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FY 2013
R&D Annual Review

August 2015

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FY 2013 R&D Annual Review
August 2015

The *R&D Annual Review* is a companion document to the *National Aviation Research Plan* (NARP), a report of the Federal Aviation Administration to the United States Congress pursuant to Section 44501(c)(3) of Title 49 of the United States Code. The *R&D Annual Review* is available on the Internet at http://www.faa.gov/go/narp.

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Introduction

The Federal Aviation Administration (FAA) research and development (R&D) mission is to 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. It supports a range of research activities from materials and aeromedical research to the development of new products, services, and procedures.

The FAA R&D portfolio supports both the day-to-day operations of the National Airspace System (NAS) and the development of the Next Generation Air Transportation System (NextGen). To achieve balance between the near-, mid-, and far-term, the FAA has defined three R&D principles to focus and integrate its programs. The R&D principles help the FAA align, plan, and evaluate its R&D portfolio. The R&D principles include the following:

- **Improve Aviation Safety –** systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve aviation and space safety and achieve the lowest possible accident rate.

- **Improve Efficiency –** systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve access to and increase capacity and efficiency of the nation's aviation system.

- **Reduce Environmental Impacts –** systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will reduce aviation's environmental and energy impacts to a level that does not constrain growth.

The *R&D Annual Review* highlights the significant R&D accomplishments of the FAA and serves as a companion to the FAA *National Aviation Research Plan* (NARP). The significant accomplishments are organized by the three R&D principles described in Chapters 1 through 3 of the NARP.

R&D Principle 1 – Improve Aviation Safety

Systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve aviation and space safety and achieve the lowest possible accident rate.

Impact Damage to Composite Aircraft Structures:

FAA research is aimed at understanding the ability of computer modeling to simulate damage to composite aircraft structures when subjected to blunt impact loads by ground service equipment. In 2013, the project completed physical testing of two large-scale panels subjected to controlled blunt impacts to better understand the predictive capabilities of the simulation models. Although researchers compared the model's results to actual events, additional effort is necessary to understand the difference between the controlled impact and actual vehicle impacts.

Ground-service equipment contact is the major source of significant damage to existing (metal) commercial aircraft and researchers expect it will be a major source of damage to the new generation of composite aircraft. The overall model development strategy involves a ground-up foundational approach, where physical-based models are developed on smaller-sized structural elements.

Accurate simulations of the separate components, for example, a skin-to-frame bracket (called shear tie) (Figure 1), is a necessary first step to predicting global structure behavior. An example of a large-scale structure model (Figure 2) predicts the damage developed to the internal structure of a composite aircraft fuselage side when it is subject to severe contact by ground equipment. The shear tie model plays a critical role in the accuracy of the predictions of the fuselage side-impact model. Such simulation capability, when established based on accurate physics-capturing foundation, is then applicable to explore many other configurations, which have not yet undergone experimental investigation. Model capability establishment and the application of these models to understanding blunt impact damage formation on new configurations is presently ongoing work performed with the University of California, San Diego (UCSD) through the FAA Joint Advanced Materials and Structures (JAMS) Center of Excellence (COE). (Advanced Materials/Structural Safety)

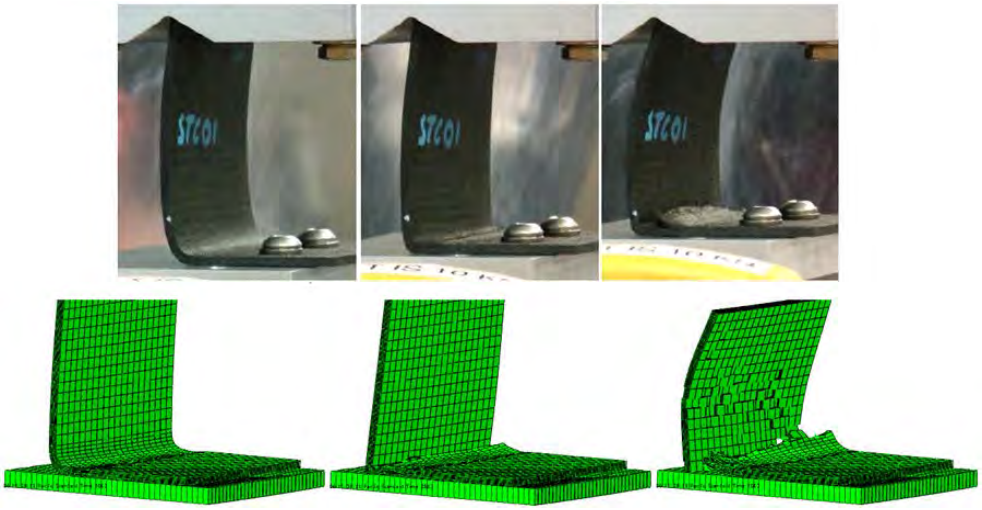


Figure 1: Establishing accurate physics-based models of basic structural elements, e.g., shear tie L-shaped bracket connecting aircraft skin to internal frames

