APPENDIX B: 2007 R&D Annual Review: Accomplishments

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R&D Vision, Mission, and Organizational Values

R&D Vision: A transformed aviation system that allows all communities to participate in the global marketplace, provides services tailored to individual customer needs, and accommodates seamless civil and military operations.

R&D Mission: Conduct, coordinate, and support domestic and international R&D of aviation-related products and services that will ensure a safe, efficient, and environmentally sound global air transportation system.

R&D Organizational Values:

- **Goal Driven:** Achieve the mission. The FAA uses R&D as a primary enabler to accomplish its goals and objectives.
- **World Class:** Be the best. The FAA delivers world-class R&D results that are high quality and relevant, and improve the performance of the aviation system.
- **Collaborative:** Work together. The FAA partners with other Federal departments and agencies, industry, and academia to capitalize on national R&D capabilities to transform the air transportation system.
- **Innovative:** Turn ideas into reality. The FAA empowers, inspires, and encourages its people to invent new aviation capabilities. It creates new ways of doing business to accelerate the introduction of R&D results into new and better aviation products and services.
- **Customer focused:** Deliver results. The FAA R&D program delivers quality products and services to the customer quickly and affordably.

By aggressively pursuing these values, the FAA will create the best value from limited R&D resources to help achieve the national vision of a transformed aviation system.

Introduction

The United States has a national aviation system that is second to none — one that has proven it can respond quickly to changing and expanding needs. It is a complex global system, with numerous public and private sector stakeholders. It consists of thousands of aircraft and airports supporting business travel, scheduled passenger service, airfreight, and recreational flying.

The growing needs of the 21st century present new challenges to the aviation system. Many experts are forecasting a tripling in air traffic in the United States by 2025. To meet this projected increase, the U.S. Congress and the President have set out a vision for a transformed national aviation system, the Next Generation Air Transportation System (NextGen). Their intent is to field NextGen, capable of handling three-times the capacity demands of the current aviation system with the same level of outstanding safety performance by 2025. That vision has been captured and represented in the Operational Evolution Partnership (OEP), the FAA's plan and process for achieving NextGen. The FAA uses the OEP to provide a cross-agency view of implementation, to prioritize resources, to focus future development, and to partner with industry. OEP Version 1, published in June 2007, describes the framework for the implementation plan and is divided into three domains:

- air traffic operations, focused on transformative operational capabilities;
- airport development, focused on new airport surface infrastructure that provides significant capacity increases; and
- aircraft and operation requirements, focused on developing a common view of avionics requirements and timelines that can provide the operational capabilities demanded by NextGen.

OEP contains both commitments, which are fully-funded implementation activities, and strategic initiatives, which are being validated for implementation.

FAA R&D programs are now focused on the development and implementation of the NextGen concept. In fact, R&D is central to the NextGen concept and its success. Ever-evolving R&D helps to achieve virtually all of the FAA's short and long term goals and objectives. Dedicated professionals facilitate the day-to-day operations of the National Airspace System (NAS) while they simultaneously develop NextGen. The R&D community conducts research activities ranging from fire safety and human factors studies to the prototyping and creation of new products, services, and procedures. Much of the R&D focus is experimental and iterative; it is only through multiple experiments and iterations that the FAA will be able to determine the best solutions for NextGen.

This *2007 Annual R&D Review* showcases the FAA's accomplishments in 2007 to make progress toward its ambitious goals. Through pivotal milestones, the FAA plans to demonstrate that its major NextGen goals can be achieved. Each year, the agency will continue to report its efforts and accomplishments against the goals and objectives of the NextGen concept, as crystallized in the NAS Enterprise Architecture, an extremely detailed system engineering plan that defines timelines and milestones for key infrastructure programs, as well as serves as the backbone of the OEP.

Aeromedical Research 2007 Accomplishments

Distribution of Fluoxetine in Human Fluids and Tissues

Medical researchers in the FAA's Civil Aerospace Medical Institute (CAMI) continue to make significant advances in the analysis of postmortem fluids and tissues following fatal aircraft accidents. 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.

Fluoxetine is a selective serotonin reuptake inhibitor (SSRI). According to the manufacturer, fluoxetine is the most widely prescribed medication in history for the treatment of depression, obsessive compulsive disorder, premenstrual dysphoric disorder, and panic disorder. Treatment of depression with fluoxetine is relatively safe; however, certain side effects of this medication, including drowsiness, dizziness, abnormal vision, diarrhea, and headache, could affect pilot performance and become a factor in an aviation accident. Therefore, the use of this medication by pilots is not permitted by the FAA. For this reason, each pilot fatality received by CAMI is screened for fluoxetine.

A limited amount of scientific information concerning the distribution of fluoxetine has been reported. Additionally, none of this data pertains to therapeutic levels of the drug. Since scientific information concerning the distribution of fluoxetine at therapeutic levels is not available, in FY 2007, researchers determined its distribution in various postmortem tissues and fluids in 11 separate aviation fatalities. Blood fluoxetine concentrations in these 11 cases ranged from 21 to 1,480 ng/mL. This research determined distribution of fluoxetine in postmortem specimens and identified specimen types that may be suitable for estimating blood concentrations of fluoxetine in the event that blood is unavailable for analysis.

First-Generation H_1 Antihistamines Found in Pilot Fatalities of Civil Aviation Accidents, between 1990 and 2005

First-generation H_1-receptor antagonists (antihistamines) are popularly used for alleviating allergy and cold symptoms, but these antihistamines cause drowsiness and sedation. Such side effects could impair performance and be a significant cause or a factor in accidents. Therefore, the prevalence of these antagonists was evaluated in aviation accident pilot fatalities. During civil aircraft accident investigations, postmortem samples from pilots involved in fatal aviation accidents are submitted to CAMI for toxicological analyses. These analytical findings are stored in a FAA database. In 2007, the CAMI toxicology database was examined for the presence of the first-generation antihistamines in pilot fatalities of civil aircraft accidents that occurred during the 16-year period between 1990 and 2005.

Of 5,383 fatal aviation accidents from which specimens were received by CAMI, there were 338 accidents wherein pilot fatalities were found to contain the following antihistamines: brompheniramine, chlorpheniramine, diphenhydramine, doxylamine, pheniramine, phenyltoloxamine, promethazine, and triprolidine. Of the 338 accidents, 304 were general aviation accidents; 175 of the 338 pilots held private pilot airman certificates. Antihistamines were detected alone in 103 fatalities (one antihistamine in 94 fatalities and two antihistamines in nine), while other drug(s) and/or alcohol were also present in an additional 235 fatalities. Thirty-five of the 338 fatalities had more than one antihistamine.

The use of antihistamines, with/without other drugs and/or alcohol, was determined by the National Transportation Safety Board (NTSB) to be the cause in 13 and a factor in 50 of the 338 accidents. The majority of the accidents were of the general aviation category. There was an overall increasing trend in the use of antihistamines by aviators during the 16-year span. Blood levels of the antihistamines were in the sub-therapeutic to toxic range. Findings from this study will be useful in investigating future accidents involving antihistamines.

Validation of Alcohol Responsive Differential Gene Expression Data by Quantitative Polymerase Chain Reaction (QPCR)

Toxicological detection of alcohol use in aviation accidents is still problematic in 30 to 40 percent of cases. A study of moderate alcohol use was initiated to determine differentially expressed genes at five different blood alcohol levels. The gene discovery phase of this 2007 study was performed by interrogating >54,000 probe sets on microarrays. Quantitative Polymerase Chain Reaction (QPCR) is an alternative method that can be used to determine differential expression of individual genes suspected to be regulated in response to a stimulus. QPCR is often used to validate microarray data.

From microarray gene expression data, a total of 11 genes were chosen from two analyses. QPCR data validated that 10 of the 11 genes had the same expression pattern as seen by microarray analysis. Furthermore, these 10 genes were found to be differentially expressed to statistical significance, again bearing out the results from microarray analysis. Finally, the degree of change also was in good agreement with the microarray data. The single gene that was not validated by this method had the lowest fold-change of all the genes tested, 1.25. The next lowest gene by fold-change had a value of 1.5 indicating that the limit of detection by QPCR is between 1.25 and 1.5. This finding is in agreement with other investigators' findings seen in the literature.

QPCR has been shown to be similar to microarray analysis in ability to detect differential gene expression. This alternative methodology will be useful as a less expensive alternative to microarray analysis in research projects where a set of genes is suspected to be differentially expressed but needs to be empirically proven. In addition, QPCR has now been shown to be useful as a diagnostic tool for analysis of factors important in aerospace medicine.

Analysis of Aeromedical Decision Making and Aviation Safety Consequences

Bioinformatics methodologies are used to assess pathology questions in aeromedical certification. As part of the increasing trend toward evidence-based medicine and data driven decision making, FAA researchers developed a Scientific Information System (SIS), to assist in the analysis and modeling of aeromedical certification decision making and aviation safety. The SIS provides a continuous monitoring of medical certification records compared to aviation accidents or incidents and post-mortem toxicology reports. Researchers use a team-based and multidisciplinary approach, since no single person or approach works for all aviation safety problems. The analysis team includes people with aerospace medicine, medical certification, accident investigation, piloting, computer science, mathematics, and biostatistics skills to examine and solve problems in aviation safety, particularly in aeromedical certification cases.

To demonstrate the usefulness of SIS in aviation medicine, in 2007 researchers chose to study the most common form of cardiac dysrthymia, atrial fibrillation, in the U.S. civil pilot population. Almost 20 million electronic medical records of 2.5 million pilots from 1983 to 2005 were included in the study. Pilots with atrial fibrillation are as safe and, by some measures, slightly safer in terms of the chances of having an accident. The only fatal accidents due to atrial fibrillation as a cause or factor in the NTSB reports are due to three pilots who *falsified* their medical certification applications by not reporting their atrial fibrillation medical condition.

Researchers found that no pilots who were properly certified had an accident due to their atrial fibrillation and that their accident rate was the same as or better than all other pilots in comparison. No properly certified pilot with atrial fibrillation had an accident of any sort due to a medical event.

Improving Airplane Signage Display for Passenger Safety

Current federal aviation regulations require specific materials and presentation modes for safety information displayed aboard transport airplanes. These design criteria are based on significant research and years of application that have proven their effectiveness. Advancements in commercial presentation media and information displays present opportunities for new airplane signage and briefing materials, pending approval. The first such request for approival is a graphical exit sign (a lighted silhouette of a running figure) in lieu of the word “EXIT,” as required by FAA regulation 14CFR25.811.

Approval of replacement by advanced media of the required signs and placards requires comprehension testing of candidate materials to assure understanding by the flying public. Only minimal comprehension testing of a limited number of graphical sign exemplars had been previously conducted. In 2007, FAA researchers conducted a broad-based study of graphical signs and placards to support certification decisions by the FAA.

Results of the study provided comprehension assessment for four graphical exit signs and 15 safety briefing card pictorials and pictograms. Comprehension was tested with standalone graphics, as well as with signs placed within an airplane context. The safety briefing card pictorials and pictograms were taken from cards currently in use aboard airliners flying in the United States. Standalone graphical signs averaged comprehension in the mid 40 percent range, whereas comprehension of signs within an airplane context improved, on average, to the lower 60 percent range. Mean comprehension of briefing card pictorials and pictograms reached 65 percent. Extended analysis of the results and application of these findings to support certification decisions is in progress.

Aircraft Accident/Injury and Autopsy Data System (AA-IADS) Incidental Cardiovascular Findings

In 2007, researchers conducted a study to determine the cardiovascular abnormalities found in the autopsies of pilots involved in fatal aircraft accidents in the United States between January 1995 and December 2000, including all types of civilian operations. Specifically, they were looking at incidental cardiovascular findings (ICFs), ICFs may or may not have been the cause of death or accident, but were reported by the medical examiner/pathologist. The NTSB database, along with 919 autopsy reports from the CAMI Autopsy Database for the same period, was searched to determine the number of fatal accidents the fatalities were reviewed for the presence of ICFs in pilots medically certified by the FAA. The medical records of all fatally injured airmen were reviewed using the Aerospace Medical Certification Division (AMCD) Document Imaging Workflow System with the purpose of identifying previous cardiovascular conditions as established by AMCD via cardiovascular pathology codes. Pre-existing pathology codes were compared to autopsy cardiovascular findings.

Cardiovascular abnormalities were found in 43 percent of the study cases. Consistent with previous studies, the study also showed an increasing prevalence of cardiovascular diseases with age, particularly in pilots older than 40 years. Cases with evidence of acute myocardial infarction need further analysis to rule out a sudden medical incapacitation as the cause of the accident. Based on FAA findings, any cardiac risk detection program in pilots should be aimed primarily at general aviation pilots. Finally, the study provides additional information to support the use of autopsy data for decision making, to improve accident analysis and to confirm if coronary heart disease trends in pilots are changing.

Aircraft Safety 2007 Accomplishments

Terminal Area Safety

The area around terminals continues to be the most hazardous area in the NAS. The majority of accidents occur in the takeoff and landing phases of flight. While capacity issues have become very important, the accelerated introduction of new technology, procedures, and equipment to solve the capacity problems must be integrated into the existing operational infrastructure so that maximum benefits for both safety and efficiency are realized. Examples of what might be involved include land-and-hold short operations, terminal area navigation, air traffic control (ATC) operations, controlled flight into terrain on approach or landing, closely spaced runway operations, communication procedures, and airport lighting and signage.

In 2007, under a collaborative agreement between the FAA, the Netherlands Civil Aviation Authority, and the Dutch National Aerospace Laboratory, a study was conducted on aircraft landing performance of subsonic narrow-body jet aircraft during instrument landing system (ILS) approaches. One study developed methods to identify the aircraft touchdown points during commercial operations by using ILS information, based on analysis of 50,000 records of operational flight parameters. The objective was to support development of guidelines for land-and-hold short operations and aid in understanding the causes of runway overruns.

The FAA is also working with the Air Force Research Laboratory's Human Effectiveness Directorate to improve aircrew safety in situations where lasers are carelessly or maliciously pointed at aircraft. Through this inter-agency partnership project, a laser system was installed in the FAA B-737-800 advanced flight simulator in Oklahoma City to simulate the effects of unauthorized laser illuminations from ground sources. The system realistically mimics a laser flashed at an aircraft cockpit from the ground. With eye-safe lasers integrated into a flight simulator, the research team monitored pilots' reactions and recommended appropriate countermeasures to support AC70-1, “Outdoor Laser Operations” and AC 70-2, “Reporting of Laser Illumination of Aircraft.”

Safety Analysis Methodology

Aircraft type certification regulation includes the requirement to conduct a system safety assessment to demonstrate regulation compliance. Current regulations for type certification of large commercial aircraft state that certification credit in both quantitative and qualitative assessments may be taken for correct and appropriate corrective action by a flight crew to mitigate the effect of a system failure. According to the same regulations, quantitative assessments of the probabilities of flight crew errors are not considered feasible. As a consequence, the aircraft designer is allowed to take all the credit for correct flight crew action in response to a failure. Since flight crew error continues to be implicated in the majority of fatal accidents, there is a need for a methodology that provides certification credit for desirable design features intending to reduce these errors.

In 2007, the FAA, the Netherlands Civil Aviaition Authorities, and the Dutch National Aerospace Laboratory developed a list of key flight-deck design characteristics with descriptors for different performance levels and developed a scoring algorithm that combines design characteristics into an overall level of certification credit for flight crew intervention in the case of system failures. The method was prepared in three different ways. First, the method was applied to 68 cases of in-flight aircraft system failures. The cases described failures of four different systems for eight different aircraft types. Second, all failure cases for the Fokker 100 aircraft were ‘replayed’ in a Fokker 100 Level D training flight simulator. Finally, validation was provided by discussing the design of the Fokker 100 cockpit with representatives of the original Fokker design team.

