides easily understood information on event investigation, documentation, training, shift turnover, and fatigue/alertness. The final chapter addresses the issue of program sustainment and cost justification. For each of the subjects covered, the manual provides information on why the topic is important, how the human factors practice can be implemented into an organization, how to measure success, and where to find additional information.

The manual is a result of joint government/industry effort to improve aviation maintenance human factors. In addition to the FAA, participating organizations included: NASA; jetBlue Airways; Northwest Airlines; US Airways; American Airlines; FedEx; Saint Louis University; the Boeing Company; and major airline labor organizations. Users of the manual include aviation maintenance managers, quality managers, and training personnel. It provides supplemental information for FAA aviation safety inspectors and personnel overseeing airline maintenance, repair, and overhaul.

Establishing Proficiency Standards for Advanced Aircraft

The advent of technically advanced general aviation aircraft, such as the Eclipse 500, requires that pilots, instructors, and evaluators master a wide variety of new concepts and skills. To help the aviation community, researchers produced a comprehensive list of knowledge and skills that are important for pilots, instructors, and evaluators who operate, teach, and test in technically advanced aircraft.

This research will be used to develop a new technical publication to serve as an official information source for these new areas of proficiency. It will be similar to the *Airplane Flying Handbook* (FAA-H-8083-3), *Instrument Flying Handbook* (FAA-H-8083-15), and the *Pilot's Handbook of Aeronautical Knowledge* (FAA-H-8083-25).

Using Advanced Technology for General Aviation Inspection Training

The majority of all general aviation aircraft inspections are visual. As aircraft become more technologically advanced, the inspector's job becomes more difficult. To prepare inspectors for new aircraft, new tasks, and new inspection techniques, FAA human factors specialists are demonstrating how advanced technology can improve training. This effort will reduce inspector errors in the general aviation maintenance environment.

FAA-funded researchers at Clemson University have developed a prototype computer-based training tool called the General Aviation Inspection Training System (GAITS), which will improve defect detection. This training program is organized into separate modules: introduction; training; simulation; design and analysis; and, simulator. Specific activities conducted in support of the development of

GAITS included: development and evaluation of alternate interfaces, and development of scripts and story boards.

GAITS allows for individualized training, as well as evaluation of a maintenance inspector's performance. The Design and Analysis module, for example, helps the instructor customize the training program to suit individual needs. If an inspector needs help in locating corrosion defects, he or she can access information about different types, severity, and locations of corrosion. Similarly, the simulator can be tailored to provide specific feedback to enhance the learning experience.

Developing a Web-Based Surveillance and Auditing Tool

The FAA is developing a web-based surveillance and auditing tool (WebSAT) that will provide a standardized format for maintenance data collection, reduction, and analysis to identify factors contributing to maintenance errors. The goal of this research is to reduce errors and improve the reliability of aircraft inspection operations. WebSAT will aid in standardizing the data collection process supporting analysis of maintenance errors prior to aircraft dispatch. This will facilitate analysis across airlines. In addition, WebSAT can be combined with existing training programs to facilitate consistency in inspection training, provide adaptive training, and support record-keeping and performance monitoring. A FAA-funded research team at Clemson University is conducting research in the areas of user-interface, data reduction techniques, and data analysis strategies. The research team is also developing a reliable risk model to analyze data collected from various surveillance, technical auditing, and airworthiness directive work functions. They have completed the technical auditing module.

Establishing Requirements for Simulator Training

FAA-funded research is underway at the Volpe National Transportation Systems Center to establish flight simulator qualification standards for pilot training. Because air carrier certification, qualification, and continuing qualification is accomplished in simulators by most air carriers, simulation must accurately replicate the airplane and aviation environment.

Previous studies investigated the effects of motion in recurrent pilot training. Researchers recently completed work with a major air carrier and its Boeing 717-200 fleet to determine the effects of simulator motion on initial pilot training. They trained and tested over 40 pilots on a full flight simulator airplane after completion of ground school. They trained half of the pilots with motion and the other half without motion. To assess the effect of motion on transfer of training, the research team then tested all of the pilots in the simulator with motion as a stand-in for the airplane. They collected data from the simulator and with questionnaires. Analysis is underway, and additional research must be performed before the researchers issue their final conclusions. Early results, however, support previous findings and suggest that flight-simulator motion will not benefit recurrent training.