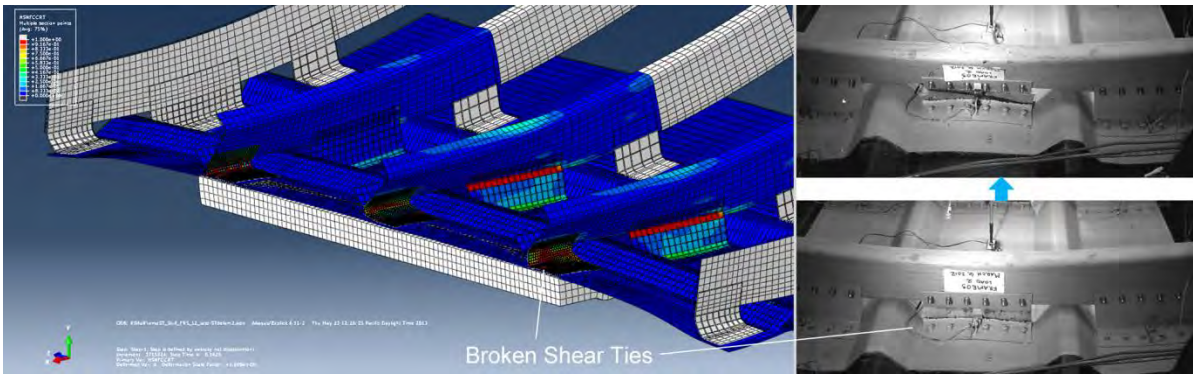


Figure 2: Application of element models into full-scale structural models to simulation scenarios of blunt impact damage produced from ground service equipment

Development of Test Method for Environmental Durability of Bonded Joints:

The FAA is developing guidance to assess the durability of bonded structures in aviation applications. In FY 2013, the FAA investigated the limitations of the standardized test used for adhesive bond durability. This test, the American Society for Testing and Materials (ASTM) International's ASTM D 3762, "Standard Test Method for Adhesive-Bonded Surface Durability of Aluminum (Wedge Test)" determines variations in adhered surface preparation and adhesive environmental durability for metal to metal bonds. The test method has been in existence for many years and the ASTM standard is common in many industries.

The guidance in the standard was not adequate for use in critical aircraft structures as identified by several industry experts. The FAA began an investigation of the sensitivities of ASTM D 3762 to develop changes to the standard and additional guidance needed to ensure a level of reliability suitable for critical aircraft applications. The research focused on providing detailed information on the standard test.

The areas addressed include the following:

- Editorial revisions (e.g., clarification of geometry, correction of procedure problems, and improvement of figures)
- Specimen preparation (e.g., controlling bondline thickness and machining specimens from panel)
- Testing procedure (e.g., method of wedge insertion, measurement of initial crack length, specimen orientation during testing, specification of test environment)
- Interpretation of results (e.g., role of initial crack length, role of crack growth, and role of failure mode in test area)

The FAA submitted the results of the investigation to ASTM to be included in the standard. In addition, the FAA is in the process of issuing detailed guidance for the ASTM test method in a FAA Technical Report. The University of Utah (UU), through the FAA Joint Advanced Materials and Structures (JAMS) COE, participated in the bond durability test method research. (Advanced Materials/Structural Safety)

Repair of Bonded Composite Structures at Depots:

The FAA is assessing the variability of repair processes between different depots with technicians having varying experience and training levels. Questions remained on the variability of repairs done at four depots 10 years ago. The research evaluated existing original equipment manufacturer (OEM) and Society of Automotive Engineers (SAE) Commercial Aircraft Composite Repair Committee (CACRC) standards and materials for repair of composite airframe structures.

The program consisted of manufacturing standard composite sandwich elements representative of composite aircraft production parts. The fabrication used OEM materials and processes (Figure 3) and then depot technicians made repairs on the elements using field methods and materials. Researchers provided the same repair procedure to all depots along with kits with the required repair materials. Depot technicians performed the repairs at the participating depots using CACRC standard repair process (Figure 4). Depot technicians then documented the entire repair process on worksheets. The researchers surveyed depot technicians on their perceptions of the CACRC standards and to identify any concerns. The FAA will conduct static, fatigue, and residual strength tests to assess repair performance.