The method is easy to apply, provided that the system failure modes and associated flight deck annunciations are known. The time needed to determine the amount of flight crew intervention credit for a single aircraft / failure case combination depends on the complexity of the system and the associated failure, and the familiarity of the analyst with the system involved. In the analyses, where the analysts had only limited pre-existing knowledge of the aircraft systems, application of the method required approximately one to two hours per failure case. Application of the method is expected to take only 10-15 minutes per failure case if the analysts are familiar with the systems involved, as might be expected during the aircraft's type certification process. The method produces higher average scores for more modern cockpits. The most modern aircraft in the example cases (Boeing 777 and Airbus A-330) did not obtain the maximum possible score, indicating that even for those aircraft there is still room for improvement. It was therefore recommended that the Aviation Rulemaking Advisory Committee be informed of the results of this study so that this method can be further developed under the committee's guidance.

Unmanned Aircraft Systems

In FY 2007, the FAA initiated a new research program on unmanned aircraft systems (UAS). The research program, which was authorized by Congress, supports FAA regulatory actions and safety oversight necessary to ensure the safety of civil operations in the NAS. The program's worldwide research activities focus on technology surveys, methodology development, data collection and generation, laboratory and field validation, and technology transfer. These activities provide the basis for developing airworthiness standards, devising operational requirements, establishing maintenance procedures, and conducting safety oversight activities for UAS civil applications.

The UAS research is focused on four technical areas: technology survey; system safety study; detect, sense, and avoid (DSA); and command, control, and communication (C3). Key research tasks within these six technical areas are: UAS regulatory study; propulsion technology and associated certification issues; DSA technology survey and regulation gap analysis; C3 technology and certification requirements; development of UAS system safety management; and UAS bandwidth requirements.

The objective of these research tasks is to provide technical information with supporting data towards development of UAS regulatory standards for operation in the NAS. These new standards will lead to implementation of UAS certification procedures, airworthiness standards, and operational requirements.

Software and Digital Systems

The combination of rigorous design and verification assurances has led to safe and reliable operation of civil aviation software and digital systems. Historically, such systems were designed as federated architectures, and although some significantly successful efforts in integrated modular avionics (IMA) system integration have occurred, such as in the Boeing 777 aircraft, documentation of practices and guidelines for integrating such complex systems is lacking.

The 2007 report "Real-Time Operating Systems and Component Integration Considerations in Integrated Modular Avionics Systems Report" (DOT/FAA/AR-07/39) was prepared by United Technologies Corporation, Pratt & Whitney Aircraft Division. This work was based on previous studies conducted for the FAA that discussed issues regarding the use of software, electronic hardware, and commercial off-the-shelf (COTS) components in aviation systems; provided a detailed look into the safety and compliance issues of using a COTS real-time operating systems (RTOSs) in aviation applications; and investigated the safety aspects of using a partitioned COTS RTOS and its integrated architectural features in aviation systems.

The 2007 work researched the integration of the RTOS and other software modules and components into the overall IMA system. The technical report presents the results of a research effort intended for use by both the certification authorities and industry to formulate a basis for evaluating the integration of RTOSs and other associated modules that support partitioning in space, time, input/output, communications, and other shared resources on an IMA system. Further, this report presents approaches to apply system safety assessment methods to IMA systems and details several role players (platform supplier, RTOS supplier, application supplier, and IMA system integrator) in IMA system development and their roles for integrating multiple functions at different integration stages. Information from the report is included in several publications: RTCA Special Committee SC-200 in the development of RTCA/DO-297 “Integrated Modular Avionics (IMA) Development Guidance and Certification Considerations”; “Beginning of a Job Aid on IMA”; and AC20-145, “Guidance for IMA”.

Aircraft Icing

In FY 2007, the FAA joined with industry, Eglin Air Force Base, NASA Glenn Research Center, and the University of Illinois to conduct a propeller-icing test at the U.S. Air Force McKinley Climatic Laboratory. Previously, very little information on propeller icing and no data from controlled testing in a ground icing facility, had been available. A primary objective of the propeller testing was to document leading edge and runback ice accumulation characteristics in controlled conditions on both new propeller blades (metal and composite) and in-service metal blades. Performance measurements were made to provide data for analysis of propeller performance losses due to the ice accumulation.

A turbopropeller engine was tested with several propeller combinations on a thrust stand exposed to a simulated in-flight icing environment.

Ice shapes were documented in several ways: tracings of the final ice shapes were made at several locations; still photographs were taken of the final ice shapes; and stop action video of the propeller were made in real time during the test. Engine RPM, torque, propeller blade pitch angle, and thrust were measured continuously. The test was successful in approximately duplicating some results from flight testing. For some conditions, the ice accumulation covered a large portion of the propeller blade span. The data and information from this test established a more extensive basis for guidance on addressing propeller icing in the aircraft certification process.

Commercialization of Metallic Materials Properties Development and Standardization (MMPDS)

The Metallic Materials Properties Development and Standardization (MMPDS) project is an effort led by the FAA to continue the process described in the handbook *Metallic Materials and Elements for Aerospace Vehicle Structures* (MIL-HDBK-5). The commercial version of the MMPDS-03 Handbook was released in April 2007. There has been a substantial upgrade with approvals from the 7th through the 9th MMPDS General Coordination Meetings. This includes 12 new alloys and over 300 pages edited or added.

The handbook is recognized worldwide as the most reliable source for verified design allowables needed for metallic materials, fasteners, and joints used in the design and maintenance of aircraft, missiles, and space vehicles. Consistent and reliable methods are used to collect, analyze, and present statistically based aircraft and aerospace material and fastener properties.

The objective of the MMPDS project is to maintain and improve the standardized process for establishing statistically-based allowables that comply with the regulations, consistent with the MIL-HDBK-5 heritage, by obtaining more equitable and sustainable funding sources. This includes support from government agencies in the Government Steering Group, from industry stakeholders in the Industry Steering Group and from profits selling the handbook and derivative products.

Damage Tolerance Testing of Composite Honeycomb Fuselage Panels

Rising aircraft operating costs are driving aircraft manufacturers to reduce weight and improve efficiency by using more composite materials in aircraft design. Composite honeycomb sandwich fuselage designs have been used quite successfully in general aviation and commuter aircraft. The advantages of using composite structres compared to conventional structures include weight savings, an increase in bending rigidity and in-plane strength and stiffness, and improved stability. A critical technical challenge in airplane sandwich design is to adequately predict residual strength of a damaged structure.

Classical damage-tolerance philosophy, long used in the design of conventional metallic airplane structure, cannot be directly applied to composite sandwiched structure for several reasons. First, damage in composite structures is seldom representative of a single dominant crack necessary to apply continuum fracture mechanics principles. Second, due to its heterogeneous nature, damage in composite sandwiched structures is much more complex than in conventional metallic materials. It can be quite extensive, yet nonvisual, and can pose difficulties with regard to inspections. Third, there is a general lack of understanding of failure mechanisms and their interaction in the overall structural response. Fourth, linear engineering models are not typically equipped to handle complex nonlinear behavior exhibited by composite sandwiched structures and have limited predictive capability; however empirical approaches based on experimental data from coupon, subcomponent, and full-scale testing is time consuming and very costly. The FAA has performed several studies to develop models that predict structural response, damage progression, and residual strength. Methodologies have been developed and validated in a building block approach at the coupon and sub-element levels.

In this 2007 study, the damage tolerance characteristics of several all-composite sandwiched fuselage panels were undertaken using the Full-Scale Aircraft Structural Test Evaluation and Research Facility. The objective was to determine the effects of various damage scenarios, such as holes and notches, on the residual strength of composite panels that reflect a typical honeycomb sandwich fuselage structure subjected to combined loading. Six composite panels were loaded quasi-statically to failure while recording the structural response, damage evolution, and residual strength. A photogrammetric method was used to obtain full-field displacement and strain measurements at equal load intervals up to failure. The acoustic emission method was used to monitor damage growth in real time and served as an early warning for imminent failure. Several nondestructive inspection methods were used to scan for non-visual damage, including flash thermography and computer-aided tap testing. This study provided test data to validate predictions from earlier coupon and sub-element research as well as provides an accurate assessment of sandwich damage tolerance and design principles for use in aircraft.

Propulsion Malfunction Research

The FAA has an ongoing, multi-year effort to study propulsion malfunctions that precipitate inappropriate crew response type accidents and incidents. This effort is in response to research recommendations from a 1998 Aerospace Industries Association (AIA) report. The “Engine Damage Related - Propulsion System Malfunctions,”" study, completed in 2007, directly supports the AIA Propulsion Indications Task Team (PITT) that is working to develop recommendations for future changes in the Federal Register, Title 14 Code of Federal Regulations (CFR) Part 25.1305. This research also provided input for the propulsion section of recently published AC25-11A.

The 2007 study reviewed in-service accident and incident data to determine the potential to identify which engine was malfunctioning and annunciate the information to the pilot. Potential combinations of parameters were considered and analyzed to improve indication reliability.

The study primarily used available data (reports and flight deck recorder data) to document engine damage events and make generalized conclusions and recommendations for future areas of development. The final report includes detailed descriptions of the malfunctions and expected affects on the flight crew. Work is continuing in support of the AIA PITT team with the development of an information based display concept that will tie annunciations to pilot actions and minimize troubleshooting of propulsion malfunctions in the flight deck.

Assessing Airworthiness of Small Airplanes

The FAA established a research program to determine if potential continued airworthiness problems, due to aging, exist in the small airplane fleet. Researchers conducted an airworthiness evaluation of four aged airplanes used in commuter service: two Cessna 402s, a Piper Navajo Chieftain, and a Beechcraft 1900D Airliner. The intent of the program is to provide insight, from a flight safety perspective, as to whether a correlation exists between maintenance history and the condition of a typical aged airplane. The results have provided information for use in raising the awareness of aging on small airplanes and recommendations to enhance current maintenance guidance.

In FY 2007, an airworthiness evaluation of an aged Beechcraft 1900D aircraft was completed. The evaluation was conducted in two phases for the airframe, aircraft systems, and wiring: an inspection phase, and a teardown examination phase. During the inspection phase, tasks included (a) a survey of the aircraft maintenance records, (b) visual inspection of the airframe structure, and (c) Supplemental Inspection Document inspection. The teardown examination phase included four tasks: disassembly of the airframe and major aircraft sections; structural assessment utilizing alternative nondestructive inspection techniques; post nondestructive inspection; and microscopic examination including fractographic analysis of critical structural areas. As part of the destructive evaluation, inspections and laboratory testing were also performed on the electrical systems of the aircraft to assess the condition and degradation of electrical systems in small aircraft and to evaluate maintenance procedures.

Application and Validation of CVM Sensors for In-Situ Crack Detection in Aircraft Structures

Current aircraft maintenance operations require entry into normally inaccessible or hazardous areas to perform mandated, nondestructive inspections. To gain access for these inspections, it is often necessary that structure and sealant be removed and replaced, fuel cells be vented to a safe condition, or other disassembly be completed. These processes are not only time consuming but could do damage to the structure. The Comparative Vacuum Monitoring (CVM) sensor is a small, self-adhesive, elastomeric patch that can detect cracks in the underlying airframe material on which it is mounted. The sensor has laser-etched rows of tiny, interconnected channels and is mounted under near-vacuum conditions. Any propagating crack under the sensor breaches the near-vacuum and the resulting change in pressure is monitored. The sensor can be attached to aircraft structure in areas where crack growth is known to occur. Since the sensor is based on pressure measurements, there is no electrical excitation involved.

In FY 2007, a team consisting of the FAA, industry, several major airlines, and the developers of CVM technology completed a three-year validation study that resulted in the incorporation of CVM sensors into the *Boeing Common Methods NDT* (non-destructive testing) *(CMN) Manual*. During this validation study, CVM crack detection sensitivity was determined, installation procedures were developed, environmental tests were conducted, and numerous sensors were flown on aircraft to demonstrate their durability.

This was a significant accomplishment in two respects: it represented the first time a manufacturer has adopted Structural Health Monitoring techniques to allow the use of mountable sensors; and it was a major advancement from the traditional methods used to inspect aircraft. This recognition of in-situ crack detection as an allowable inspection method is an aviation industry first. CVM technology is now available for use as a validated means for performing in-situ crack detection inspections on Boeing aircraft, to address future service bulletins, and as an Alternative Means of Compliance for existing inspections.

Methodology to Evaluate Mechanical Systems

In an attempt to be proactive in the area of transport category mechanical systems safety, the FAA started a research program to identify any deficiencies in past design, current maintenance, and/or safety reporting with regards to commercial aviation mechanical systems. This work is consistent with recommendations in the FAA 1998 report titled “FAA Aging Transport Non-Structural Systems Plan.”

Researchers developed a methodology that could potentially be applied to any mechanical system on an aircraft. In FY 2007, the methodology and case study were published in an FAA technical report entitled, “Aging Mechanical Systems Program.”

This methodology involved the following: reviewing past designs and comparing them to today’s design standards; reviewing maintenance practices; and reviewing airline safety reporting practices. The goal was to locate and identify any potential risks and rectify the associated issues before an accident occurred.

In parallel with the methodology development, a case study was used with the purpose of testing and improving the methodology.

Second Generation Arc-Fault Circuit Breaker Development and Testing

In 1998, the FAA and the Office of Naval Research (ONR) initiated a program to develop arc-fault technology for aircraft. The program was started with recommendations from the National Transportation Safety Board investigations of the TWA-800 and SwissAir-111 accidents. Arc-fault circuit breakers (AFCBs) reduce the probability of electrically ignited fires on aircraft. The first stage of the program developed a single-phase, 400Hz AFCB that has now accumulated over 200,000 flight hours.

In FY 2007, FAA and ONR completed the second phase of the AFCB program that calls for development of 28Vdc and 3-phase AFCBs. The second generation units have passed safety of flight-testing and many design qualification tests. The units are currently being flight tested on the F15, F18 and P3 aircraft in a joint program with the U.S. Navy and Air Force. The successful completion of the second-phase AFCB program provides the aviation community with new circuit protection options for the current and future aircraft.

New Fatigue-Crack Growth Test Method for Rotorcraft

An assessment of American Society for Testing and Materials (ASTM) test method E-647 and the development of a new fatigue-crack growth test method to address fatigue life predictions were completed in FY 2007. The new test method was developed to address concerns with existing fatigue-crack-growth rate and threshold data.

Method E-647 has been used over the past 25 years to generate information on fatigue-crack growth for a wide variety of materials; however, research shows that calculated data can result in imprecise life predictions, especially for high cycle fatigue components such as in rotorcraft. Method E-647 was satisfactory for some materials, but quite unsatisfactory for others. FAA-sponsored research at Mississippi State University has led to the development of the new test method that uses a compression-compression pre-cracking amplitude or load reduction test.

This new method produces more accurate constant-amplitude crack-growth rate data and will provide input data to more accurately design aircraft and rotorcraft components against fatigue damage. The test method has been independently verified by both analysis and tests, and the ASTM E-08 Committee on Fatigue Growth Rate has accepted the data and subsequently agreed to revise the current test method, ASTM E-647.

Aluminum Failure Modeling using Johnson-Cook Formulation

In 2007, the FAA and its partners in the Airworthiness Assurance Center of Excellence completed a multi-year effort to study aluminum's ability to mitigate blade fragment penetration of aircraft fuselage and components. The University of California, Berkeley led the team that was supported by Lawrence Livermore National Laboratory (LNLL) and the aviaition industry. This effort developed an aluminum failure model that can be tuned based upon the thickness of the material. The effort was not successful in developing a single model that could transition from petaling to plugging failure modes as the thickness of the fuselage simulator increased. These models will be used as part of the LS-DYNA Aerospace Quality Control process, along with a significant repository of test data and analytical analysis of the various test completed under this effort. LS-DYNA is a general purpose nonlinear finite element program capable of simulating complex real world problems.

Berkeley facilitated the team and was the primary interface to the FAA. They also performed 50 caliber impact tests on various thickness aluminum sheets in their ballistic facility and worked with LLNL and industry to model the tests and compare the results to the test data.