Training Pilots and Crew

In most air carrier pilot training programs, instructional strategies that seek to improve teamwork in the cockpit (crew resource management skills) are treated as stand-alone entities. However, research indicates that crew resource management should be integrated into all aspects of training. Situational training will improve pilot performance and enable air carriers to prepare pilots to manage more effectively the range of flight situations they may experience.

Current FAA-funded research at Battelle Memorial Institute is investigating the advantages and implications of using a situational training framework. Based on this work, researchers expect to develop a catalog of situational events that the FAA and air carriers can employ in training development. They plan to develop a training framework that integrates crew resource management training with the more technical training. Such a training program would make pilots aware of the consequences of situational factors and tap crew resource management skills to manage and resolve potentially dangerous flight situations.

Standardizing Event Reporting

Over the last decade, the FAA has introduced a broad range of industry safety programs designed to enhance safety by collecting data on human and aircraft performance. One of these programs is the Aviation Safety Action Program (ASAP) developed to encourage airline employees to voluntarily submit safety-related reports.

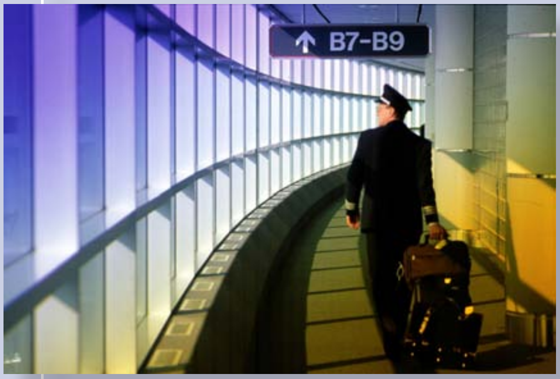
In a typical report, the pilot voluntarily writes a short narrative describing the event and the causal factors, and provides recommendations to prevent recurrence. From this, air carriers prepare training objectives. Because ASAP programs are carrier specific, the FAA is working to develop a means to share data and accident/incident mitigation strategies among the various air carriers collecting ASAP data. To accomplish this, the Agency must develop uniform incident classification tools that various air carriers can use to collect and analyze their data.

In 2005, FAA-funded researchers at the American Institutes for Research developed, tested, and validated the Aviation Causal Classifications for Event Report System in coordination with a regional air carrier. Completion of this taxonomy yielded a document that illustrates seven high-level causal contributors to human error in aviation, and shows the hierarchical assignment of an additional 70 detailed factors to these seven categories. Definitions are provided both at the category and factor level. This taxonomy provides a uniform set of descriptors and is now available to industry.

Training Pilots for Unexpected Events

The goal of this research at the University of Central Florida is to provide the FAA and air carriers methods to develop training curricula that will prepare pilots to respond to abnormal or emergency operational conditions. Training pilots to cope with and react to unexpected events continues to be a challenge for the air carrier industry. Each year, the air carriers conduct special training sessions to train their pilots for newly identified, safety-critical maneuvers and operations. Yet, at the same time, this type of event-specific training will not, and cannot ,prepare pilots for all possible eventualities. Instead, pilots need to be prepared to react flexibly and creatively to previously unexperienced events.

This research project addresses the psychological, cognitive, and behavioral processes contributing to surprise, and identifies factors underlying events perceived as abnormal or emergency. In 2005, researchers completed a field study investigating factors underlying a pilot's ability to recognize and react to various flight abnormalities, including upset recovery. The research team has analyzed the data and issued a final report outlining preliminary suggestions for training development and recommendations for further research. Suggested actions include development of training interventions to manage unexpected events, such as scenario-based training, metacognitive training, and adaptive expertise training. These interventions will be prototyped and tested in upcoming years.