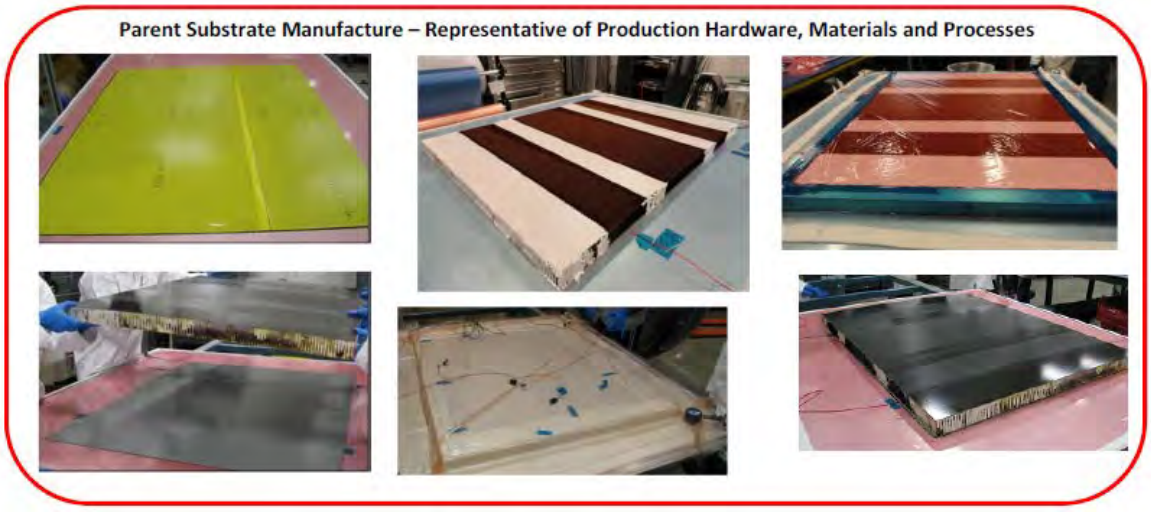


Figure 3: Parent substrate manufacture

These tests assess the ability of depot personnel to perform technical repair operations. The next step in the research will be to assess the capability of the depots to perform the repairs without a standard set of instructions, thus determining possible vulnerabilities in their ability to complete a repair without outside assistance. This research will provide Aviation Safety Inspectors and Certification Engineers with part of the data required to determine whether a facility's proposed procedure is capable of producing safe and effective repairs to composite structures. The Wichita State University (WSU) conducted this research through the FAA Joint Advanced Materials and Structures (JAMS) COE. The results of the repair fabrication have already been provided internally to the FAA's Aviation Safety group for their reference and use. (Advanced Materials/Structural Safety)

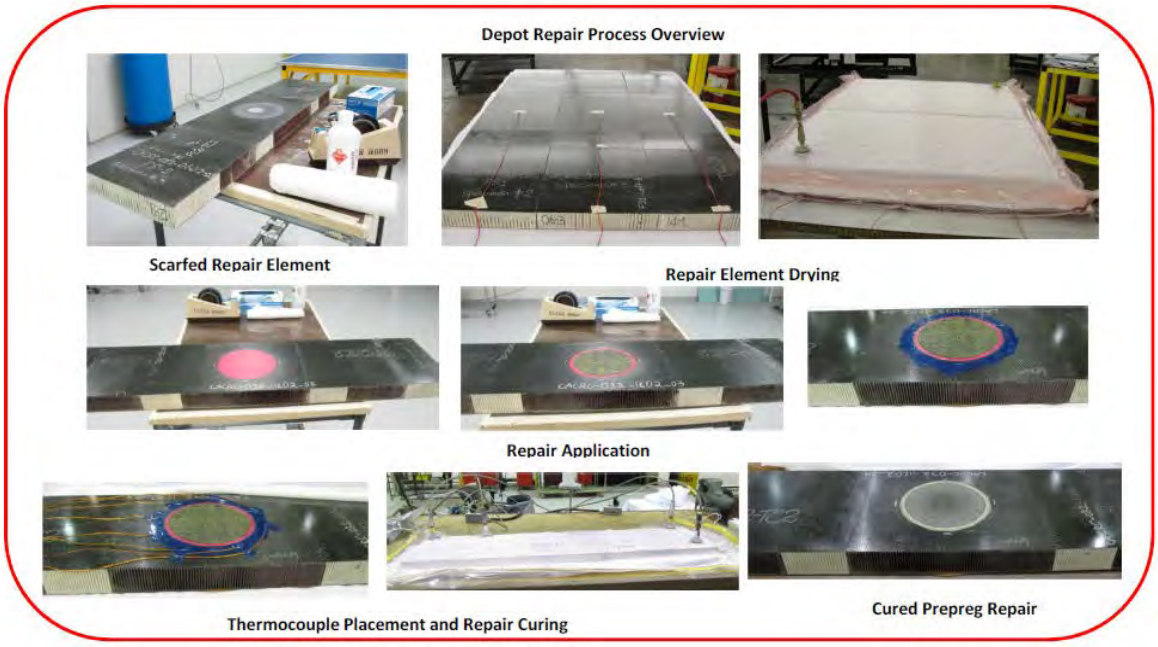


Figure 4: Overview of the Depot Repair using CACRC Standard Repair

Composite Materials Handbook 17 Issues Revisions and Starts CMC Work:

Composites Materials Handbook (CMH-17) released an updated Metal Matrix Composites,Vol. 4, as well as a completely new Sandwich Structures, Vol. 6 in FY 2013. This update has provided a substantial increase in the information available on developing composite structures and material property data for design assistance and manufacturing aid. The FAA has used this handbook as a repository for the results of its research conducted in the area of composite structures. The successful delivery of these volumes followed the release in 2012 of Guidelines for Characterization of Structural Materials, Vol. 1; Materials Properties, Vol. 2; and Materials Usage, Design, and Analysis, Vol. 3. These volumes were last updated in 2002 and the FAA incorporated many important advances into the 2013 release, revised volumes shown below.