During this effort, LLNL worked to improve the aluminum failure model developed under a previous FAA grant. Detailed analysis of the test data resulted in a new appreciation for the failure process, which identified a thickness dependency for the range of material thickness and impact speeds associated with uncontained engine debris impacting the aircraft fuselage. For any given thickness the failure could be tuned, but the penetration velocity for thinner material would be over predicted and for thicker material under predicted. This effort highlighted shortcomings in the commonly-used Johnson-Cook formulation for detemining structural damage that prompted the FAA and NASA to initiate an effort to develop a new material model that is currently being investigated.

Engine Containment Modeling

The FAA and its partners in the Airworthiness Assurance Center of Excellence completed a multi-year to study high-strength fabrics and their ability to contain blade fragments in engine containment systems. Arizona State University led the team that was supported by NASA and the aviation industry. The effort has developed a generic engine containment model that will be used as part of the LS-DYNA Aerospace Quality Control process along with a significant repository of test data and analytical analysis of the various test efforts.

NASA Glenn Research Center performed a test program where blade fragment simulators were shot into a fabric ring to determine the ballistic limit of the fabrics. The test program was the foundation for the containment modeling verification effort.

During this effort, industry researchers worked to improve the fabric impact material model developed under a previous FAA grant. Detailed analysis of the test data resulted in a new appreciation for the failure process that allowed the revised material model to better simulate the test data.

Researchers applied the new material models to proprietary engine models and provided a results-comparison against full scale engine containment tests. This experience was also used to develop a generic ring and fabric wrap model that can be used in the quality control process for LS-DYNA and also in aerospace training programs on the use of the code.

Arizona State University facilitated the team and was the primary interface to the FAA. They also performed detailed quasi-static testing of the fabric material in their laboratory and worked with industry to model and compare analytical results at multiple facilities to the test data. This effort highlighted differences in the results that prompted the FAA and NASA to initiate the LS-DYNA Aerospace Users Group with members from government, industry and academia. This group continues to meet and works to establish controls for consistency of the analysis in aerospace problems. The group has been very successful and has the full support of an ongoing FAA grant at George Washington University.

Standardized Training Requirements for Critical Composite Maintenance and Repair Issues

Standardized training requirements for awareness of the unique operational demands of composite aviation structures were developed in FY 2007. These training requirements will provide an awareness of safety issues regarding the maintenance and repair of composite materials utilized in aircraft structure. The audience for this training includes engineers, technicians, inspectors, and other individuals associated with aviation operations including those interfacing with composite aircraft structures on the flight line, in repair facilities, and overhaul locations.

A principal objective of the training requirements is to provide an industry standard for awareness of composite maintenance and repair safety issues which reflect the insights of worldwide experts in the field. The curriculum was developed, primarily through collaborative workshops and other forums, in order to involve industry, academia, and government regulatory agencies, to achieve complete and balanced standards.

Development of the awareness course resulted in a framework with safety messages, assessments for course developers, and teaching resources. These provide an industry standard that represents a complete and balanced approach with the consensus of experts from around the world. The Society of Automotive Engineers has adopted the terminal course objectives developed in this program as an Aircraft Certification Service standard for identification of key elements required to create acceptable awareness courses. In addition, detailed teaching material is provided in an FAA Aviation Research Report.

Aging Composite Structures Evaluation

The FAA recently undertook a program to examine as many aging aircraft with composite structures as possible. The focus is civil-composite primary and secondary structures put into service in the early development years that have reached or are nearing their service life. These composite structures will be evaluated to determine if the original certification requirements were met after their years in service. The goal is to assess the efficacy of civil certification requirements in providing a safe aircraft structure. Additional goals are to assess the aging mechanisms, characterize their effects on the composite structure, and to give recommendations pertaining to characterizing composite aging. This effort will provide design and certification guidelines for composite aircraft structures.

The first structure examined was a Boeing 737 composite stabilizer with 18 years of service and over 50,000 flight cycles. The B737-200 graphite/epoxy stabilizer was developed as part of the 1977 NASA Aircraft Energy Efficiency (ACEE) Program and was certified in 1982. The ACEE Program challenged aircraft manufacturers to redesign existing aircraft components using graphite/epoxy composites in early efforts to develop lighter structures.

The investigation consisted of nondestructive inspection (NDI), disassembly of the components, and physical, thermal, and mechanical tests. NDI evaluation with the recommended field methods verified the damage state of the retired stabilizer. Additional sophisticated NDI techniques, not available at the time of fabrication, such as shearography and laser ultrasonic testing were also used to characterize the damage state. NDI, mechanical, and physical test methods were compared with those used in the development program to assess differences in capabilities between 1982 and modern methods. Destructive evaluation, using the original certification test methods, established the end of service life capabilities of the structure.

The evaluation of the B-737 stabilizer determined that the composite structure was capable of meeting its design requirements even when retired from service. This examination of a sample civil composite aircraft structure demonstrates that the certification basis provided adequate safety even at the end of its service life. This gives the FAA certification service information to better assess new composite structures for safety and assure they exceed the established requirements.

Traffic Alert and Collision Avoidance System (TCAS)

Traffic Alert and Collision Avoidance System (TCAS) I is a mandated system for aircraft with less than 31 and more than 10 passengers, with no resolution advisory. TCAS II is a mandated system for all aircraft flying within the NAS and Europe with more than passengers or maximum certified takeoff weight greater than 33,000 lbs. TCAS II includes resolution advisories (RA) to instruct flight crews if a collision is imminent.

In 1993, TCAS was mandated within the United States after several notable midair collisions and near-collisions that had occurred over the previous 19 years. Congress enacted two public laws during that time period that called for the development of an anti-collision system. Since that time, the original Minimum Operational Performance Specification (MOPS) has been modified to Version 7 in order to accommodate over 300 Change Requests and Problem Trouble Reports submitted against Version 6.04A. These problems were identified as a result of active TCAS monitoring in Europe and the United States, pilot reports, and applied research activities. Version 7 of the MOPS was implemented globally.

While U.S. aircraft were not mandated to equip with Version 7, currently, two-thirds of the current U.S. commercial fleet is equipped with it. Europe elected to mandate TCAS Version 7.

In 2004, RTCA reconstituted its TCAS Special Committee (SC-147), as a direct result of a TCAS-related crash in Europe and a near-collision that occurred in Japan. The committee was tasked with examining these events to determine the cause and contributing factors. It was determined that TCAS suffers from a problem called reversal logic problem (i.e., SA01). In certain encounters between two aircraft, TCAS does not issue a sense reversal (e.g. change a “climb” command to a “descend” one) in a timely manner, if at all.

Based on limited monitoring in the United States and Europe, approximately 11 reversal logic episodes have been detected. The predicated rate of mid-air collisions associated with this problem is estimated to be once every four years, unless a fix is implemented immediately. Europeans have concluded that the primary causal factor of the opposite responses is the use of the ‘Adjust Vertical Speed, Adjust’ aural enunciation.

The Europeans have proposed two Critical Avoidance Safety (CAS) logic changes known as Change Proposal 112E (CP112E), to improve the reliability of the Sense Reversal RAs, as well as CP115 to improve pilot response to the negative resolution advisory RAs.

Based on limited monitoring in the United States and Europe, approximately 11 “reversal logic” episodes have been detected. The predicated rate of mid-air collisions associated with this problem is estimated to be once every four years, unless a fix is implemented immediately.

Additionally, monitoring of TCAS performance has identified instances where flight crews initially respond in the opposite direction to that specified by TCAS when a negative resolution advisory (RA) is displayed and announced to the flight crews. Europeans have concluded that the primary causal factor of the opposite responses is the use of ‘Adjust Vertical Speed, Adjust’ aural annunciation.

The Europeans have proposed two Collision Avoidance System logic changes known as Change Proposal 112E (CP112E), to improve the reliability of the Sense Reversal RAs, as well as CP115 to improve pilot response to the negative resolution advisory RAs.

The Advanced Technology Development & Prototyping (ATD&P) TCAS Program is overseeing the finalization and validation of a correction to these problems, updating the TCAS II MOPS (DO-185b), developing a w TCAS Encounter Model, and coordinating the appropriate rulemaking within the FAA for TCAS II equipage throughout the national fleet.

The ATD&P TCAS Program made the provided following accomplishments in FY 2007:

- developed Safety Risk Management Documents (SRMD) for CP112e (i.e., Sense Reversal Logic) and CP115 (i.e., LOLO);
- completed validation / verification simulations on updated TCAS pseudo-code;
- incorporated agreed upon change proposals into a revised version of the TCAS II version 7 MOPS in preparation for formal RTCA SC-147 Final Review and Comment (FRAC);
- completed RA monitoring feasibility testing on BI-6 & Mode-S systems; and
- conducted an ATC Operational Survey as part of CP115 (i.e., LOLO) safety validation activities.

Airport Technology 2007 Accomplishments

Automated Foreign Object Debris (FOD) Detection System Evaluation

The presence of foreign objects in the airport environment presents a major hazard to aircraft safety. Foreign object debris (FOD) is any substance, debris, or article found on an airport surface that could potentially cause damage to an aircraft or vehicle. The presence of FOD can be the result of the loss of parts from aircraft, pavement cracking, wildlife, ice and salt accumulation, or construction debris. Identification of FOD at airports requires regular observation of airport surfaces by airport personnel, or by chance recognition by aircraft pilots operating on airport pavement. Removal of such FOD is triggered only by those actual observations. In 2005, the FAA, in cooperation with the University of Illinois, conducted a preliminary short term evaluation of a radar-based FOD detection system at the John F. Kennedy International Airport. Through the use of millimeter-wave radar, this system demonstrated the capability to detect objects as small as a two-inch bolt on the pavement surface. As a result, it was determined that this type of system could provide airport personnel with timely FOD alerts, and provide specific information on the location of the object. The conclusions from the preliminary research effort demonstrated successful FOD detection under many operational and environmental conditions, but also identified a need to conduct further evaluation of the FOD radar on a longer term basis, under varying seasonal conditions. In 2007, two separate millimeter-wave radar units were installed at the Theodore Francis Green State Airport for further long-term evaluation. The FAA is also developing plans for further research of other FOD detection technologies, including high powered camera systems at three large U.S. airports. Evaluation of these new technologies will begin in early 2008, while the evaluation of the radar system is scheduled for completion in early to mid 2008.

Operation of New Large Aircraft – Second Level Fire Fighting Evaluation

Today, two major aircraft manufacturers are developing large commercial aircraft capable of carrying over 500 passengers on two levels and 80,000 gallons of fuel. These airplanes meet the FAA's Airport Design Group VI classification. The Airbus A-380 and the Boeing 747-8I, are the largest passenger carrying aircraft ever built, and have thus earned the name, New Large Aircraft (NLA). Scheduled service for the A380 in the United States is slated to begin in late 2008, with the 747-8I following a few years later. The physical size, both in passenger and fuel carrying capacities, of these aircraft require examination of the current Aircraft Rescue and Fire Fighting (ARFF) service standards and recommended practices for their adequacy to combat post-crash events. In January 2001, the FAA issued DOT/FAA/AR-0067, *Rescue and Firefighting Research Program*, covering several ARFF interrelated areas to improve passenger survivability when involved in post-crash fires. One of the key areas of that study was the identification of firefighting requirements in terms of training, firefighting techniques, and specialized equipment related to NLA. The need for a revised or new methodology to determine firefighting agent quantities required for NLA type aircraft was also mentioned. Current federal minimum agent requirements may not be sufficient to extinguish a major NLA fire. Physically, NLA will be significantly greater in fuselage surface area, wingspan, and tail height, and feature full upper passenger deck, significantly increased fuel loads, unique tail-located fuel tanks, and greater use of composite materials.

In response to this need for ARFF-related NLA research, the FAA, in cooperation with the Air Force Research Lab at Tyndall Air Force Base, constructed a mockup of full scale section of a NLA that will enable researchers to conduct large scale fire evaluations. The mockup has two passenger levels, a lower cargo level, three metal evacuation slides, the beginnings of the right wing root, and one inboard engine. The entire assembly is positioned inside a 100-foot diameter, environmentally-contained fire pit that can be filled with calibrated amounts of jet fuel for ignition. In addition, the mockup features three replaceable penetration points where aircraft skin piercing equipment can be evaluated. There are also three authentic evacuation slides that can be attached to the mockup for non-fire evaluations. The mockup was completed mid-2007 and will be undergoing a series of baseline testing throughout the remainder of 2007 into early 2008. With this valuable testing facility completed, the FAA is prepared to conduct several evaluation programs that will assist in finding the answers to the questions regarding what kinds of tools, strategies, and agents will be required to handle a fire event involving a NLA.

Deploying FAARFIELD – Advanced Airport Pavement Thickness Design Software

Researchers completed the new computer program, FAA Rigid and Flexible Iterative Elastic Layer Design (FAARFIELD) in August 2007. The program incorporates three-dimensional (3D) element structural analysis to compute stresses for rigid (concrete) pavement and rigid overlay thickness design. Previous FAA computer programs for thickness design, such as the LEDFAA 1.3, estimated rigid pavement stresses based on layered elastic analysis. FAARFIELD is a significant advancement in pavement design technology, representing the first time the powerful and accurate 3D finite element method has been used in a routine design procedure to compute the critical design stresses, such as stresses at the slab edges, for complex aircraft gears. Previously, 3D finite element based procedures were considered impractical for PC-based design applications because of the excessive time it took to complete modeling. A combination of faster computer processors and innovative programming methods reduced run times to the point where FAARFIELD can be used for routine pavement design. Some of the strategies employed by the FAA included optimizing the 3D meshes and using less accurate, less computationally-intensive methods in initial iterations to reduce overall processing time. The look and feel of FAARFIELD is virtually identical to LEDFAA 1.3, so users will have no trouble adjusting to the new program; however, researchers have incorporated many changes into the new software. The entire program uses the Microsoft Visual Studio.NET programming environment, making it more compatible with current PCs and operating systems. Engineers have completely revised the rigid pavement failure models to incorporate new full-scale test data for four- and six-wheel gears from the National Airport Pavement Test Facility rigid pavement tests. For flexible pavements and overlays, FAARFIELD incorporates all the changes made in LEDFAA 1.3 and adds automatic base layer design. Researchers also have completely rewritten the rigid overlay design procedures, making them more efficient than previous algorithms. FAARFIELD 1.1 will be the basis for the newly revised AC150/5320-6E, expected in early 2008. In anticipation of this change, FAARFIELD includes more runtime guidance. Also, the internal aircraft library has been revamped and expanded to include all current fleet aircraft and new models, including the Airbus A-380 and the Boeing B-787.

Rigid Pavement Test Sections at the National Airport Pavement Test Facility

In preparation for a new series of full-scale traffic tests on overlaid rigid pavements, engineers constructed three pavement test items at the National Airport Pavement Test Facility. In a project administered by the Innovative Pavement Research Foundation (IPRF) and funded by the FAA through a cooperative agreement, the overlay tests were designated Construction Cycle Four (CC4). This construction cycle differs from previous studies conducted at the facility because, under the agreement, the FAA was required to remove and replace the subgrade soil to IPRF specifications of thickness and strength, provide facilities for data collection, operate the test vehicle, and demolish and dispose of the pavement. The project is being done in two phases. In phase A, the subgrade was reworked to grade at a California Bearing Ratio of approximately eight. Portland Cement Concrete (PCC) slabs were placed in three different thicknesses on an aggregate sub-base and a one-inch-thick asphalt interlayer placed on top of the slabs. A PCC overlay was placed on top of the asphalt so that the finished grade was the same along the full length of the test pavement. Each test item was 300 feet long and simulated an overlaid PCC pavement with three different combinations of under- and overlay slab thicknesses. Construction of the test pavement for Phase A was completed in March 2006, including installation of the instrumentation, most of which was imbedded in the pavement. Phase A traffic testing was completed in November 2006 and the post-traffic materials testing, including removal of the overlay and interlayer, was completed in December 2006. Phase B started with trafficking of the underlay to achieve a uniform level of cracking in the test items and a new overlay with the same specifications as the first was completed in April 2007. Trafficking on Phase B started in September 2007. The CC4 series of tests provides full-scale test data on the performance of concrete overlays on concrete pavements to fill a gap in empirical knowledge. Previous tests on this type of construction are at least 35 years old and do not reflect current construction practices or aircraft loads. The present tests are intended to yield reliable performance data that the FAA can use to update the overlay thickness design procedures in its FAARFIELD computer program. The CC4 testing program largely follows a test plan that was prepared under a previous IPRF project, and is available at www.iprf.org.