Understanding the Effects of Mixed Fleet Flying

FAA-funded scientists at Research Integrations, Inc., conducted a longitudinal study to identify whether skill degradation occurs when pilots have not recently flown the aircraft upon which they have been trained. The primary topics of investigation included examining the possibility of pilots making errors in one airplane because of their experience with another airplane, and the likely degradation of pilot skills if they have not flown one of the planes for up to six months. Prior to this study, researchers had identified the potential for human error if pilots trained in one aircraft flew another type of aircraft without training.

Researchers have analyzed data from this study to determine the magnitude of potential safety vulnerabilities. They identified one safety concern related to the design of the Takeoff/Go-Around (TOGA) switches. Other findings showed that several procedural and training items must be addressed for pilots to fly successfully two types of airplanes. They also determined that for most of the operations and maneuvers tested, a six-month currency cycle is acceptable. Research results will help the FAA and the airlines to identify constraints and establish requirements for air carriers where pilots fly two different types of aircraft.

Analyzing Opiates in Postmortem Fluids and Tissues

Researchers in the Aerospace Medical Research Division of the FAA Civil Aerospace Medical Institute (CAMI) are making significant advances in the analysis of postmortem fluids and tissues following fatal aircraft accidents. Forensic toxicology researchers routinely detect and measure drugs, alcohol, toxic gases, and toxic industrial chemicals in the remains of accident victims to rank these factors among the causes of accidents. They also analyze clinical chemical parameters in search of significant health trends affecting aviation personnel.

Opiates are some of the most widely prescribed drugs in the U.S., but they are often abused. Derived from a seed-pod of the poppy plant, their general effects include sedation, slowed reflexes, sluggish movements, and slowed breathing. The research team has developed a simple method to determine the presence and qualities of as many as eight opiate compounds from a single sample.

One of the primary goals of this research is to make sure drug positives have not resulted from the incidental use of common food products or postmortem artifacts. Eating foods such as poppy seed bagels and muffins, for example, can make a person test positive for morphine and codeine. This person also is likely to test positive for thebaine, a unique marker for poppy seeds. In contrast, a person taking prescription codeine tests positive for codeine and morphine but not for thebaine. Until recently, toxicologists could not easily and quickly tell the difference between codeine use and poppy seed consumption in laboratory tests.

Studying Gene Expression Changes in Response to Mild Alcohol Ingestion

Aerospace medical researchers are conducting focused studies on the expression, function, and interactions of genes to identify ways of preventing accidents. For example, researchers are working to identify genes associated with impairment. This research will ultimately result in new methods to identify pilots whose potential impairment might lead to an accident.

Among other investigative techniques, researchers use microarrays (also known as “DNA chips”) in a method that screens a biological sample for the relative expression pattern of all its contained genes. They have demonstrated the effectiveness of microarray analysis for detecting mild ($\leq$ 0.08 percent) alcohol consumption and identifying genes associated with alcohol consumption. This genetic knowledge can now be used to evaluate aviation accidents in terms of alcohol consumption and impairment.

Functional genomics research pushes the FAA’s aerospace medicine community towards the forefront of scientific discovery and therefore the realization of state-of-the-art safety processes. Continued investigation will allow researchers to tell the difference between alcohol that developed in a victim’s body after death as a result of normal microbial activity and the remains of alcohol that the victim had actually ingested. This research directly supports the Office of Science and Technology Policy Interagency R&D Fiscal Year 2005 priorities by enabling a molecular level understanding of normal life processes and those associated with disease. This understanding will lead to improved aeromedical safety operations.

Using the Scientific Information System for Research Studies

Researchers apply computational and analytical methods to understand very complex biology. They have developed a scientific information system that permits the comprehensive, systematic study of pilot-related mishaps (accidents and incidents) due to medical and human factor causes. The process involves examination of millions of records from FAA medical certification efforts in combination with accident investigation findings from the National Transportation Safety Board.