In FY 2013, the FAA Office of Environment and Energy (OEE) joined the Office of Aviation Safety (AVS) in sponsorship of the handbook to develop information critical to the manufacture of Ceramic Matrix Composites (CMC) for aircraft applications. The FAA envisions these materials as replacements for high temperature metals in hot sections of turbine engines. The use of these materials will allow higher operating temperatures, which will increase efficiency and reduce weight. Ceramic Matrix Composites, Vol. 5, originally released in 2002, is currently out of date. The OEE's sponsorship has reinvigorated participation in the coordination group and a revised volume is now planned by the end of 2015. This revision will provide information on testing, design, and manufacturing as well as basic material property data for use in developing ceramic structural products. This volume will deal with export-controlled information and special consideration given to assure the volume is available to the largest audience possible.

The FAA has acted as primary sponsor and steward of the Composites Materials Handbook 17 (CMH-17) since 2005 when the Handbook name was changed (it was formerly MIL-HDBK-17). The Composite Materials Handbook organization creates, publishes, and maintains proven, reliable engineering information and standards, subjected to thorough technical review, to support the development and use of composite materials and structures. The Composite Materials Handbook strives to be the authoritative worldwide focal point for technical information on composite materials and structures for aircraft applications. (Advanced Materials/Structural Safety)

Composite Structures Training Requirements Established:

The FAA began developing a core-training program for composite structures because of the rapid development of composite aircraft. The concern is mainly for the quickly changing environment for the typical aviation worker who will have to deal this new technology. Researchers divided the training program into three tiers. The first tier provides a familiarization with the basics of the technology. The second tier covers three major aspects: (1) maintenance and inspection; (2) structural engineering; and (3) manufacturing. The final tier includes advanced topics that would become areas of specialization. The FAA defined the content of the courses on the first and second tiers, which created standard course content for these levels; the third tier training development will the responsibility of the industry.

The FAA previously developed the first two elements of the second-tier: Composite Maintenance Training (CMT) and Composite Structural Engineering Training (CSET) awareness course requirements. In FY 2013, the FAA completed the third and final element, the Composite Manufacturing Technology (CMfgT) awareness course requirements. The FAA developed the content for the awareness course using information provided by academia, industry, and FAA research. The training requirements include instructional course material as well as a practical workshop. The target audience of this course includes FAA MIDO inspectors participating in the certification of composite structures and FAA designees responsible for approval of manufacturing details of composite structures.

The FAA uses the CMT course for Aviation Safety Inspector training. The CSET course, intended for designers and corrective action personnel, has been offered twice and was modified to reflect participant and instructor feedback. The CSET course is the basis for an FAA training course required for FAA personnel dealing with certification of composite structure. These courses provide the basic information for dealing with newly introduced composite structures on civil aircraft and provide an effective means to increase the safety of these products. (Advanced Materials/Structural Safety)

Chemical Kinetic Models for Bleed Air Systems:

Most environmental control systems on commercial airliners receive fresh outside air from the bleed air systems of the compressors of the jet engines or from the auxiliary power units. Although outside air is clean and sterile during cruise conditions at flight altitudes, spurious air contamination events have been reported. Contamination can occur in the bleed air supplies during ground operations by de-icing fluids entering the bleed air supply. Contamination in the bleed air supply can also be dye to hydraulic fluids and engine oil from worn mechanical seals. This project evaluated the applicability of commercial air quality sensing technologies to provide the following:

1. Accurate, reliable, in-flight detection of bleed air contamination incidents
2. Real-time determination of root causes of air contamination incidents to facilitate corrective or adaptive action in-flight
3. Pre-incident detection and reporting to enable preventative maintenance

4. Post-incident reporting and assessment of recorded information to enable appropriate corrective maintenance actions

Non-dispersive infrared (NDIR) technology and electrochemical sensors are widely used in commercial applications to sensing carbon dioxide (CO_2) and carbon monoxide (CO), respectively. Both methods offer considerable promise for aircraft measurements of these same gaseous contaminants. However, existing sensor packaging and maintenance and calibration methods must be adapted to the distinctive environment and more stringent performance requirements anticipated for aircraft. In addition, research into the response times of the sensors is critical to ensure quick and reliable detection of transient bleed air events. The FAA submitted a final report for the project during FY 2013. (Aeromedical Research)

Cannabinoids in Fatally Injured Pilots Involved in Aviation Accidents:

This project evaluated the prevalence of marijuana use in pilots who died in aviation accidents. The FAA evaluated concentrations of the psychoactive ingredient of marijuana, Δ9-tetrahydrocannabinol (THC), and its major metabolite, 11-nor-9-carboxy-THC (THCCOOH), to characterize the distribution of these components in postmortem fluids and tissues (Cardona, P. S., Chaturvedi, A. K., Kemp, P. M., and Soper, J. W. *Distribution of Δ9-Tetrahydrocannabinol and 11-nor-9-carboxy-Δ9-Tetrahydrocannabinol in Postmortem Biological Fluids and Tissues from Pilots Fatally Injured in Aviation Accidents*. Office of Aerospace Medicine report No. DOT/FAA/AM-13/24). (Aeromedical Research)