Installation of Next Generation High Reach Extendable Turret

Past research done by the FAA Aircraft Rescue and Fire Fighting (ARFF) Research Program established the advantages and benefits of ARFF vehicles using High Reach Extendable Turrets (HRET) equipped with penetrating nozzles in aviation fire fighting. Since the introduction of HRETs in 1986, approximately 400 of the turrets have been retrofitted into existing ARFF vehicles or integrated on new ARFF vehicles. Some advantages and benefits of this technology include: increased throw range performance; increased range of motion of the turret, more efficient application of the agent by directing it to the seat of the fire; faster extinguishing of two-dimensional pool and three-dimensional flowing fuel fires; and the ability to penetrate inside an aircraft to cool the interior cabin and extinguish fire. This technology increases passenger survivability, protects property, and extinguishes fire faster right after an aircraft crash.

The December 18, 2003, aircraft accident at Memphis International involving a wide body DC-10 cargo aircraft demonstrated the importance an HRET outfitted with a penetrating nozzle can have at an accident. Upon landing, the failure of one landing gear caused the aircraft to skid on its fuselage and catch fire. While two ARFF vehicles concentrated on the fuel spill fire, the ARFF vehicle with the HRET penetrated the aircraft from the opposite side. Firefighters were concerned that the fire would burn through the fuselage and create an interior fire. The HRET-equipped vehicle flooded the interior with foam and 99 percent of the cargo was spared fire damage. The saved cargo value, estimated at $25 million, was greater than the value of the aircraft. This accident demonstrated the need and ability of a HRET at an aircraft accident, and the role it can play in protecting cargo and increasing survivability in passenger aircraft.

Because the current HRET performance criteria have been in place for over a decade, researchers have begun work to develop new HRET performance criteria to meet the challenges posed by the new Airbus A380 and other New Large Aircraft (NLA).

The distance from the front of the ARFF vehicle to the burning aircraft fuselage is commonly referred to as standoff distance. Current HRETs cannot reach a second level doorway of a Boeing 747 or Airbus A380 unless the ARFF vehicle is positioned right next to the aircraft fuselage. Unfortunately, this placement eliminates visibility of the operator controlling the HRET as well positioning the operator in the hazardous area. Other challenges that NLA present to the firefighters are complex slide arrangement and engine pylon locations.

The ARFF Research Program has completed the installation of a 65’ next-generation HRET on their research vehicle. Testing of this new technology has begun with the objective to further refine the performance requirements to meet the challenges of the commercial aviation fleets of today and tomorrow.

Wildlife Mitigation R&D Program

The FAA's wildlife hazards mitigation R&D program consists of three main areas aimed at reducing the risks of aircraft encountering wildlife on or near airports. Many of the studies are carried out through partnerships with other federal agencies and academic centers of excellence.

The first area, Wildlife Hazard Management research, focuses on techniques for managing the wildlife habitat on or in the vicinity of airports by making them less attractive to wildlife. Wildlife Hazard Management involves the study of methods for controlling wildlife presence, including deterring or scattering birds. The second area involves the detection and tracking of birds on or near airports to reduce the risk of an aircraft strike. The third area is the development of a North American Bird Strike Advisory System (NABSAS). All three areas currently focus on obtaining accurate and timely information that will ultimately lead to reducing the risk of severe and potentially catastrophic wildlife-aircraft strikes.

Wildlife Management and Control R&D Projects were carried out under agreements with the U.S. Department of Agriculture (USDA). Studies conducted in FY07 included the establishment of a new Interagency Agreement with USDA to characterize bird use of storm water detention basins on airports in the Southwest region of the United States. Alternative varieties of vegetation continued to be evaluated to identify bird foraging preferences and ultimately make airport vegetation less attractive to birds. The USDA completed the study of trash transfer facility types and characteristics that make them wildlife attractants.

In 2006, the FAA established several cooperative agreements with key universities, agencies and airports as first steps toward the development of the NABSAS. The system is based on a strategic plan drafted in 2005 by the FAA, U.S. Air Force, and Transport Canada. The vision of the original draft focused on providing near real time hazard advisory information to a variety of end users such as pilots, air traffic controllers, airport operators and wildlife control personnel. While that long-term objective is still viable, recent lessons learned and advances in technology have shifted the approach toward initially validating current avian radar capabilities, and providing risk assessments for key flight operational zones in the airport environment. Major cooperators in this study are the U.S. Air Force; the USDA; the University of Illinois at Urbana-Champaign; Embry Riddle Aeronautical University; several commercial airports, including Seattle-Tacoma, John F. Kennedy International and Dallas/ Fort Worth International; and avian detection radar vendors. The FAA also serves as a participating partner in a complimentary effort being conducted by the U.S. Navy.

Field studies began at the first of several test sites in early 2007. The first test avian radar system was deployed at Seattle-Tacoma International where it currently detects and tracks bird movements in that locale. Additional avian radar systems are slated for deployment at John F. Kennedy International, and Dallas/Ft. Worth International Airports.

Light Emitting Diode (LED) Airport Applications

For over 50 years the standard light source used for airfield lighting was an incandescent lamp. These lamps are not very efficient in producing light as most of the energy is in the form of heat. With the advancements in the Light Emitting Diode (LED) field, it has become viable to consider their use as a replacement for the incandescent lamp. LEDs have the potential to provide significant energy savings, reduced maintenance, and overall life-cycle cost savings while providing a more reliable visual cue. During the initial implementation of LEDs it was discovered that this new source did not act the same as the incandescent source. Items such as brightness perception, and their ability to handle the airfield circuits that were designed around the incandescent lamp needed to be addressed.

A study was completed May 2007 that investigated the brightness perception issue and found the LED has the perception of being brighter.

An FAA/Industry team was formed for the development of a common electrical infrastructure for LED lights sources. This infrastructure included a power distribution system that:

- maximizes efficiency of the LED fixture
- supports reduced total cost of ownership
- supports an open architecture.

Runway Incursion Reduction 2007 Accomplishments

Overview

The Runway Incursion Reduction Program (RIRP) within the Advanced Technology Development and Prototyping group (ATD&P) conducts research, development, and operational evaluation of technologies to increase runway safety. Consistent with NTSB recommendations and initiatives identified in the FAA Flight Plan, research emphasis remains on technologies that provide for direct safety warnings to pilots and aircrews as well as those that can be applied cost effectively at small to medium airports. The program explores alternative small airport surface detection technology and the application of these technologies to pilot, controller, and vehicle operator situational awareness tools. Initiatives include operational evaluation of alternative Runway Status Lights (RWSL) configurations to address diverse airport runway geometries, Low Cost Ground Surveillance (LCG) and Final Approach Runway Occupancy Signal (FAROS) awareness tools. When appropriate, solutions are prototyped and tested in an operational setting to validate their technical performance and operational effectiveness.

Runway Status Light

For FY 2007, ATD&P completed the evaluation and testing of RWSL using Takeoff Hold Lights (THLs) at Dallas-Fort Worth International Airport and Runway Entrance Lights (RELs) at San Diego International Airport. The RWSL project leverages the existing FAA investment in Airport Surface Detection Equipment Model X (ASDE-X) to augment a layered defense system and reduce the likelihood of a runway collision at selected airports in the NAS. RWSL integrates airport lighting equipment with the ASDE-X approach and surface surveillance system to provide a visual signal to pilots indicating that it is unsafe to enter/cross or begin takeoff on runway. It was developed and evaluated through the RIRP to assess its performance and suitability for integration at high volume airports. RWSL will contribute toward the reduction of Category A and B (high-hazard) runway incursions. The ATD&P group successfully completed the initial investment decision process (JRC 2A) and transferred this program to the Terminal Service Unit for implementation throughout the NAS.

Low-Cost Ground Surveillance Systems

In addition to RWSL, the ATD&P group tested and evaluated two LCGS systems at Spokane International Airport. These non-cooperative sensors can provide essential surveillance capability at small and medium airports. Two different LCGS candidates were evaluated: the Critical Area Management System (CAMS) and the NOVA 9000 ATC System.

- CAMS uses an array of millimeter wave sensors (MWS) distributed throughout the airport movement area to provide coverage of runways, taxiways, and ramp areas. MWS requires no aircraft-installed equipment to operate. The current system installed at Spokane as part of the LCGS evaluation is integrated with the Automated Radar Terminal System (ARTS) ARTS-IIE. This system can also be integrated with an Optical Identification Sensor (OIS).
- The NOVA 9000 ATC System uses Terma X-Band radar to provide complete coverage of the airport movement area. It requires no aircraft-installed equipment to operate. The current system installed at Spokane is also integrated with the ARTSIIE system.

A final evaluation report was submitted to the Office of Runway Safety in September 2007. The project had such favorable results that the FAA is developing a pilot program to deploy LCGS systems at up to three additional airports in order to gather further business case data in anticipation of an investment decision in FY09.

Final Approach Runway Occupancy Signal (FAROS)

The ATD&P group also tested a basic FAROS concept at Long Beach Airport, using in-pavement loops to sense the presence of an aircraft or vehicle on the runway. This system indicated traffic on the runway, by flashing Precision Approach Path Indicators, in three limited areas. An advanced version of FAROS is being developed to employ ASDE-X and Airport Surveillance Radar to determine, for a specified critical point on the approach path, whether there might be traffic on the runway that will conflict with approaching aircraft. This improved surveillance and smaller alert window is necessary at busy, high capacity airports, such as Dallas – Fort Worth International Airport, where the system will be installed and tested.

Aviation Weather 2007 Accomplishments

Avoiding In-Flight Icing Conditions

The formation of even a thin coat of ice on an aircraft surface can seriously affect an airplane's ability to fly by increasing drag, increasing aircraft weight, and decreasing lift. In many cases, ice build-up is so rapid that the pilot does not have enough time to take corrective action. NTSB reports 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-funded researchers have developed the Current Icing Product (CIP-Severity) and the Forecast Icing Product (FIP-Severity). These products alert users to areas of known and forecasted in-flight icing by graphically displaying the probability that icing will occur along their planned flight path.. During fiscal year 2007, the joint FAA/National Weather Service Aviation Weather Technology Transfer Board approved the FIP-Severity for experimental use. During the experimental use phase, users can view the product and provide performance feedback to researchers for refinements before making the capability fully operational.

FIP-Severity has the following new features: Expected Icing Severity; Probability of Icing Encounter; Improved Color Scale; and Improved Cloud Top Estimates. These new features were added to mitigate risks identified by assessments conducted by the FAA. Severity is needed to delineate where icing conditions reside, so that uncertified aircraft can avoid these areas. The new product uses a relative scale that has been calibrated to depict the probability of encountering icing. The FIP-Severity also has improved cloud top estimates which will reduce the volume of airspace being depicted as hazardous without compromising safety. Additionally, supercooled large drop regions, which represent conditions outside the current certification envelopes, are depicted as cross-hatched overlays for quick reference.

These improvements will allow users to plan more effective routes of flight that will avoid hazardous icing areas.

Mitigating the Effects of Low Ceilings and Visibility

According to a University of Illinois study, pilots licensed to operate in visual flight rules who lack instrument training lose of control of their aircraft in less than 3 minutes, on average, from the time they lose visual orientation. Low cloud ceilings and poor visibility conditions are safety hazards for all types of aviation. 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 have been developing a National Ceiling and Visibility Analysis (NCVA) and a forecast capability to warn users of areas with low ceilings and poor visibility.

The NCVA provides users in the lower 48 states an automated graphical display, updated every 15 minutes, showing current ceiling, visibility, and flight category conditions along their route of flight. The NCVA capability also incorporates tools that allow concurrent examination of other weather data, including satellite and radar imagery.

NCVA was approved by the joint FAA/National Weather Service Aviation Weather Technology Transfer Board for experimental use in FY 2005. User feedback obtained during the experimental phase resulted in improvements to NCVA including an enhanced cloud-mask that identifies cloud free areas between data sites. Development of NCVA was completed in 2007 and is expected to be approved for full operational use in FY 2008.

Wind-Dependent Wake Turbulence Mitigation

In 2007, the FAA completed the concept feasibility demonstration of a cross-wind based air traffic wake turbulence mitigation decision support tool to enable greater capacity for closely-spaced runways. The FAA also completed assessment of NASA's concept for wind-dependent wake turbulence mitigation procedure for aircraft arriving on closely spaced parallel runways.

Wake Turbulence Operational Change

Relying on NASA's wind-dependent wake turbulence mitigation procedure, in June 2007**,** the FAA approved an operational change at Lambert-St. Louis International Airport (STL) for ATC operation of the airport's closely spaced runways**.** The requested change allows STL to accept traffic on both of its closely-spaced parallel runways under adverse weather conditions. Under previous wake mitigation guidelines, STL would have had to shut down one of the runways for arriving traffic. This change in procedure allows pairing of aircraft as they approach the STL runways, requiring the leader of the pair be a small or large weight category aircraft. This change implemented dependent staggered Instrument Landing System approaches in Instrument Flight Rules conditions, allowing significant arrival and departure capacity increases, and minimizing flight delays.

Capacity 2007 Accomplishments

Center for Advanced Aviation System Development (CAASD)

AviationSimNet® Simplifies Testing of New Aviation Concepts

In the past, joining laboratories at government agencies, commercial airlines, and universities to conduct distributed evaluations of new aviation concepts was expensive, time consuming, and required dedicated communications lines and proprietary interfaces. This environment limited opportunities for joint research. To increase joint research and reduce the cost and preparation required, CAASD, in conjunction with others in the aviation community, defined and developed a standard to facilitate distributed evaluations between simulation laboratories.

Known as AviationSimNet, this standard is a flexible, reusable technical specification for conducting real-time air traffic management (ATM) simulations over the public Internet. Building upon proven simulation and communication standards like the Department of Defense's high-level architecture, DIS 1278.1a, and FAA and International Civil Aviation Organization (ICAO) standards, AviationSimNet reduces the time and cost of fielding new capabilities.

The AviationSimNet Specification Version 2.0 was made available to the public in August 2006, and continues to be expanded to meet needs identified by the AviationSimNet community. The publicly available AviationSimNet Federation Object Model was updated in September 2007 to include flight object, weather extensions, and additional simulation management capabilities.

Organizations participating in AviationSimNet include: the Air Line Pilot Association, The Boeing Corporation, the Center for Applied ATM Research at Embry-Riddle Aeronautical University, Lockheed Martin Transportation and Security Solutions, NASA's Ames Research Center and Langley Research Center, Raytheon, and United Parcel Service. In addition to building gateways that make their labs accessible via AviationSimNet, participating organizations are also hosting SimCenters, which are communications facilitators for the simulation environment that include labs at multiple organizations.

More information can be found at http://aviationsimnet.net/.

Clean Sheet Airspace Design Tools

Historically, airspace has been redesigned by air traffic controllers when they identify a problem, like a busy merge area with too much traffic to handle efficiently. Since many airspace design efforts cross facility boundaries, redesign can be costly and labor intensive processes, at times taking controllers away from directing air traffic for extended periods of time. Also, due to the size, complexity, and interconnectedness of the NAS, controllers' solutions to their local problems may have unintended ripple effects elsewhere in the system.