Researchers recently completed the evaluation of atrial fibrillation (AFIB), a medical condition of importance to aeromedical examiners when evaluating aircrews. AFIB is the most common form of arrhythmia, a heart condition affecting more than two million people annually. Its prevalence increases with age and complications include stroke and congestive heart failure. Bioinformatics research has found that the overall safety record of pilots with AFIB is no different from that of pilots in general. Also, the mishaps studied were not related to the medical condition of the pilots. This review provides a fact-based foundation for decision-making and supports the safety of current certification procedures. Accident precursors are becoming much more visible as a result of this type of research, thereby enabling more effective and timely introduction of countermeasures.

Testing the LASER Transmissivity of Aircraft Windows

Between January 2004 and January 2005, 53 out of 90 reported LASER (Light Amplification by Stimulated Emission of Radiation) sightings were associated with commercial aircraft. Thirteen of the 90 reports resulted in some degree of pilot visual impairment or distraction. Brief exposure to a LASER beam can cause discomfort and temporary visual impairments such as glare, flash-blinding, and afterimages. To a pilot, these visual distractions can produce spatial disorientation or loss of situational awareness.

Reports of intentional and unintentional illuminating of aircraft by LASERS triggered new Department of Transportation rules on the reporting of LASER sightings and subsequent investigation of the events. As part of an ongoing research program, the vision research team collaborated with the U.S Army in LASER testing involving eight aircraft windscreens. These tests addressed related safety concerns of both the Department of Homeland Security (DHS) and the FAA. Partial analysis indicated that, as expected, LASERS in the visible light spectrum easily transmit through cockpit glass.

Simulating Aircraft Cabin Evacuation

Airliners certified by the FAA to operate in the national aerospace system generally must pass a test to evacuate a full load of passengers and the flight crew in 90 seconds with one half of the exits blocked. Because real-life certification tests for passenger cabin evacuations are expensive and dangerous, the test is usually limited to a single event under fixed conditions. Actual accidents may result in a variety of damage conditions affecting cabin evacuation. Damaged doors, broken seats, blocked aisles, fire, or airframe damage may impede evacuation and cannot be included in most testing.

To provide information on aircraft designs and potentially supplement certification procedures, FAA researchers collaborated with Rutgers University to develop a computational aircraft evacuation model that uses features such as the shortest distance to exits, speed of an evacuation cue line, gaps in the evacuation cue line, and flow rate at exits. It has evacuees cut in front of one another in a cue, move to a different exit if the line is moving too slowly, and engage in other behaviors characteristic of aircraft evacuations.

Researchers applied the model to several aircraft, including the Airbus 320 and 380 and the Boeing 767 and 777. With further development and validation, the model may be used to improve training strategies to enhance passenger survival rates in the event of an accident. It will also help to enhance escape simulation efforts studying the role of cabin fire and smoke, optimize aircraft cabin design and escape routes, and develop assisting devices.

Information Technology

Securing Information Systems

Visitors to sensitive information sites may not find what they are looking for in a single document, but when they combine information from various documents – within and across sites – they may learn more than the keepers of the sites intended to reveal. Information managers need automated tools that will generate plausible "concept chains" to expose such links. These tools would sift through extensive collections of documents to detect risks and identify seemingly innocuous information that, when pulled together from various sources, can yield useful intelligence to an adversary.

A project is underway to develop a new search engine that seeks hidden vulnerabilities and will be used to protect the FAA's sensitive information assets. The next phase to be completed in FY 2006 will demonstrate a prototype on actual data sets and automatically generate detailed graphs revealing potentially hidden associations among semantic concepts. Eventually, the search tool may also be used for other applications, such as helping biomedical researchers conduct more effective investigations into the connections between genes, proteins, and disease.

The FAA must also be prepared to prevent cyber attacks against its safety-critical mission support networks and systems. Adaptive intrusion quarantine research combines the proactive capabilities of behavior-based tools with the reactive effects of rules-based tools. Although this is the only research project in the Federal Government currently using this strategy to protect against security threats, its commercial-off-the-shelf architecture would make it readily transferable.