Hypoxia, Time of Useful Consciousness:

Researchers conducted the study protocol to establish times of useful consciousness (TUC) for aviators exposed to high altitude, rapid decompressions using new physiological monitoring technology (Figure 5). Researchers will use data from this study to update FAA Circular 61-107(B) regarding operations of aircraft at altitudes above 25,000 feet. (Burian, D., Mandella, J.G., and Self, D. A., *Physiological Determinants of Human Acute Hypoxia Tolerance.* Proceedings of the Aerospace Medical Association. *Aviat Space Env Med 2013;84*(4):324[157].) (Aeromedical Research)

Figure 5: New monitoring technologies used to obtain physiologic variables to evaluate TUC at high altitudes.

Aerospace Accident/Injury and Autopsy Data System (AA-IADS):

Researchers developed and implemented the Aerospace Accident/Injury and Autopsy Data System (AA-IADS) (Figure 6) to provide injury description and injury mechanisms analysis to support the development of prevention and mitigation strategies. This tool is used by aeromedical research personnel to review the medical aspects of aviation accidents, particuarly airmen certification records and the results of autopsy and forensic toxicology tests in support of accident investigation personnel (FAA and NTSB), education practices, and medical certification decision-making processes. On April 12, 2013, AA-IADS transitioned from development into production. (Aeromedical Research)

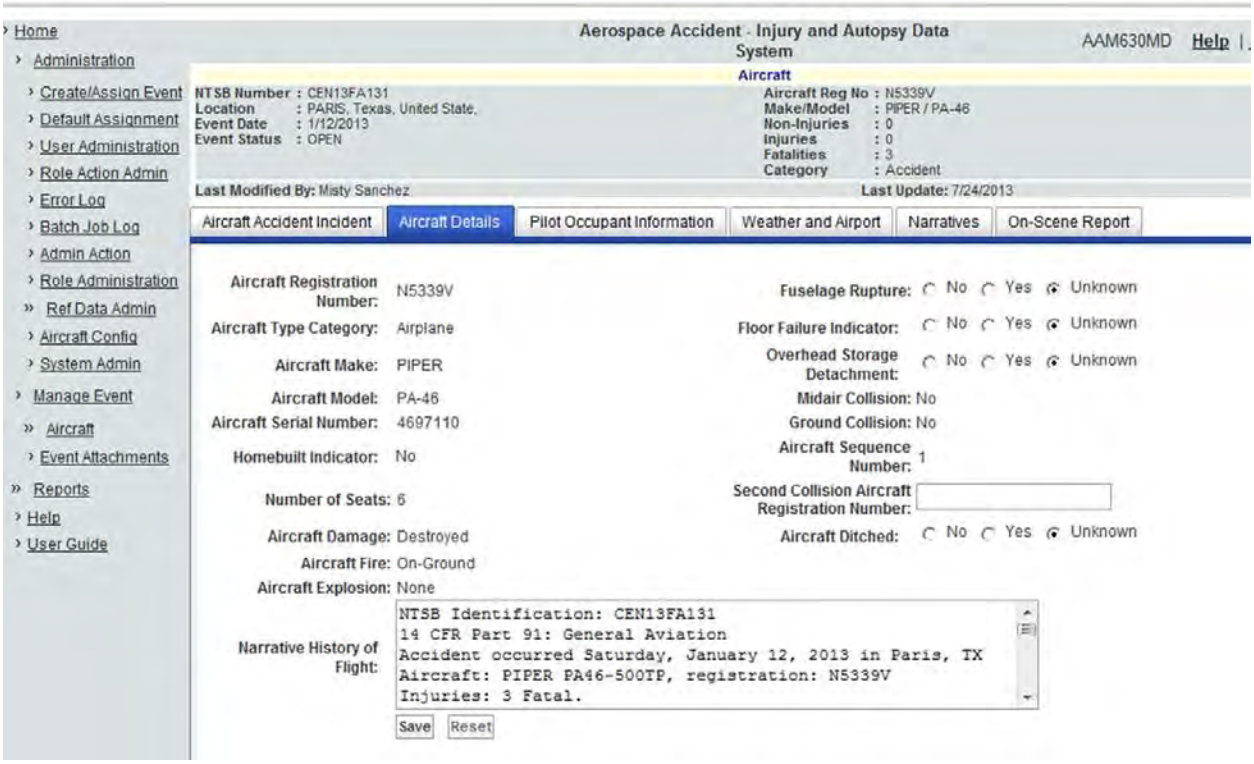


Figure 6: Sample screen shot of AA-IADS showing data collected

Inflatable Emergency Equipment:

The FAA has established testing requirements and minimum performance standards that life preservers used on commercial aircraft must meet. In FY 2013, researchers at the FAA Civil Aerospace Medical Institute (CAMI) evaluated individual inflatable life preserver donning tests to support the FAA response to National Transportation Safety Board (NTSB) Recommendation A-10-85: Revise the life vest performance standards contained in Technical Standard Order-C13f to ensure they result in a life vest that passengers can quickly and correctly don. The Cabin Safety Provisions Technical Committee, S-9, is also conducting this study in support of the potential revision of SAE International Aerospace Standard (AS) 1354, Individual Inflatable Life Preservers. (Aeromedical Research)

Advanced Analysis and Analytical Methods for Rotor Burst and Blade Release:

During FY 2013, the Aircraft Catastrophic Failure Prevention Program continued work on advanced analysis and analytical methods for rotor burst and blade release. The research was divided into four tasks that were performed by The George Washington University (GWU), The Ohio State University (OSU), Arizona State University, Central Connecticut University, National Aeronautics and Space Administration (NASA) Glenn Research Center, Naval Air Warfare Center (NAWC) China Lake, and the Aerospace Users Group of LS-DYNA. The aerospace industry is driving the research focus on LS-DYNA, with Livermore Software

Technology Corporation (LSTC) as a partner providing resources for the effort. The research is developing predictive metal failure models for impact conditions experienced when engine fragments impact either engine containment structures, or in rare cases when uncontained fragments impact the fuselage structure. In a parallel effort, the FAA also maintains and improves the Uncontained Engine Debris Damage Assessment Model (UEDDAM), which was developed under an interagency agreement with the NAWC to assess the multiple fragment threat from an uncontained engine failure at the aircraft level and provide a means to assess the merits of different aircraft designs for vulnerability reduction.

The first task related to predictive metal failure modeling was to complete documentation of a three-part report covering the following:

1. Background of the need for MAT224;
2. Theoretical development of the model, with a detailed explanation of how to turn experimental test data into the tabulated input for aluminum 2024 material; and
3. Experimental test program to develop data for the various failure conditions that create the predictive tabulated failure surface.

The FAA completed the draft report in FY 2013.

MAT224 is a von Mises-based damage and failure model, fully implemented into LSTC explicit finite element (FE) code LS-DYNA. In von Mises' theory, the yield in tension is equal to the yield in compression, and the theory only uses one yield value. In cases where the one yield dominates across failure cases, the model provides excellent correlation to test results. Predictions for aluminum 2024 are promising.

The second task in 2013 was to expand MAT224 to include a generic yield surface option. This creates a computational burden on the code as the algorithm is significantly more complicated, but in order to provide predictive results for metals like titanium, where the yield in tension and compression are different, the adding computation time to achieve a predictive result is an excellent investment. Researchers developed a model and are currently testing a beta version of the code. The model leverages the work of Drucker-Prager and Cazacu-Barlat. These two efforts extended von Mises with a linear relation of the three yield stresses: tension, compression, and shear. MAT224-GYS encompasses these linear relations with an area to expand the ratios of the three stress values into an area defined by the LODE parameters of –1, 0, and 1, which builds the most flexibility possible into the new model. Initial results are promising, showing improved accuracy over von Mises for materials and failures where these conditions exist.

The third task is working with the LS-DYNA Aerospace Users Group to develop guidelines and sample problems that advance the toolset available for aircraft certification to evaluate certification by analysis for fan blade off testing. This year, researchers officially published the Aerospace Guidelines on the user group website with new material models added to the quality assurance problem set. The QA set is necessary to ensure new releases of LS-DYNA produce the same results as previous versions for specific problems of interest to the aerospace community. The FAA and NASA established the group a decade ago, and it has grown to 16 member organizations across industry, academia, and government.

The final task is the UEDDAM. This vulnerability analysis tool was developed to support the Aviation Rulemaking Advisory Committee in the new multiple fragment rule for 14 CFR 25.903 (d) 1. In 2013, a training class took place for certification engineers, which produced a revision to the code and provided a release for the Linux operating system.

In addition to planned tasks, the Transport Airplane Directorate requested support for the Open Rotor Turbine Engine design and sought ideas to mitigate the vulnerability created after removing fan containment. The program coordinated work with our partners at NASA Glenn and Naval Air Warfare Center (NAWC) China Lake to use UEDDAM and LS-DYNA to study the impact of adding fuselage protection to mitigate the consequences of a released open rotor fan blade. (Aircraft Catastrophic Failure Prevention Program)

Development of a New Material Model for Certification by Analysis:

In 2013, the FAA completed the new predictive material model for metal impact and failure. DOT/FAA/TC-13/25 is a three-part report covering the background, algorithm development, and testing program involved in creating the new predictive modeling capability.

A team consisting of OSU, GWU, and NASA Glenn Research Center worked with the FAA Aircraft Catastrophic Failure Prevention Research Program to develop a new material model in LS-DYNA for 2024 aluminum. The new constitutive material model developed under this joint effort, MAT Tabulated Johnson Cook (LS-DYNA MAT 224), provides the means to predict multiple modes of failure, and along with other quality control and guidance materials developed by the group, significantly advances the overall process toward the goal of certification by analysis.