To make airspace redesign more efficient, CAASD has partnered with the FAA and developed a prototype set of Clean Sheet airspace design tools that offer a three-step, semi-automated process for airspace redesign. The term "clean sheet" is used because the tools are intended to wipe the slate clean of preconceived notions about airspace redesign and produce completely objective solutions. The tools are programmed to develop sector designs to service any user input traffic flow, regardless of existing sectors or control facility boundaries. Using objective, repeatable, and transparent methods, the tools allow faster, less expensive, and more efficient airspace redesigns.

The first step creates a map of geographically distributed traffic complexity (based on a specific set of metrics) in the area to be redesigned. Once a map is created, an automated airspace partitioner divides the airspace into areas of equal complexity. The target amount of complexity for each partition is adjustable and can be used to design sectors requiring up to three controllers. The second step in the Clean Sheet process uses fast-time, dynamic simulation to test the complexity regions and identify operational problems that controllers might have. The third step employs a knowledge database of airspace design principles and best practices captured from ATC experts to suggest solutions to the problems identified in the second step. Work continues to enhance the knowledge database and apply it more efficiently.

In 2007, this process was used to inform airspace design decisions in Florida, Chicago and New York. The results of these efforts are being incorporated into on-going design work in these critical regions of the NAS..

Integration of Advanced Simulation Technologies into Controller Training

Transformation toward NextGen will require significant improvements in the technologies and processes used to train controllers in the en route and terminal domains. The FAA is faced with the additional challenge of training approximately 12,000 new en route and terminal controllers over the next decade to fill the void of the air traffic controllers that are expected to retire during this timeframe. Currently, training and certifying a controller requires significant instructor resources and can take on average, three to five years in the en route domain, and over two years for many facilities in the terminal domain.

To improve controller training in terms of quality, effectiveness, cost to the FAA, and to prepare for evolutionary changes toward NextGen, advanced simulation technology for controller training is being developed and adapted by CAASD. Leveraging its accomplishments in aviation system concept exploration, prototype development, and field evaluations, CAASD has developed a stand-alone en route training simulation prototype, referred to as the “*enroute*Trainer”**.** A prototype is currently in use at the Indianapolis Air Route Traffic Control Center to valuate these advanced capabilities in an operational setting. With its high-fidelity, scenario-based instruction, the *enroute*Trainer provides students with a realistic practice environment, simulating the effect of winds, aircraft climb/descent rates, and aberrant conditions. The system**’**s speech recognition and synthesis capabilities simulate pilot/controller interaction, enabling self-paced training, and increased standardization. The *enroute*Trainer also simulates a variety of scenarios to familiarize the student with sector and area operations, procedures, and traffic patterns. The prototype enables the instructor to play back any trainee scenario to assess a student’s performance and can generate reports on significant measures, including operational deviations and errors.

In FY 2007, CAASD continued the evaluation of the *enroute*Trainer at the Indianapolis center. A group of students were trained using this system as their primary tool during their final stage of radar simulation training (e.g., Stage IV) before beginning their on-the-job training with live traffic. The primary objective of this on-going field evaluation is to determine the set of validated simulation capabilities and training curriculum that can be integrated into the overall controller training process that will shorten training time, reduce the cost to certify a controller, improve the quality and consistency of training, and to enable a more effective transition of automation/ procedural advancements into operational use. A significant area of research in which CAASD is in the forefront is the development of Intelligent Tutoring Systems that will enable self-paced and accelerated training, and increased standardization, while reducing training staffing costs. This is viewed as a key enabler to support the evolution toward NextGen.

The first group of students completed their on-the-job-training in 50 percent less time than scheduled (with the acceleration attributed in part to improved realism) and achieved Certified Professional Controller status a full seven months ahead of schedule (about a 20 percent reduction in training time). CAASD is working with FAA to transfer this technology to industry for broad application across the FAA's training program.

In the terminal domain, CAASD is leading the development and assessment of new concepts for improving the delivery of critical ATC training information, and has developed an initial prototype that demonstrates the concept of use for airspace and procedures as well as enhanced simulation training. The objectives are similar to en route training: to shorten training time;

reduce the cost to certify a controller; improve the quality and consistency of training; and enable a more effective transition for the future.

Performance-Based Air Traffic Management: Validation Activities toward OEP/NextGen

Increases in air traffic volume and complexity, combined with projected budget constraints over the coming years, will create challenges for the U.S. air traffic management system. The safety, capacity, and productivity of the NAS can be significantly improved through the OEP by integrating enhanced automation technologies and procedures to enable operational demands on the NAS to be met efficiently and safely.

CAASD and the FAA have jointly developed an operational concept as a subset of the OEP evolution toward NextGen known as Performance-Based Air Traffic Management (P-ATM). The concept introduces fundamental shifts in the use of automation capabilities across the NAS in order to increase operational productivity while maintaining a human-centered operation. The path toward NextGen will require significant improvements in technologies as well as fundamental shifts in the roles and responsibilities of the users and service providers. CAASD has played a significant role in helping the FAA develop and validate operational capabilities for a subset of key OEP initiatives to support traffic demands and improve services over the next decade and beyond.

Under P-ATM, many routine ATC tasks will be automated. Terminal operations will leverage a network of highly precise Area Navigation/Required Navigation Performance (RNAV/RNP) routes. These routes would be designed to increase flexibility, efficiency, and capacity. Flight deck automation would enable aircraft to fly these routes and altitude profiles precisely while exchanging flight status and intent information with the ground system. In en route operations, responsibility for problem prediction would migrate from controllers to ground automation, and controllers would solve problems using automated resolution assistance. The integration of advanced automation with air/ground data communications would assist the controllers in accommodating pilot requests and providing more efficient maneuvers when resolving predicted conflicts.

The P-ATM concept provides for better management of uncertainty with capabilities that support enhanced decision-making and efficient execution of flight-specific initiatives. The reduction in execution time, along with improved tools for defining and monitoring the initiatives would allow for better flow planning and provide the opportunity to implement initiatives incrementally and only when necessary. In this highly predictable operational environment, user preferences would be better accommodated through collaborative ATM activities. The P-ATM portfolio of capabilities can provide vastly improved air traffic services that promote increased safety, capacity, efficiency, and operational productivity.

In FY 2007, CAASD designed and conducted numerous human-in-the-loop experiments of this future environment. These experiments evaluated specific operational conditions and traffic scenarios that extended previous experiments. FAA managers from across the country were the key participants for assessing both the quantitative benefits and operational feasibility of this P-ATM concept.

In addition, CAASD developed an evolution path toward this integrated set of capabilities, identifying incremental operational changes and capturing dependencies among the capabilities that will enable these operational changes. This evolution path will help the FAA in developing the detailed plans for achieving a subset of capabilities defined in the OEP. CAASD also conducted a preliminary safety analysis to identify potential safety concerns, influence the concept development as appropriate, and identify key research areas to address these concerns. CAASD has also begun identifying potential customer benefits that can be achieved with these operational changes.

The results of the work conducted thus far have a significant impact on the FAA's plans for NextGen. The P-ATM concept aligns very well with the core capabilities that are part of the NextGen vision, but also represents a set of operational changes that can be achieved in a more near-term timeframe. The P-ATM research and validation activities will continue to inform OEP activities for transforming air traffic operations toward NextGen and changing the controllers' roles and responsibilities to safely and efficiently meet the future demand on the NAS.

Estimating Runway Capacity at Complex Airports

An estimate of runway capacity can provide a key measure of the effectiveness of new technologies, procedures, and infrastructure intended to improve the ATC system. An accurate model for estimating runway capacity is a valuable tool for predicting the effects of new technologies on the system and for making decisions about building new runways. Accurately modeling runway capacity has become increasingly complex because today's environment consists of multiple decision support systems in the cockpit and on the ground, specialized separation rules for multiple approach and departure traffic streams, and interactions between nearby airports in major terminal areas.

To capture the dynamic effects of the interactions between traffic streams in runway capacity modeling, CAASD researchers developed a prototype simulation-based modeling system called *runway*Simulator. In less than an hour, a trained analyst can configure this system to simulate the traffic streams for a set of runways at a single airport, or a group of nearby airports, operating under any set of ATC separation techniques. The simulation presents its results both as numerical measures of throughput and as an animation of the aircraft traffic streams that produced the numbers. The modeling system captures statistics describing runway usage, interactions between the traffic streams, and flow rates. These results are categorized in a variety of ways, including by the particular aircraft types and runways being used. Together, the statistics and animation provide increased insight into the most efficient way to operate a complex system of runways.

The new *runway*Simulator provides important advantages over the Enhanced Airfield Capacity Model that is currently used to calculate estimated runway capacity. The older analytical steady-state model estimates the average maximum sustainable throughput for a limited set of configurations using predetermined separation rules. The new system also estimates the average maximum sustainable throughput, but it can model any configuration and any set of separation rules. In addition, being a simulation, it also captures the dynamic interaction between traffic flows and produces much more detailed output that permits greater insight into why an airport is limited to a given capacity. In FY 2007, the development team introduced the *runway*Simulator to the modeling experts within FAA. Together, they began a thorough evaluation of the model's capabilities to assess the potential effects of planned procedures, technologies, and infrastructure upon an airport's capacity.

Modeling Improvements to the National Airspace System

The performance of the NAS, commonly measured by flight delays and traffic loads on airports and airspace, depends on the complex interactions of airspace users, air traffic service providers, aviation infrastructure, and weather. Analysts use simulations to capture these complexities when estimating the effects of increased traffic volumes, new fleet mixes, alternative route structures, new runways, and improved technologies, procedures, and operational concepts on the NAS.

In 2007, CAASD, improved its new fast-time simulation capability, *systemwide*Modeler, which increases the fidelity and speed with which it can examine the future NAS. It simulates the progress of individual flights through airports, terminal areas, and en route sectors while modeling delays and workload caused by congestion and weather, airport capacities, and traffic management initiatives. Implemented in a state-of-the-art simulation language with a flexible architecture, *systemwide*Modeler simulates a day of NAS operations in tens of minutes and can report details for aggregate or focused analysis and visualization. It has already been used by CAASD to provide the FAA with an analysis of the FAA's Operational Evolution Partnership plans, to predict airports that will have capacity problems, and to inform analysis of data communications investments.,

The *systemwide*Modeler includes a unique model of controller workload for en route traffic that reflects the differences in work associated with different flight activities: merging and spacing flows, resolving conflicts, and managing climbing and descending traffic. Through its representation of traffic events and controller tasks, it goes beyond traditional traffic count-based models to help analysts understand the effects of new communications and automation technologies as well as new procedures and airspace design.

Operational Concept Validation 2007 Accomplishments

"Big Airspace" Study

The strain of increasing air traffic demand is especially apparent in the arrival and departure airspace surrounding major metropolitan areas, particularly those where there are multiple airports with interacting arrival and departure flows. A study called the Integrated Arrival/Departure Control Service, or "Big Airspace," was undertaken by the FAA in 2007 to develop and validate an operational concept for improving operational efficiencies in major metropolitan areas. The study was performed using a combination of procedures, such as integrating arrival and departure airspace into one control service and one facility as well as employing dynamic airspace reconfiguration of bi-directional arrival/departure routes.

To test the operational feasibility of Big Airspace, a series of simulation studies employing different techniques was conducted. The studies included fast-time system performance simulation, fast-time human performance simulation, and real-time human-in-the-loop simulation. Each technique had its own unique strengths, thus enabling a comprehensive evaluation of Big Airspace regarding its impact on efficiency, capacity, safety, and human performance. Using generic airspace as a platform for analysis, the simulation evaluations supported the BA concept. The studies also helped drive operational and technical requirements for further development of the concept by demonstrating service provider improvements and operational efficiencies. These benefits were evaluated in terms of workload, task performance, safety, and controller acceptance. Operational efficiencies include savings in flight time and distance flow with more efficient flow strategies. A preliminary cost-benefit analysis shows that all sites evaluated are expected to produce cost benefits with a short payback period with benefits rates ranging from 2.8 to 11.7.

Commercial Space Transportation 2007 Accomplishments

Safety Operations Personnel Duty and Rest Analysis

In 2007, the FAA developed rest and duty restrictions to ensure the safety of commercial space transportation. These regulations were based upon crew rest requirements imposed by the Air Force at federal launch ranges. The FAA, in cooperation with industry and other government agencies, commissioned Clemson University to review the scientific literature pertaining to crew rest and duty restrictions and provide recommendations for those involved in commercial space transportation. The goal of this effort was to improve commercial space transportation safety system by ensuring that ground support personnel and flight crewmembers have the opportunity to get the needed rest to safely perform their routine and emergency duties.

The study focused on sleep, circadian rhythms, stages of sleep, best time to sleep, effect of sleep disruptions, sleep requirements, countermeasures to fatigue and insomnia, shift-work, shift-work scheduling tools, and current aviation and space flight crew rest and duty time requirements. The study found the following: although all sleep is beneficial, slow wave sleep is more recuperative; the best time to sleep is during the circadian trough (between 22:00 and 08:00); interruptions of nighttime core sleep reduce sleep quality and effectiveness; individuals need roughly eight hours of sleep to be properly refreshed; and sleep loss is cumulative and may take multiple nights of sleep to fully recover. The study also provided recommendations for managing commercial space transportation crew duty and rest.

Human Space Flight Training Preparation Study

The recent development of commercial launch vehicles designed to carry humans has created a need by the FAA to determine if space flight crews meet training requirements that ensure the safety of the crew and the uninvolved public.

In 2007, the Commercial Space Flight Launch and Reentry Vehicle Pilot Training Survey was developed to help the FAA understand the opportunities available in critical aviation and space flight training fields, by supplying profiles of training providers as well as a final report that summarizes the survey.

The following disciplines where surveyed:

- physiological training;
- high-performance jets;
- high-performance gliders;
- altitude chamber (hypobaric and hyperbaric);
- parachute training;
- unusual attitude training;
- high-altitude flight;
- high-g (gravity);
- low-g (gravity);
- pressure suit training;
- flight simulation; and
- spaceflight operations.

Each profile included the following items:

- list of the training area(s) that the organization provides;
- contact information;
- description of the training course(s);

- brief background and professional training experience of the organization;
- description of the equipment and facilities that the provider owns or uses to conduct the applicable training; and
- data on the cost of the training offered.

Historical Database of Failures & Reliability of Rocket-powered Vehicles

In 2007, at the suggestion of the of the Commercial Space Transportation Advisory Committee Reusable Launch Vehicles Working Group, a database review of historic failure modes of rocket powered vehicles (both expendable and reusable) using open source literature was conducted. The ultimate goal is to provide the emerging commercial space transportation industry with insight into which components of rocket powered vehicles fail and why.

In this database, the definition of "failure" draws from a clause in the FAA Office of Commercial Space Transportation *Guide to Probability of Failure Analysis for New Expendable Launch Vehicles*, specifically: "an in-flight failure occurs when a launch vehicle does not complete any phase of normal flight." This definition excludes failures where a vehicle's lower stages had already placed the spacecraft in orbit, such as the failure of an apogee kick motor attached to a satellite that had already been placed in a transfer orbit by the lower stages of its launcher.

The study progressed in two phases: first for all U.S. and foreign expendable-launch vehicles over the last 50 years (e.g., Atlas) and followed by rocket-powered aircraft (e.g., X-15). For the 255 expendable launches for which a failure reason could be determined during the 1957-2007 period, propulsion anomalies were found to be the salient failure mode (51 percent) with guidance and navigation as the next leading cause of failure (20 percent). Upon review of the 142 launch failures with known causes that have occurred since 1980, propulsion anomalies remain the salient failure mode at 54 percent, guidance and navigation remains the next leading cause of failure although it has dropped significantly to 12 percent, and software and computing-related failures is growing and has become significant at 9 percent. The database for rocket powered aircraft has been completed but is still under review and will be finalized in FY2008.