Costing Secure Software Systems

The FAA is currently studying the feasibility of adding a security module to the University of Southern California-developed Constructive Cost Estimation Model (COCOMO II), and using the model to estimate the cost of adding security to systems. The results will identify security cost drivers and provide a tool for program managers to evaluate the cost benefits for security elements. With the current COCOMO II, users can estimate the cost, effort, and schedule involved in planning a new software development activity. There is a need for this tool as there is a wide variation in the additional estimated costs involved in developing software–intensive systems that require security. Other government agencies have expressed an interest in the progress of this project.

Currently, researchers are developing simple "rule-of-thumb" costs, based on security cost drivers, cost estimation relationships, and applying the COCOMO II security extensions to a small number of pilot security projects.

Collaborating to Improve Information System Security

Federal Agency Administration of Science and Technology Education and Research (FASTER): The National Science and Technology Council Subcommittee on Networking and Information Technology R&D recently created FASTER as a Community of Practice for the highest level of federal information specialists who administer science and technology education and research programs. FASTER representatives, including FAA researchers, seek to accelerate deployment of promising research technology, share information on protocols, standards, best practices, and coordinate technology assessments and test bed development through agency collaboration. The group is pursuing the exchange of information in a number of areas including the Federal Enterprise Architecture, Internet Protocol version 6 (IPv6), the semantic web, and the Federal Data Reference Model that combines elements of the Semantic Web and the Federal Information System.

Center for Identification Technology Research (CITeR) : The CITeR is a National Science Foundation Industry/University Cooperative Research Center focusing on biometric identification technology. Its research portfolio addresses identification technologies that encompass vulnerabilities, multimodal systems, biometric modalities, biometric image coding and quality, performance framework, system modeling, and socio-legal and business studies. Twice yearly participation in the organization allows the FAA to leverage R&D in the area of identification technologies funded by the National Science Foundation, industry and other federal government sponsors. As a member, the FAA gains:

- Access to students involved in center research as future employees;
- Cost-effect, highly leveraged research;
- Access to interdisciplinary faculty teams spanning health sciences, the sciences, and engineering to address cross-cutting biometric system challenges;
- Access to a broad spectrum of research labs;
- Advance copies of research results and publications; and
- Proprietary position on technology transfer licensing.

The FAA recently joined the Air Force Research Laboratory and George Mason University to identify and mitigate potential attack paths to mission critical resources. Through this work, called Combinatorial Analysis Utilizing Logical Dependencies Residing on Networks, researchers are promoting earlier detection and faster resolution of security events and increasing productivity levels. Specifically, they are:

- Providing context for total network security;
- Analyzing network modifications;
- Prioritizing potential security incidents;
- Addressing insider and outsider threat; and
- Reporting only those vulnerabilities associated with possible attack paths.

In addition, through this project, the FAA is developing critical enhancements to support information system security architecture optimization.

MIT Center for Information Systems Research (CISR): The Center for Information Systems Research (CISR) conducts field-based research on issues related to the management and use of information technology (IT) in complex organizations. Established at the MIT Sloan School of Management in 1974, the mission is to develop concepts and frameworks to help executives address the IT-related challenges of leading increasingly dynamic, global, and information-intensive CISR research. The associated identification of best practices could benefit to the national airspace system and the business systems that enable the operation of the Agency. Expectations are that FAA operational procedures, acquisition policies, and orders will be updated to incorporate the results as a current best practice.

Safe Flight 21/Alaska Capstone

Deploying Automatic Dependent Surveillance–Broadcast (ADS-B)

Automatic Dependent Surveillance–Broadcast (ADS-B) has emerged as the FAA's leading "technology opportunity" for transforming the national airspace system into the Next Generation Air Transportation System. ADS-B is a two-way data link system that supports both "core surveillance" and "cockpit based-capabilities" within a single multifunction display.