Part one of the report describes the challenges, background, and previous work. It also explains the current physics-based tabulated approach, which has made significant strides in solving a problem identified in modeling for many years; that is, that models could be tuned to match testing and a type of failure, but a single material model would not accurately predict the crossover in failure modes.

Part two of the report describes the development of the new material model at GWU. Large deformations, high strain rates, temperature softening, and varying stress states affect materials under impact and finally may lead to failure. Research has shown that the impact characteristics are prone to change with several independent factors, such as impact speed, material thickness, and shape and orientation of the impacting object. A new, generic, thermo-elastic viscoplastic material model with regularized failure was developed. A von Mises type isotropic, isochoric plasticity is used, where isotropic hardening, strain-rate hardening, and temperature softening are considered. The model takes adiabatic heating and softening into account due to the plastic work. Tabulated inputs of characterized material test results are directly used for both the constitutive and failure treatment of the new material model (Figure 7). It was shown that the new material model is capable of predicting ballistic limit and failure modes accurately for structures under impact even if the failure mode changes drastically.

Part three of the report describes the experimental material characterization work conducted at OSU. The plastic deformation and ductile fracture behavior of 12.7 mm, 6.35 mm, and 3.175 mm thick 2024 aluminum plate and sheet were investigated. Researchers conducted tension, compression, and shear experiments at strain rates ranging from 10-4 s-1 to 11000 s-1 and temperatures ranging from –50 °C to 50 C. Results show that the material flow stress is insensitive to strain rate in tension, compression, and shear between 10-4 s-1 and 5000 s-1. In compression, increased stresses occur at strain rates between 5000 s-1 and 11000 s-1. Flow stress decreases monotonically with increasing temperature. The strain hardening behavior of the material also changes dramatically between 150 and 300 C. A 12.7 mm thick 2024-T351 plate is anisotropic with respect to plastic deformation. Tensile and compressive stresses determined from specimens oriented ±45° to the plate's rolled direction (Figure 8) were significantly lower than those determined from specimens oriented in the rolled and transverse directions. This data was used in a coupled experimental-numerical technique to develop a fracture locus for 2024-T351 aluminum in the second part of the report. (Aircraft Catastrophic Failure Prevention Program)