Environment and Energy 2007 Accomplishments

Developing Analytical Tools for Effective, Comprehensive Noise and Emission Mitigation

The FAA, in collaboration with Transport Canada and NASA, is working with an international team of researchers to develop a comprehensive suite of software tools. In 2007, the FAA demonstrated capabilities that included incorporating the latest aviation noise/emission science, aircraft technology forecasting, and cost analyses of environmental impacts for aviation. These new capabilities are the cornerstone of a new comprehensive approach to assessing environmental policies that help guide policies and actions that annually cost the FAA $500 million in mitigation expenses and industry between $5 billion and $6 billion in implementation expenses.

Policy, Analysis, and the Aviation Environmental Design Tool

During 2007, the Aviation Environmental Design Tool (AEDT) was used to support several domestic and international initiatives at both the regulatory and policy levels. In support of the ICAO's Committee of Aviation Environmental Protection, AEDT was the centerpiece of an exercise that was designed to assess the tool's readiness for conducting a policy analysis for various nitrogen oxide (NOx) stringency scenarios. Researchers integrated common modules and databases as well as implemented many concepts of the overall AEDT architecture to develop worldwide estimates of fuel burn, emissions, and noise. The effort included a comparison of AEDT with other international environmental tools and analysis of reduced NOx limits, also called "NOx stringency" in the years of 2012 and 2016 at reduced levels of 0 percent (no stringency), 6.5 percent, and 18 percent. The use of an integrated tools suite, including the economic analysis capability in the Aviation Environmental Portfolio Management Tool (APMT), demonstrated the unique capabilities of the FAA's tools, such as the ability to investigate noise and emissions interdependencies to better inform policymakers. Model outputs compared very favorably with the other tools exercised and AEDT was the only tool to provide global fuel burn, emissions, and noise results.

In 2007 AEDT was also used in the analysis of Continuous Descent Arrivals (CDA) at a major U.S. airport. A total of nine modeling scenarios were generated to investigate the fuel burn, emissions, and noise benefits of CDA implementation. The scenarios were generated using historic trajectory information based on actual radar data for the baseline arrivals and with optimal vertical components for the CDAs , directly linking model results to actual operations. Previous modeling efforts quantified only one environmental effect due to a single or handful of events; AEDT provided comprehensive results, at a level of detail typical of that required by a National Environmental Policy Act analysis.

Development efforts in 2007 included initiation of the integration of AEDT with databases that support the Joint Planning and Development Office's vision for NextGen. This work involved updating AEDT modules and databases to work directly with the NASA Airspace Conflict Evaluation Simulator (ACES) tool. Full integration of ACES and AEDT will allow for streamlined and consistent analysis of aviation environmental issues during the design of NextGen.

The AEDT development team, led by the FAA with support from the U.S. Department of Transportation's Volpe Center and industry ,initiated a design review group, consisting of both aviation noise and emissions experts to help guide the development of the tool. The review group, assembled from members of the existing Emissions and Dispersion Modeling System (EDMS) and Integrated Noise Model (INM) review groups, will be integral to ensuring stakeholder interests are met throughout the AEDT development process. AEDT connectivity with APMT and the Environmental Design Space (EDS) was substantially advanced during 2007. For example, development and use of the Flight Operations Module was carefully coordinated between the AEDT and APMT development teams. Significant efforts were also undertaken to ensure that the AEDT Fleet Database meets all the needs of AEDT, APMT and EDS. This is especially important to ensure consistent use of assumptions across environmental modeling (e.g., AEDT), implementation of technology assumptions (e.g., EDS) and exercise of policy scenarios, especially the potential economic and human impacts (e.g., APMT).

Predicting Scenarios and the Environmental Design Space Tool

EDS estimates source noise, exhaust emissions, performance, and economic parameters for aircraft designs under different technological, policy, and market scenarios. These capabilities allow for assessments of interdependencies between aviation-related noise and emissions effects. In 2007, the EDS Technical Advisory Board, initially formed to guide development and facilitate industry review of EDS, was expanded to allow for a more thorough assessment of EDS processes and assumptions, including model components and structure, and model capabilities in predicting aircraft noise and emissions levels relative to appropriate validation data. The new EDS Independent Review Group (IRG) brings together industry experts to review specific details of the model in the areas of engine performance, aircraft performance, noise, and emissions. The IRG also includes members of various research establishments to provide a level of independent review. The IRG currently includes representatives of the aircraft and engine manufacturing industry, the EDS development team, NASA, the FAA, and several European research organizations.

The EDS development team continued a rigorous assessment of EDS in 2007 through close collaboration with engine and airframe manufacturers. A key result of this assessment was an update to the fundamental architecture of EDS from a single point to a multiple point design for the engine based on airframe thrust requirements. The multiple point design approach is more consistent with current industry practice. The update to the EDS architecture for the 300 passenger class vehicle has been completed and is in review by the IRG. The EDS development team also working with the IRG to assess the sensitivity and uncertainty of EDS input parameters and results. This will enable the accuracy of the EDS tool to be better understood and will also highlight EDS components in need of improvement.

EDS connectivity with both AEDT and APMT was established and demonstrated through a sample exercise designed to assess the readiness of the environmental tool suite for conducting a policy analysis for various NOx stringency scenarios. In support of the ICAO's Committee of Aviation Environmental Protection's Modeling and Database Task Force, EDS provided the technology response to a potential NOx stringency in years 2012 and 2016, including proposed stringency levels of 0 percent (no stringency), 6.5 percent, and 18 percent. EDS provided future aircraft designs that could be potentially introduced to the fleet in response to proposed NOx stringency levels.

Aviation Environmental Portfolio Management Tool

Historically, aviation environmental modeling tools generated either noise or emissions outputs, after which the costs to implement a policy were considered against a single environmental performance indicator (e.g., NOx emitted). Subsequent advances on common databases and inputs have highlighted the need to better consider noise, local air quality, fuel burn, and greenhouse gas emissions interdependencies and to monetize costs and benefits. The FAA is developing a comprehensive suite of software tools that will allow for thorough assessment of the environmental effects of aviation. The main goal of the effort is to develop a new capability to assess the interdependencies between aviation-related noise and emissions effects, and to provide comprehensive impact, and cost and benefit analyses of aviation environmental policy options. The impact and economic analysis function of this suite of software tools has been given the rubric APMT.

The design requirements for APMT are built on the efforts of previous aviation environmental economic analysis tools, as well as projected international and domestic analysis needs and best practice guidance. The resulting architecture of APMT takes aviation demand and policy scenarios as inputs, and simulates the behavior of aviation producers and consumers in order to evaluate policy costs. Detailed operational modeling of the air transportation system within AEDT provides estimates of the emissions inventories and noise exposure. Then, a benefits valuation module within APMT is used to estimate the health and welfare impacts of aviation noise, local air quality and climate effects, using a variety of metrics. These metrics include monetary estimates of the value for these changes in environmental quality.

In 2007, several critical APMT capabilities were demonstrated. At the start of the year a workshop for the Transportation Research Board was held to brief the results of initial testing of the APMT prototype functionality for addressing various policy questions, as well as assessment and propagation of uncertainties. Lessons learned from the initial prototype testing effort influenced design modifications that led to APMT version 1.

Releasing Integrated Noise Model (INM) Version 7.0

As the last major version release before its full integration into the AEDT, INM Version 7.0 represents a significant improvement over the INM 6 series as the FAA's current standard tool for predicting noise impact in the vicinity of airports. In addition to several updates related to aircraft noise/performance for commercial aircraft, Version 7.0 includes detailed modeling of helicopter noise based on the FAA's Heliport Noise Model Version 2.2, and algorithms consistent with updated guidance documents, including the European Civil Aviation Conference (ECAC) Doc 29 (3rd Edition) "Report on Standard Method of Computing Noise Contours around Civil Airports."

INM Version 7.0 includes the following new operational and computational features:

- improved helicopter noise modeling capabilities;
- compliance with ECAC Doc 29, the European standard;
- scenario-case format;
- new multi-threaded run mode; and
- graphical user interface changes.

INM 7.0 provides much more accurate noise modeling capability to the over 1,000 users of INM worldwide.

Emissions and Dispersion Modeling

Version 5.0 of EDMS was released by the FAA as the last stand-alone in the series before EDMS becomes the local air quality module within the AEDT. The major enhancements to EDMS 5.0 represent the important steps toward integration of noise and emissions assessment capabilities. A dynamic flight profile generator, common to noise assessments, has been incorporated using the best available methodologies and aircraft performance data from the Society of Automotive Engineers, Boeing Fuel Flow Methods, and EUROCONTROL's Base of Aircraft Data. In addition, common airport and aircraft fleet databases from FAA's other environmental models, including INM, System for Assessing Aviation's Global Emissions (SAGE), and Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA) provides harmonization for interdependency tradeoff analyses performed on the global, regional, and single airport scales.

At the request of expert EDMS users, several new sophisticated features have been incorporated into EDMS 5.0 to improve the fidelity of airport activity and accuracy of emissions estimates, which will become the cornerstone capabilities for AEDT in the future. An enhanced airport configurations function now allows the user to model aircraft operations consistent with actual airport procedures by matching runway use with wind speed and direction. The model can now accept aircraft schedules to separate arrivals and departures as well as enable the user to route aircraft on unique taxi paths, which facilitates the use of an improved aircraft queuing model to improve the accuracy of aircraft ground emissions calculations. For the first time, EDMS 5.0 calculates start-up emissions from aircraft engines. EDMS 5.0 incorporates the latest advances in the First Order Approximation method to predict particulate matter (PM) emissions from aircraft engines. Fleet coverage has been expanded by over 220 new aircraft and 65 new engines.

Modeling and Analysis of Aviation Emissions Impact

With the projected demand for aviation expected to grow, aviation emissions and associated environmental impacts contributing to climate effects will consequently increase. Although at present, aircraft emissions are a very minor contributor to overall emissions, relative magnitude of aircraft emissions is expected to increase, owing to generally decreasing emissions from non-aviation sources.

With environmental factors identified as a major constraint of the NextGen, the Joint Planning and Development Office (JPDO) has developed an integrated plan for implementation that calls for development of environmental protection by 2025 that allows for sustained aviation growth. In particular, one of the NextGen objectives is to reduce uncertainties for aviation-induced climate impacts to a level that would enable appropriate actions to address them.

With this stated objective, the FAA and NASA, as participating federal agencies to the JPDO, co-sponsored an international workshop on the Impacts of Aviation on Climate Change in June 2006 to assess and document the current state of scientific knowledge, identify key uncertainties and gaps, and make recommendations on how to address them. One consensus finding is the acknowledged need for focused research efforts to address identified uncertainties and gaps in the understanding of current and projected impacts of aviation on climate and to develop metrics to characterize these impacts. The workshop report is available at: http://web.mit.edu/aeroastro/partner/reports/climatewrksp-rpt-0806.pdf.

Following the workshop recommendation, with the support from the U.S. Climate Change Science Program, in 2007 the FAA and NASA have jointly developed the Aviation-Climate Change Research Initiative (ACCRI) with the objective to improve the state of scientific knowledge through research while making the best practical use of available science and modeling capability to update and refine the magnitudes of climate impacts of aviation. From the policy perspectives, another key objective of ACCRI is to identify and develop metrics for aviation-induced climate impacts at all relevant spatial and temporal scales.

The overall structure of ACCRI is based on a sequential, four-step process with the vision that outcomes of the prior steps will guide the direction and expectations to the next step. The timelines to implement various steps of ACCRI and their expected outcomes are designed in a way that they will provide timely intermediate input toward scoping and implementation of subsequent steps while scientifically informing policy-making decisions for NextGen and the ICAO Committee on Aviation Environmental Protection. The four key steps of ACCRI are as follows: 1) develop white papers to provide in-depth reviews of the scientific understanding and key uncertainties as well as assessment of current modeling capability in seven thematic areas that are considered to be critical in understanding climate impacts of aviation; 2) convene a meeting of scientific experts to develop community consensus on composite findings of these white papers, develop pathways for research to address key gaps, develop recommendations for practical application of multiple-state-of-the-science models to simulate a number of emission scenarios that develop a range of climate impact estimates, and quantify underlying levels of uncertainties. Recommendations for practical applications and research gaps identified under Step 2 will be implemented in parallel under steps 3 and 4 respectively. Outcomes from steps 3 and 4 will provide guidance to each other for future work. Activities under step 3 will be repeated as scientific understanding improves through research activities under step 4.

With support from the FAA, ACCRI has implemented the first step, identifying seven thematic scientific areas that are considered to be critical for quantifying aviation related climate impacts and has solicited proposals from the science community. All seven in-depth review white papers under step 1 will be delivered in early FY 2008 and the science meeting under step 2 will be held early calendar 2008. Activities under steps 3 and 4 will initiate during 2008-2009.

Atmospheric impacts of aviation are most visible through the formation of contrails and induced cirrus clouds at the cruise altitude. Climate impacts associated with contrails and cirrus clouds are difficult to quantify. Over the last several years, the FAA has funded key research activities in this area. In particular, the FAA funded a modeling project with the objective of simulation of contrails and induced cirrus clouds and quantification of their associated radiative and climate impacts on the global scale within the same modeling framework, with a particular focus on the US regional domain.

Aviation Emissions and Air Quality: Air Quality and Health Impact Analysis

In preparation for meeting the projected growth in aviation, airports around the nation are considering expansion plans. At the same time, concerns are increasing about how, and to what extent, air pollutant emissions from airports contribute to local and regional air quality, and hence to potential health impacts. Airports are frequently asked, during the environmental impact study, to estimate the direct emissions of criteria and hazardous air pollutants (HAPs) from all airport sources and their potential environmental impacts. There is no consistent framework for emissions and impact analysis available that airports could employ to support their decision making. One of the key environmental protection goals of the NextGen vision is to reduce the air quality impacts of aviation emissions in absolute terms, regardless of the anticipated growth in air traffic. Therefore, to inform policy making decisions and to support environmentally conscious airport expansion plans, there is a need to understand the magnitude of incremental environmental impacts due to current and projected airport emission sources and its comparison against the changing background air quality.

Analysis of environmental impacts of air pollutant emissions goes beyond merely analyzing the magnitude of direct emissions, because these emissions undergo atmospheric evolution during their dispersion and give rise to formation of other secondary pollutants, such as ozone and PM. The FAA is undertaking a number of initiatives on both air quality modeling and measurement fronts to better characterize the airport level emissions and their potential impacts on air quality and public health.

As an example of one of these initiatives, the Energy Policy Act of 2005 requires that FAA and EPA consider the impacts of air quality and public health in assessing opportunities to enhance fuel efficiencies and reduce emissions. In response, researchers have used current models and inventories to estimate aircraft emissions at 325 airports, many of which are located in air quality non-attainment areas. These estimates are now being used to characterize the impact of aircraft operations on local air quality and their subsequent health impacts.

Recently, the Airport Cooperative Research Program (ACRP) has recognized the need to pursue airport-related air quality research activities. The ACRP is funded by FAA funded and managed by the Transportation Research Board. Currently, the ACRP is funding a number of research projects for better characterization of airport emissions for PM and HAPs.

On the modeling front, the FAA research efforts include sub-scale dispersion simulations encompassing regions within the airport vicinity and larger multi-scale grid resolution based air quality modeling and analysis for both criteria and HAPs. In addition, the FAA is pursuing analysis of air quality measurements specific to airport emissions as well as community-based monitoring of air pollutant concentrations within the airport vicinity. This fine-scale ambient monitoring of air pollutants is essential to characterize their concentration gradients particularly from the health impact analysis point of view. Consistent air quality analysis through model simulations and measurements for the same period and ambient conditions helps to guide the need for further improvements and establishes the confidence in the models and analysis that can be applied to other airports and conditions. This type of comparative analysis also helps with interpretation of results from the source attribution studies. The results from these stated air quality analysis projects directly feed into the exposure and health risk analysis specific to airport emissions that the FAA is pursuing through the Harvard School of Public Health.