ADS-B onboard avionics send a radio message about once per second giving the aircraft's position, velocity, identification, and other information. The position information is derived from the highly accurate Global Positioning System. Aircraft equipped with ADS-B cockpit displays can receive reports from similarly equipped aircraft near them as well as from ground-based systems. Broadcasts also can be received by air traffic surveillance services and the airlines. The sharing of situational awareness among aircraft, air traffic control, and airlines could reduce operation and maintenance costs, increase efficiency and capacity, and improve safety.

Work continues on development of the ground infrastructure to integrate ADS-B into the national airspace system. Researchers completed a data collection effort to help develop ADS-B validation techniques. They also tested a prototype ADS-B ground receiver developed by Raytheon Systems, Ltd. In addition, they undertook data collection, test, and analysis of ADS-B data links and continued support of international ADS-B standards development.

The FAA's Safe Flight 21 Program is currently delivering ADS-B services along the East Coast from southern New Jersey to Florida, as well as parts of Ohio, North Dakota, and Arizona. It is also planning service expansion to Pennsylvania and Tennessee in the near future. The FAA recently evaluated the business case for ADS-B technology, and is in the final stages of making a decision for a national ADS-B strategy.

Advancing the Capstone Program

The FAA has demonstrated that Capstone technologies can improve aviation safety and efficiency in Southwest and Southeast Alaska. Aircraft in both areas are now equipped with avionics that display the positions of other aircraft along with weather and terrain data. Additionally, Capstone-equipped aircraft in Southeast Alaska can now fly routes based on the use of the Global Positioning System with Wide Area Augmentation System augmentation. These capabilities support safe operations at lower altitudes than those supported by land-based navigational aids.

The Capstone effort has contributed to a steady decline in accident rates in Southwest Alaska. A MITRE Center for Advanced Aviation System Development and the University of Alaska study reports that, during the last three years, the accident rate for Capstone-equipped aircraft was 47 percent lower than for an equipped aircraft.

Capstone's Wide-Area Multilateration Project has demonstrated a way to augment ADS-B capabilities. Transponders aboard ADS-B-equipped aircraft in the Juneau terminal area now transmit identity and location data to a network of ground sensors. The complementary wide-area multilateration technology enables situational awareness in areas that lack radar coverage.

Capstone is preparing an investment business case for using the wide area augmentation system statewide to replace existing navigational aids. By 2007, the FAA envisions that this four-year effort will reduce operational costs in addition to improving safety.