Aircraft Emissions Characterization Roadmap

A recent review of updated data reveals significant new information on the behavior of pollutants, especially PM and the inclusion of hydrocarbon species, often called HAPs, which are not unique to aircraft engine emissions. Regardless, HAPs are a growing concern associated with airport development activities. The FAA is addressing this and other concerns with efforts that include measurement methodologies, database development, and analytical procedures for compilation of inventories to establish a knowledge-base that properly quantifies these emissions.

The data collected thus far seems to confirm scientific theories on the relationship among pollutants, the emissions levels, and characteristics at different engine power settings. The Society of Automotive Engineers is using this research to develop important new Aerospace Recommended Practices. These recommendations will help in selecting the proper instruments and measurement methodologies for quantifying levels of PM emitted from commercial as well as military aircraft engines. This work is nationally coordinated under the FAA- sponsored Aircraft Emissions Characterization (AEC) Roadmap. The AEC Roadmap serves as a foundation for promoting research coordination and collaboration to understand particulate matter (PM) and HAP emissions from aviation. It defines work plans to conduct needed research resulting in knowledge that can inform policy decisions. Close coordination of all aviation related HAP and PM emissions research activities is the primary goal of the AEC Roadmap to establish a sound basis for decision-making relative to domestic compliance and internationally relative to standard setting, particularly those activities being undertaken by the ICAO Committee of Aviation Environmental Protection.

Comparative Emissions Database

The FAA and the U.S. Department of Transportation's Center for Climate Change and Environmental Forecasting (CCCEF) jointly funded an effort to create a comparative emissions database. Researchers collected emissions data from a wide variety of transportation sources using multiple research-grade instruments that measured gaseous and particle emissions in a number of focused field studies. These datasets represented state-of-the-art measurements that continue to provide insights into specific transportation-related issues, such as PM formation mechanisms and chemical speciation of particulate emissions. Aerodyne compiled and compared these unique datasets from aviation, heavy-duty diesel, automobile, and marine vehicles for key emissions characteristics.

Emission indices were obtained for the following: NOx; carbon monoxide; specific hydrocarbon species; and particulate mass, number, and chemical composition. The resulting reduced data and analysis of the similarities and differences across transportation modes were included in a final report and a presentation of results to the FAA and the CCCEF. The final report focused on how the analyzed data could be added to existing emissions inventories for the respective transportation modes and used in quantifying contributions to local and regional air quality and, especially, global climate change. The work provided a foundation that will allow for more informed decisions concerning mitigation of the environmental impact of various transportation sectors in a manner that maximizes impact while minimizing cost.

PARTNER Turns Four

The PARTNER Center of Excellence, established in 2003 by the FAA, in collaboration with Transport Canada and NASA, turned four and entered its second phase in 2007. Originally comprising eight universities, the second phase PARTNER consists of lead university, Massachusetts Institute of Technology and the following members: Boise State University, Georgia Institute of Technology, Harvard University, University of North Carolina, Pennsylvania State University, Purdue University, Stanford University, University of Missouri-Rolla, and York University in Canada. With 50 advisory board members, PARTNER brings academia, industry, and government into one organization to promote and sponsor advancements that enhance mobility, economy, national security, and the environment.

One of PARTNER’s strategic growth areas is international collaboration. PARTNER has established collaboration with Omega, a group of nine universities formed in 2006 by the British government to help the aviation industry meet the environmental challenge. Through PARTNER, the FAA and the United Kingdom are working together to establish collaborative efforts on several fronts, including modeling, measurements, alternative fuels, and economic assessment. This collaboration will enable a greater ability to share knowledge, and foster a common commitment to the mutual goals of PARTNER and Omega.

PARTNER is also contributing to fostering the next generation of scientists who will tackle aviation environmental effects. The PARTNER Joseph A. Hartman Student Paper Competition is a prime example. This competition captures the best technical solutions, economic analyses, methodologies, and processes that work towards reducing aviation noise and emissions exposure through source reduction technologies, noise abatement operating procedures, compatible land use management, and airport operational control measures. At the March 2007 PARTNER Advisory Board meeting in Cincinnati, Ohio, two first place winners were honored for their accomplishment. Dr. Liling Ren, whose paper won First Place Graduate Paper Award in 2007, and Daniel Robinson, who took the First Place Graduate Paper Award in 2006, presented their work. This type of effort demonstrates PARTNER’s commitment to furthering research in sustainable aviation by all of academia.

In 2007, PARTNER was awarded the ‘Best Innovation’ in Airlines Operations Research award by the Airline Group of the International Federation of Operational Research Societies for a paper presented at the organization’s annual symposium in Rome in October 2006. The paper, “Continuous Descent Arrivals: Flight Procedures that Reduce Fuel Burn,” was based on PARTNER research. CDAs are proving to be a highly effective and efficient way to reduce emissions and mitigate aviation noise effects on local communities. Both the economic and environmental advantages of CDA offer it as a way forward in sustainable aviation and PARTNER is leading the way. The delegates to the symposium, representing airlines from around the world, believed that the paper possessed the attributes that best contribute the technical development and deployment of an original idea.

Whether it’s investigating alternative fuels, environmental impacts, noise mitigation, or aiding industry research, PARTNER remains an integral element in effecting a safer, cleaner, more viable aviation for tomorrow.

Understanding Low Frequency Noise

While the level of aviation-associated noise that individuals can tolerate seems variable and personally determined, researchers need a generic, scientifically-based metric to assess the effects of aircraft noise on humans. In its search for such a metric, the FAA funded the Partnership for AiR Transportation Noise and Emissions Reduction (PARTNER), an FAA-Transport Canada-

NASA sponsored Center of Excellence, to study low frequency noise. The resulting study encompasses factors such as noise source level and spectrum, atmospheric propagation, and the impact on homes in the form of noise, vibration, and rattle.

In 2007 researchers conducted laboratory-based psycho-acoustic testing of human subjects using noise signatures recorded indoors at Washington Dulles International Airport in 2004 for subjective assessment of annoyance. Several variations of recorded signatures were designed with different target frequency ranges using a synthesis process. The recorded signatures and their variations having different levels of low-frequency noise were reproduced in a simulator and then the subjects were asked to rate the signatures for annoyance. Subjective judgments were statistically analyzed and compared between each signature and within each signature set against commonly used objective metrics. Results show that all other things being equal, higher levels of low-frequency content in aircraft noise can result in increased annoyance in subjects and that the C-weighted sound exposure level correlated with this annoyance response.

The results of the four-year study were documented in a PARTNER report. It confirmed that levels of low-frequency noise at houses within a few thousand feet of runways can be high enough to exceed previously establish criteria. The report includes subjective evaluations to determine the numbers and types of sound characteristics that are important, how they factor into noise annoyance, and the ability of metric calculations to predict their actual physical, as distinguished from perceived, impact. It also recommends a method of assessing the potential for a given location to have a low-frequency noise problem. The report also has practical recommendations on how to avoid onset of rattle.

Mitigating Sonic Boom

In April 2005, the FAA and NASA, through PARTNER, initiated a project on Sonic Boom Mitigation research to better understand sonic boom impacts. Pennsylvania State University and Purdue University are leading the project team. The team's long-term objectives are to aid the FAA in determining the following: what noise levels or waveforms are acceptable; whether low-annoyance waveforms remain low-annoyance after propagating through atmospheric turbulence or weather; and how to design and operate small supersonic jets so the noise levels are acceptable. During the first year, researchers designed and conducted two sets of tests to compare the realism of three existing sonic boom simulators. The tests surveyed existing sonic boom simulators to compare their abilities to reproduce sonic boom sounds and began to assess human opinions of the simulated sounds. After evaluating the tests results, researchers confirmed the existing sonic boom simulators agree and compare well to the sound of real sonic booms.

In 2007, the researchers focused on low-boom subjective testing. Researchers developed a method for generating atmospheric turbulence effects into sonic boom waveforms that are needed for subjective testing. Four project industry partners supplied signatures representing predictions of low booms based on models. The predicted low booms included waveforms types and modifications: cruise booms, acceleration booms, multi-shocks, N-waves, and variations based on different relative humidity conditions. The researchers were able to produce low-boom sonic boom waveforms including turbulence of sufficient quality for subjective testing.

Researchers carried out subjective tests using low-boom sonic booms to assess annoyance in comparison to blasts and thunder. In May 2007, the researchers conducted this test using one of the existing sonic boom simulators. A comprehensive experiment used test subjects to rate annoyance or acceptability. Research to date has confirmed that existing sonic boom simulators compare well to the sound of real sonic booms; established lexicons and vocabularies for the description of low-boom sonic booms; determined the relative loudness and annoyance of low-boom sonic booms compared to other man-made and naturally occurring transient sounds; and developed preliminary improved metric(s) for the loudness and annoyance of low-boom sonic booms. This work is a critical step toward enabling supersonic aircraft.

Alternative Fuels for Aviation

Interest in alternative fuels for commercial aviation has grown in tandem with concerns about rising fuel costs, energy supply security, and the environmental effects of aviation. At the moment, the largest single driver for industry development and adoption of alternative fuels is the high cost of petroleum. High world oil prices encourage the development of alternative sources of aviation fuel. However, the possibility of disruptions in oil supplies and possible environmental benefits are also powerful drivers. Exploring the potential move to alternative aviation fuels makes sense for a variety of reasons.

The FAA, together with U.S. industry, launched the Commercial Aviation Alternative Fuels Initiative (CAAFI) to develop a national roadmap for assessing, developing and possibly adopting, alternative aviation fuels. In less than two years CAAFI has developed into a forum focusing the alternative fuel efforts of the U.S commercial aviation supply chain and enabling all of the leading aviation stakeholders to share and collect needed data and motivate and direct research and development. Early lessons from CAAFI include: the airlines are interested in the possible savings and price stability offered by alternative fuels; the fuels industry is willing to produce these fuels if there is a viable market for them; and the aviation industry may be able to use alternative fuels to deal with some local air quality and/or global climate issues. CAAFI is demonstrating that the aviation community is able to work in a coordinated fashion to attract the attention of fuel suppliers. Thus, alternative fuels efforts may offer opportunities to achieve balanced and robust strategies to mitigate aviation’s environmental impact and improve aviation economics.

Although alternative fuels may offer environmental benefits, it is important to take into account life-cycle effects when making such an assessment, including feedstock production, fuel conversion, delivery and combustion in the analysis. Initial studies show, for example, that synthetic fuel from coal, after burning in an engine and in the absence of carbon sequestration, would have produced approximately twice as much carbon dioxide than similar fuel derived from crude oil. This type of study underscores the need for development of biomass derived fuels that can offset some or all of the carbon dioxide from production and operations. It is also important to understand the environmental impacts of fuel combustion including the impacts of fuel composition on: aircraft operating capability, aircraft fuel consumption, greenhouse gas emissions, and criteria pollutants that affect local air quality around airports.

There are also reasons for caution with respect to the prospects for alternative fuels for commercial aviation. It remains to be seen what technical difficulties may be encountered even with so-called “drop in” fuels. Slight differences in fuel composition can have a significant effect on operations over time, and there is a constant need to ensure the safety of operations. Consumption of fuel by ground transport is significantly greater than aviation fuel consumption and ground transport has considerably more experience and flexibility in alternative fuel use (e.g., ethanol and liquefied natural gas). Ground-based vehicles may compete with aviation for initial application of cleaner alternative fuels. Additionally, while oil prices have risen to one hundred dollars a barrel in 2007, the risk of a drop in oil prices is real and would remove one of the major incentives for the further development of alternative fuels. Finally the emission of carbon dioxide during the production process may be a problem with some alternative fuels.

PARTNER investigators, together with industry, completed a landmark study of alternative fuels by addressing the technical feasibility, identifying the drivers for adoption, identifying the necessary ground infrastructure to support transition, and determining what measures might be needed to promote alternative fuels. The study also began the work of defining the life cycle environmental and local air quality benefits of various fuel options. The study concluded that alternative fuels now exist that could reduce greenhouse gases and improve local air quality, but at present the ability to produce these fuels is limited and the costs of production are high. Further research and development is needed to make these promising fuels a reality.

Introduction of Continuous Descent Arrival (CDA) Procedure at Los Angeles International Airport and Related Activities

A PARTNER research team, led by representatives of the Georgia Institute of Technology – with collaborating FAA, NASA, and aviation industry members – is seeing the fruits of their labor with the first publicly-charted CDA procedure going into operation at Los Angeles International Airport in December 2007. The CDA and conventional arrivals are both enhanced due to optimized aircraft separation criteria that address the broader mix of fleet traffic types.

The PARTNER team has been advancing the design, demonstration, and provisional use of CDA aircraft flight procedures within the national airspace system. CDAs provide advantages over current arrival patterns by reducing ground noise along much of the flight path, as well as saving time and fuel. The research team continues to study the development of operational procedures, including surface management concepts, where environmental benefits can be effectively incorporated.

Similarly at Louisville International Airport, further enhancements by United Parcel Service of their initially demonstrated CDA profile are being supplemented with en route speed guidance for full-mission performance efficiency and ADS-B/GPS digital flight bag avionics for pilot situational awareness that tests the ability to maintain (cockpit) self-separation.

At Atlanta Hartsfield airport, PARTNER researchers also completed CDA flight demonstrations with Delta airlines for adapting CDA for the significant use of downwind-based and final-leg traffic patterns. Environmental demonstrations applying CDA procedures at airports with some capacity margin offer the greatest potential window of opportunity.

International Aviation Interoperability for the Environment (AIRE) is on the Horizon

During the 2007 Paris Air show, the FAA and the Vice President and Transport Minister of the European Commission announced the creation of the Aviation Interoperability Initiative to Reduce Emissions (AIRE) Partnership to work closely to: (1) hasten development of operational procedures to reduce aviation's environmental footprint for all phases of flight; (2) accelerate world-wide interoperability of environmentally-friendly procedures and standards; (3) capitalize on existing technology and best practices; and (4) provide a systematic approach to ensure appropriate mitigation actions with short, medium and long-term results.

Simply put, the FAA and European authorities would seek enhanced ATM interoperability, improved energy efficiency, reduced engine emissions, and lower aircraft noise. As such, AIRE partnership objectives include taking advantage of new technologies and air traffic procedures that offer the most immediate, near-term fuel consumption and emission reduction benefits. The FAA is also moving swiftly to establish partnerships and define the plan to begin tracking AIRE progress for major operations such as oceanic, surface, and terminal/en route. The FAA is also accelerating the programming of its AEDT to support the technical demonstration projects involved in AIRE.

Human Factors Research 2007 Accomplishments

Improving the Air Traffic Controller Experience

Performance Standards: Performance standards for the ATC occupations in tower, terminal radar approach control, and en route facilities were developed as part of the workforce training initiative in response to the large turnover of air traffic controllers. The objective of this effort was to support the Air Traffic Control Optimum Training Solution (ATCOTS) procurement by developing performance standards for each controller station. This work included a thorough job/task analysis of the three controller occupations. The FAA also conducted a series of standard setting workshops with current controllers to determine the performance standards for each station, developed corresponding proficiency level descriptors for each standard, and compiled this information into a performance requirements framework. In addition to supporting ATCOTS, this work provides an update to analyses that are used in selection and training applications for all three controller stations.

Structured Interviews: A structured interview process was developed for use in examining ATC Specialist applicants. Interviews are conducted by facility managers after a centralized selection panel has made a tentative job offer. The interview is used to make a placement decision, based on past experience, and to assess candidate suitability for the job. The interview process is now operational. Follow-up will occur to determine if the process is being used properly.

Vision Test: A prototype job-related color vision test was developed for selection of controllers who will utilize color graphical displays. Applicants must fail both the standardized and job-specific color vision tests before the decision is made that they will be unable to perform the job. Initial validation of the color vision test was promising; additional validation data are currently being collected.

Life Experience: A biographical inventory called the Life Experiences Questionnaire (LEQ) was developed by human factors researchers. The purpose of the LEQ is to identify candidates who are likely to pass the Air Traffic Selection and Training (AT-SAT) battery so they can be targeted to take AT-SAT. As the cost of taking AT-SAT is about $800 per person, it is cost-prohibitive to allow all who expresses interest to take the test. Prior to implementation of the LEQ, candidates were randomly selected to take AT-SAT, so use of the LEQ improved the selection process.

Improving Pilot Performance

Pilot Visual Approaches: Because of the current pilot shortage, air carriers are faced with training low-time pilots for jet operations. This raises the potential for safety vulnerability in operations, an issue that was raised by regional airlines. In response to these concerns, FAA researchers developed training and assessment strategies to assure effective performance on visual approaches in aircraft with this pilot population. The results of this study will be applicable industry-wide. Researchers also collected preliminary data from instructor and evaluator line check airmen to determine the current state of training and what methods work and don't work. Research continues to develop new training and assessment methods.

Pilot Automation Training: In an attempt to validate the FAA's programmatic approach to air carrier automation training, human factors researchers met with all major air carrier training organizations to collect data on their views of the current state of automation training problems. FAA researchers have developed a survey that will be administered to all training managers and flight operations managers in early FY 2008. The data will allow human factors researchers to address the most important automation issues from an industry perspective. This will be accomplished through research or training design, whichever is deemed appropriate.

Color Vision Requirements for Pilots: Researchers collected altitude chamber data to assess the effects of mild hypoxia on color vision and performance among normal and color deficient individuals. The research team is also examining differences in gene expression under hypoxic conditions. A cognitive test battery was developed to assess changes in performance at ground level and at altitude.

General Aviation Pilot Aging: Human factors researchers are collaborating with industry on proposals to research the effects of aging among general aviation pilots. To date, participants have discussed the relative merits of each proposed approach, broader limitations of both proposals, and alternatives that might advance the existing literature to produce more definitive research.

Enhancing Safety

Safety Culture: A partnership between the FAA and St. Louis University is changing the safety culture of the FAA maintenance workforce. The objective of the project is to improve the technical operations safety culture. The initial mechanism that has been introduced is a voluntary reporting system modeled after the Aviation Safety Action Program that has been highly successful among pilots and aircraft maintainers.

Electronic Flight Bags (EFBs): Human factors researchers provided input to operational approval and training guidance (including input to Advisory Circulars) to mitigate risks associated with the implementation and integration of EFBs on the flight deck. Researchers also prepared an updated review of the EFB industry. In addition, they collected safety reports related to EFBs operating in approved systems to identify issues and concerns and make recommendations for improvements.

Notice to Airmen: Safety issues surrounding the use of Notice to Airmen (NOTAMS) became a top priority in FY 2007. Human factors researchers formed and led industry working groups to discuss the human factors shortcomings of NOTAMS and the safety impact on air carrier operations. As a result of this work, previous research on NOTAMS, and recent findings of the NTSB concerning NOTAMS, the FAA is currently investigating and implementing improvements to the NOTAMS system. Research continues through working groups and data sharing meetings and by involvement in the redesign process for NOTAMS. Researchers will work to assure that the NOTAMS redesign efforts conform to appropriate human factors standards.

Human Factors Analysis

The Human Factors Analysis and Classification System (HFACS) is a system to categorize both the latent and immediate causal factors that have been identified in aviation accidents. The purpose is to provide a framework for use in aviation accident investigations and a tool for assessing accident trends. The final download of NTSB data was accomplished in January 2007, which will eventually yield a coded database of accidents from 1990 to 2006. Data analysis of HFACS data for accidents with visual flight rules (VFR) into instrument meteorological conditions (IMC) as a factor and for general aviation accidents without VFR into IMC as a factor was completed. The overall descriptive characteristics for each accident group and the human error associated with these accidents were both completed. Detailed analyses were performed on the general aviation VFR into IMC accidents.

Visual Flight Rules/Instrument Meteorological Accidents (VFR/IMC)

Human factors researchers collected data from over 200 pilots, mechanics, corporate aviation executives, and Transport Canada representatives participating in focus groups regarding interventions aimed at reducing VFR-IMC accidents. A final list of over 150 unique interventions was generated. The list was given to five general aviation subject matter experts and two human factors experts for prioritization on four dimensions: effectiveness, feasibility, acceptability, and cost. Data are currently being analyzed and a final report was submitted at the end of FY 2007.

Rudder Survey

The FAA designed a Lateral Control Events Survey (Rudder Survey) to investigate issues involved in transport airplanes and “upset” (defined by the survey as an airplane motion that a pilot believed required immediate corrective action). The survey also explored rudder pedal characteristics including pedal control, over control, cross control, sensitivity (e.g., pedal binding, unexpected control stop, heavy or light pedal forces), pedal usage and yaw/roll conditions. In addition, training, experience, knowledge of rudder, and maneuver speed were assessed. Researchers are now working to gain a better understanding of lateral control events and other rudder issues in transport airplanes. The ultimate objective of this study is to develop a knowledge base from which certain characteristics of transport category airplanes can be better understood. These characteristics include pilot and mechanical issues in upset conditions, as well as issues associated with rudder operation.

Terrain Awareness

Research on Terrain Awareness and Warning System (TAWS) feasibility for helicopter operations began in FY 2007. The team prepared profiles and measurements in fixed-wing aircraft, and collaborated with university researchers in developing profiles for simulator testing in the FAA’s helicopter simulation facility. The TAWS software was updated to incorporate displays and alerting for current fixed wing and helicopter applications. Researchers also developed profiles that allow surprise alerts, rather than planned alerts. This is evolving into a broader evaluation effort as a result of the Radio Technical Commission for Aeronautics (RTCA) Special Committee 212’s need for reaction time data to set length of time of alerting systems for helicopters.

Safety Alerts

Air Traffic Controllers receive several types of alerts that warn of potentially hazardous situations, including Conflict Alerts (CAs), Mode-C Intruder (MCI) alerts, and Minimum Safe Altitude Warnings (MSAWs). These alerts are presented visually on the radar display, and in some environments, there is a corresponding audible alert. In response to several recent incidents in which controllers may not have responded properly to alerts, researchers visited several ATC facilities, observing safety alerts during live operations, interviewing personnel about their experiences using alerts, and reviewing data and voice recordings. They also examined automation data and voice recording. Controller responses to alerts, such as issuing traffic advisories and control instructions, were analyzed when those responses occurred relative to alert activation.

Results show that 62 percent of the CAs examined and 91 percent of the MSAWs examined in en route received no response from controllers. Similarly, 44 percent of the CAs examined and 61 percent of the MSAWs examined in terminal received no response from controllers. However, in none of these cases did an operational error or deviation occur. When controllers did respond to conflict situations, they made the response prior to the alert 67 percent of the time. For MSAW situations, controllers made the response prior to the MSAW 68 percent of the time. Furthermore, 31 percent of the CAs examined in en route and 36 percent in terminal lasted such a short time that controllers must have resolved the situation prior to the alert or the situation resolved itself without action. These results led researchers to estimate that 81 to 87 percent of CAs and 87 to 97 percent of MSAWs are nuisance alerts or unnecessary, in that the alerts are valid according to the algorithms, but do not provide useful information to the controllers.

A large number of nuisance alerts can create serious human factors problems. By design, alerts cause controllers to interrupt their current tasks and focus attention on the aircraft involved. When these interruptions are frequent and unnecessary, controller workload is increased and overall performance may be reduced. In addition, a large number of nuisance alerts can desensitize controllers to the alerts overall, which may lead to poorer responses to genuine alerts. Furthermore, a large number of nuisance alerts can reduce controller trust in automation.

The research team recommends that the FAA make reducing nuisance alerts a top priority. One potential method for reducing nuisance alerts is to provide more sophisticated alert suppression functions. For example, alert suppression can act like a “snooze” function, in which a suppressed alert automatically reactivates when additional criteria are met. A second potential method is to base the alert algorithm parameters (such as the look-ahead time) on human factors data, such as how quickly controllers can identify and resolve hazardous situations. A potential method for reducing the impact of nuisance alerts is to provide graded alerts in which the alert presentation becomes increasingly obvious as the situation becomes more urgent. If the ATC alerts are improved according to these recommendations, controller performance will increase and the NAS will become safer.

Future En Route Workstation (FEWS) Research

As traffic increases in the NAS, so do delays. Some ATC bottlenecks are due to limitations of the voice communications system (controllers can only issue clearances to a limited number of aircraft per unit of time), associated data entries into the automation system, and limits on the number of aircraft the controller can effectively monitor. In FY 2007, human factors researchers completed a simulation testing of the Future En route Workstation (FEWS). The research determined whether FEWS would enable air traffic controllers to safely manage a larger number of aircraft in the same volume of airspace. FEWS was designed on the principles of integrating currently-independent automation tools, providing information when and where it is needed, and reducing the number of housekeeping tasks that controllers currently perform, thus freeing resources to focus on critical tasks of sequencing and separating aircraft.

The high fidelity, human-in-the-loop simulation compared system performance, controller workload, and situation awareness using the current Display System Replacement (DSR) workstation, the next-generation En Route Automation Modernization (ERAM) workstation, and FEWS. Some of the simulations were conducted with voice communications only and others with voice plus data communications. Simulations were used to test one- versus two-controller operations in the sector and differences in the radar associate display.

Results indicate that two controllers using FEWS and having data communications can safely and efficiently manage approximately 30 percent more traffic than a single controller with DSR and only voice communications. The FEWS interface reduced (by approximately 50 percent) the number of data entries that controllers must make with either DSR or ERAM. Researchers found that FEWS design features (e.g., automatic handoff acceptance, automatic data-block drop-off, preferred leader line orientations, data-block dragging) can be readily incorporated in the near-term. The research team is beginning work on a follow-on simulation that will include airborne capabilities envisioned in the NextGen (e.g., pilot self-spacing) and ways to reduce the number of objects controllers need to actively monitor on the radar screen.

Certification Job Aid for Flight Deck Human Factors

Certification Job Aid was developed to provide quick and easy access to regulatory and human factors information that may be used by certification personnel for identifying and addressing human factors considerations in flight deck design. The current version of Job Aid provides information addressing all human factors considerations related to the design of displays, controls, and systems in the flight deck for large transport category aircraft. Version 8.0, with completed content for Parts 23 and 25, was delivered in September 2007. Additional content includes human factors considerations for equipment, tasks and procedures; and testing assumptions. The set of human factors considerations will provide a comprehensive way to address human factors in any certification project, provide a more even approach to certification, and reduce the time required for certification.

Job Aid has been structured to allow certification team members to access information from one of three paths: FAA regulations and guidance material; information related to a specific component; and specific human factors topics. When users selects a particular regulatory or guidance document, component, or human factors topic, they will be provided with a list of related human factors considerations. This list provides a systematic method of evaluating design, and can serve as a general checklist during a certification task.

Separate sets of human factors considerations have been developed related to display design; control design; system design; equipment, tasks and procedures; and testing assumptions. The human factors considerations address the design issues of the component in isolation as well as design issues related to the integration of this component within the full flight deck environment. The tool provides summaries of regulatory and guidance material as well as human factors research literature for each human factors consideration.

Pilot Simulator Training

A shortage of qualified airline pilots represents a threat to passenger safety world-wide. Newly-hired pilots arrive with limited and diverse backgrounds. Combined with an increase in complexity of both the flight deck and the airspace due to automaton and congestion, differences in pilot experience represent a real challenge to airline pilot training. To meet this challenge, access to high-quality simulators is critical. The key issue in making simulation more available is the cost of acquiring and maintaining full-motion simulators and the equivalent training effectiveness of those simulators versus other training devices. Previous studies by human factors researchers found that, in the presence of a visual system that generates the perception of motion, the current mandatory platform-motion systems may not add any training value. Such systems nearly double the price of simulator rentals, raising not only acquisition costs but also the cost of housing, electricity and maintenance. In FY 2007, human factors researchers were invited to participate in a study employing a Full Flight Trainer (FFT) – a fixed base training device with the highest fidelity flight data package and visual system, but limited motion cues provided by a dynamic seat. Researchers assisted with a proof-of-concept validation of the FFT. Data showed that the FFT represented the airplane well and that there were no problems transitioning to the airplane. Type-rating of additional pilots served as a test bed for data collection for a more formal evaluation of the FFT's training value. One of the purposes of these studies was to validate the FFT for type rating. In FY 2008, a comparison study will be conducted. The evaluation will compare pilots trained in the FFT to pilots trained in the full flight simulator. This study will compare the training effectiveness of the FFT to the training effectiveness of the full slight simulator. It is hoped that the outcome of this and the previous studies will be considered in the determination of future U.S. and international regulations on whether alternatives to platform motion can be accepted for at least some aspects of airline pilot training. This will permit a reallocation of resources to those aspects of flight simulation that may have the largest impact on safety, such as accurate simulation of flight-deck technologies and the airline environment, including ATC communications.

Joint Planning and Development Office (JPDO) 2007 Accomplishments

NextGen Concept of Operations

The JPDO completed and issued the draft *NextGen Concept of Operations*. It provides an overall, integrated view of NextGen operations in the 2025 time frame, including the key transformations from today's operations. Version 2.0, issued June 13, 2007, identifies key policy and research issues that require resolution to achieve NextGen.

NextGen R&D Plan

The first NextGen *Research and Development Plan,* FY-2009- FY- 2013 was issued. Version 5.0 of the Plan (August 31, 2007) details the R&D requirements for NextGen operational improvements, and identifies the R&D responsibilities and contributions of each JPDO member agency.

NextGen Integrated Work Plan

Version 0.1 of the *Integrated Work Plan* was issued. The Plan describes the major implementation milestones, dependencies, responsibilities, and resources needed to achieve the end-state vision described in the *Concept of Operations*. Version 0.2 of the Plan was issued in October 2007.

NextGen Enterprise Architecture

On June 22, 2007 version 2.0 of the Enterprise Architecture was issued. The Enterprise Architecture provides traceability from the NextGen goals to the underlying technology needed to optimize performance. It compares the current state to the desired end-state to identify a transition path to NextGen, and it defines how operations, investments, policies, processes, organizational structures, information, and systems must change to achieve Next Gen.

JPDO Restructuring

The JPDO realigned its original eight Integrated Product Teams into nine Working Groups. These are: Aircraft, Air Navigation Services, Airport, Environment, Global Harmonization, Safety, Security, Net-Centric Operations, and Weather.

Next Gen Business Case

The NextGen Business Case (Exhibit 300) was completed and submitted to the President's Office of Management and Budget. The Business Case establishes the business justification for investment into the Next Gen programs and capabilities.

4D Weather Cube Requirements

A Joint Weather Study Team was established to define common functional four-dimensional (4D) weather cube requirements, evolve baseline requirements, and refine the 4D weather cube cost-benefit analysis. The Study Team will complete its work and submit a final report by January 2008.

Research, Engineering, and Development Advisory Committee (REDAC) 2007 Accomplishments

Reports

During 2007, the Research, Engineering, and Development Advisory Committee produced three reports: *Guidance for FAA Fiscal Year 2009 R&D,* November 13, 2006; *Separation Standards Working Group Final Report*, October 16, 2007 (FAA Response, May 14, 2007); and *Review of FAA Fiscal Year 2009 Program Plans,* June 12, 2007 (FAA response, August 20, 2007).

Separation Standards Working Group

The REDAC Working Group on Separation Standards completed its report, which was submitted to the FAA Administrator on October 16, 2006. The Working Group carefully examined all the issues related to separation standards in the current NAS and the future NextGen. The report recommended major R&D efforts to transform separation standards to meet demands expected over the next two decades. The FAA is implementing those recommendations within its NARP and its OEP.

Weather - Air Traffic Management Integration Working Group

In 2007, the Committee created the Weather-Air Traffic Management Integration Working Group to study the potential benefits associated with a higher degree of integration between two dissimilar and fundamentally inexact sciences, namely weather and air traffic management. The Working Group will provide specific research recommendations to the FAA that are considered most likely to lead to better, more efficient ATM solutions, in the face of weather constraints. The report is expected early in FY 2008.