Demonstrating the System Wide Information Management (SWIM) System

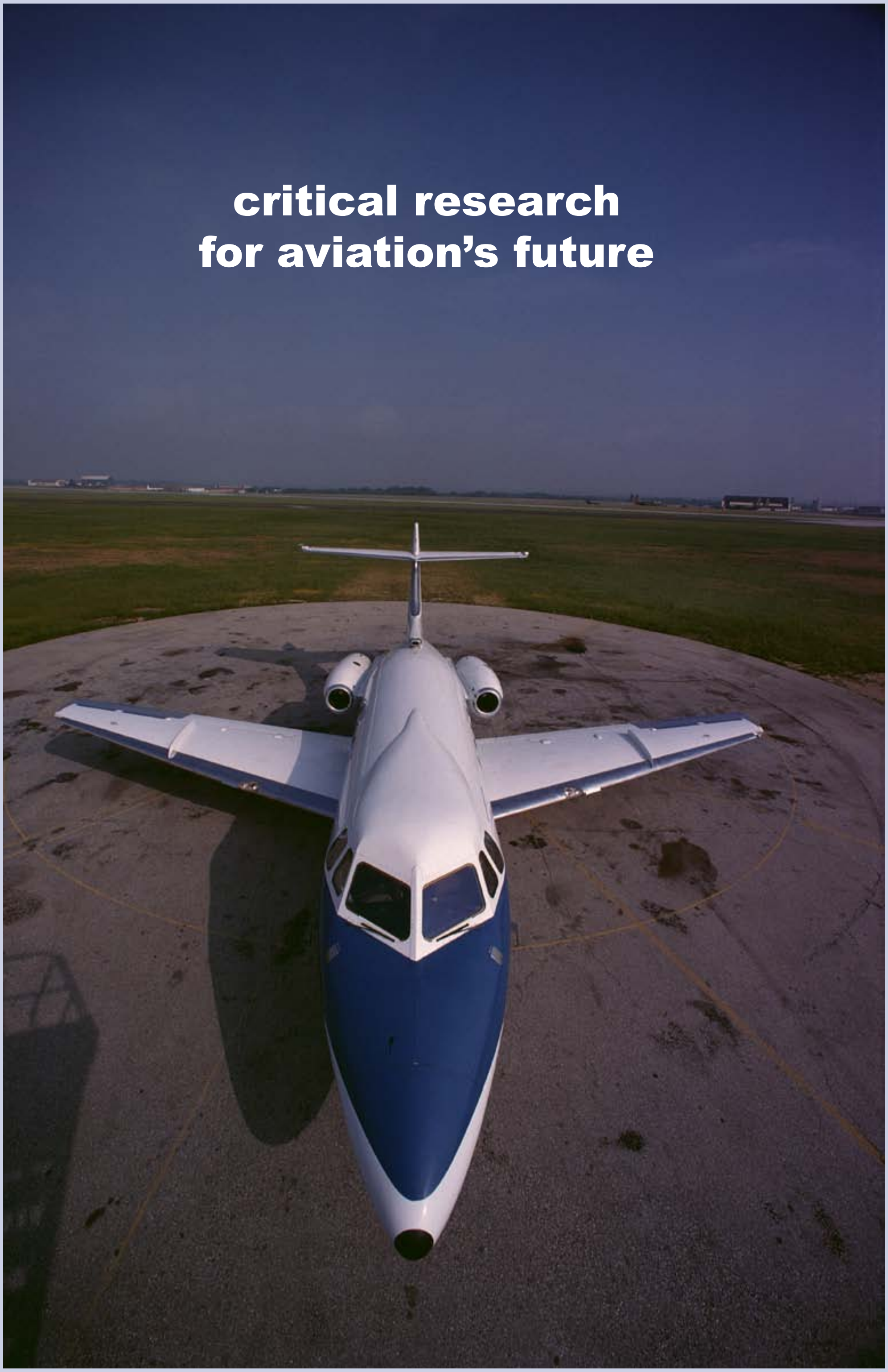
System-centric, or point-to-point, operations characterize today's national airspace system. Networks can enable multiple parties to share information by linking individual systems together. For example, shared networks would enable the FAA to share information with the international aviation community, other government agencies, and the aviation industry. Systemwide information management will help transition the national airspace system to network-centric operations by providing the infrastructure and associated policies and standards to enable system-wide information sharing. Underlying this transition is a scalable, standards-based network architecture—to be developed through this project—that seamlessly and securely connects users with the information or data they need.

Researchers and engineers at the Boeing Phantom Works, in Herndon, Virginia, successfully demonstrated the System Wide Information Management test bed and system prototype's capabilities to support information and data sharing among various national airspace systems. The test highlighted a number of system attributes, including timely information exchange, efficient use of network assets, common core services for processing and distribution, and the accessing and integrating of new information sources through simpler, lower cost and reduced-risk interfaces.

Automating Airborne Flight Alerts

On board data can indicate critical flight conditions such as when an aircraft deviates from its course when it enters restricted airspace, or when its cabin suddenly loses compression. Providing air traffic controllers timely access to this type of information could help them prevent accidents; however, the data are generally available only from the flight crew through voice communication or through post incident retrieval of the aircraft's flight data recorder. The automated airborne flight alert system, currently under development, will automatically and independently detect problems in flight and generate an alert to ground agencies.

When the Automated Airborne Flight Alert System detects anomalous flight conditions, it quickly separates safety from security issues. It then automatically transmits information to the proper organizations, including those linked to the national airspace system, to aid in collaborative decision-making. Since the system's in-flight data recorder provides near real-time data, implementation will not require new technology, hardware, or aircraft recertification. The research team has successfully demonstrated the proof-of-concept, and a flight demonstration is scheduled for FY 2006.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