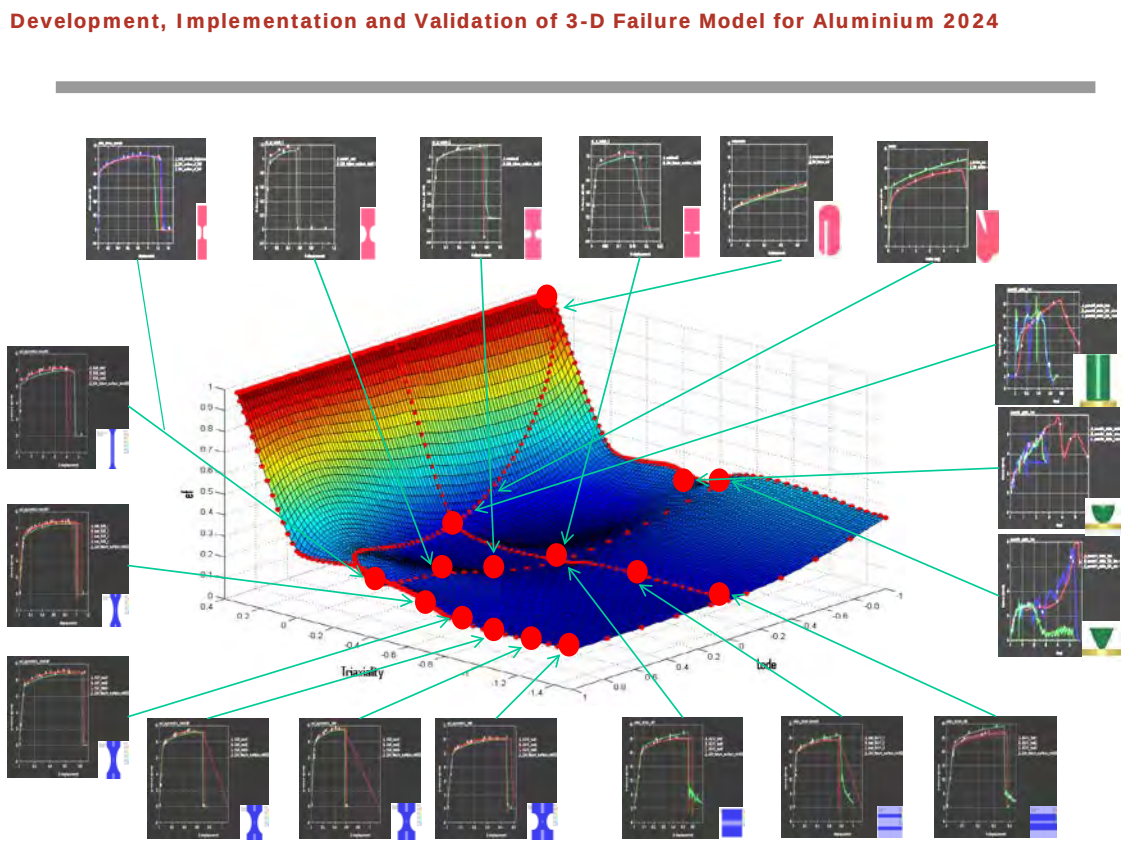


Figure 7: MAT 224 failure surface generated from test data

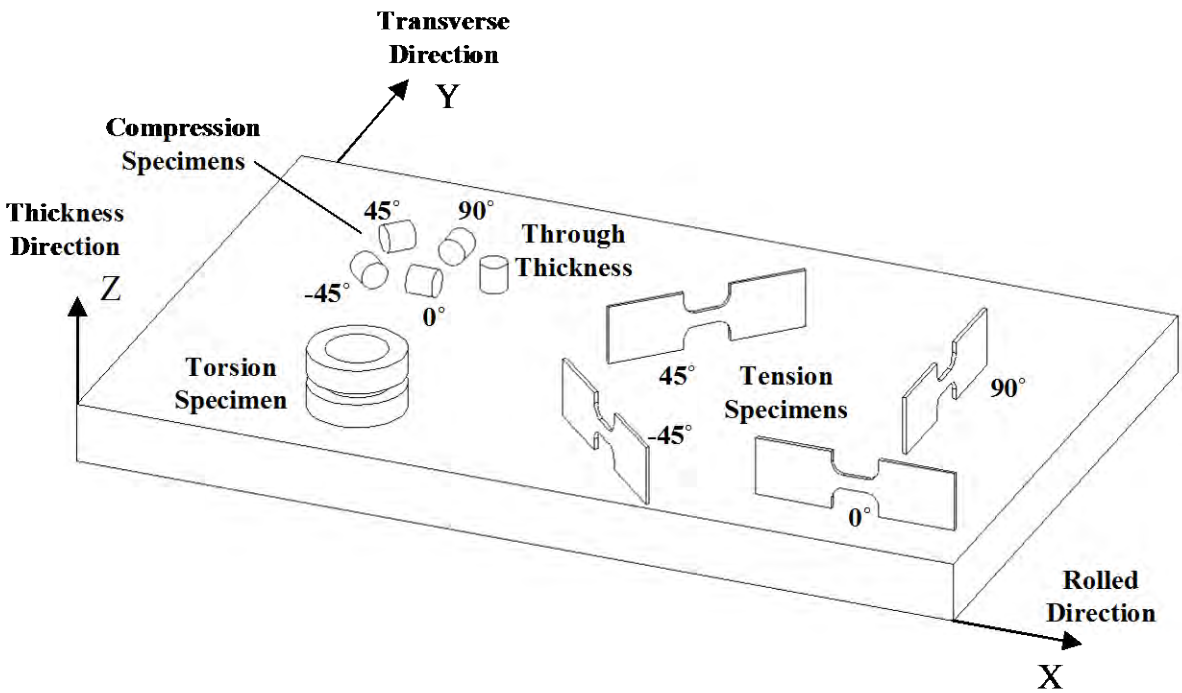


Figure 8: Orientation of specimens from plate material of aluminum 2024-T351

Unmanned Aircraft Systems (UAS) Integration in the NAS:

MITRE is working with the FAA to identify and resolve air traffic control-related issues with Unmanned Aircraft Systems (UAS) operating in the NAS. In FY 2013, MITRE assessed current UAS operations in En Route Class A airspace. Current operations of UAS in Class A often include atypical flights, such as long-duration flights, loitering at relatively slow (e.g., maximum endurance) speeds, or flying a grid pattern. The flight patterns of UAS are unusual to air traffic controllers, who are more accustomed to manned aircraft flying between two points in a fuel and time-efficient manner. In addition, aircraft performance characteristics (e.g., climb rate and cruise speed) of some UAS can be different from a manned aircraft flying in the same airspace. Currently, most UAS missions have approval to operate in areas segregated from manned aircraft traffic flows, either laterally or vertically. These operations occur under the authority of a Certificate of Waiver or Authorization (COA).

MITRE's assessment included a comparison of flight performance of unmanned aircraft and manned aircraft operating in Class A airspace, a review of recent controller and pilot-reported UAS-related events in the NAS, and the analysis of sample scenarios of UAS-related events. Issues needing further consideration were identified in such areas as controller and pilot training, dissemination of UAS mission and contingency information to controllers, communications between controllers and UAS pilots, human factors in the UAS ground control stations, and deficiencies in UAS flight plans and air traffic control (ATC) automation in processing UAS trajectories. In each of these areas, MITRE provided suggested near-, mid-, and far-term

mitigation measures for the FAA to consider for additional implementation or analysis. The FAA intends that these mitigation measures will improve the efficiency and safety of UAS operations in Class A airspace. Center for Advanced Aviation System Development (CAASD)

Block Occupancy-Based Surface Surveillance:

Surface surveillance can enhance controllers' situational awareness of the airport surface and improve the safety of operations on and around runways. At approximately 50 of the nation's large airports, the FAA is installing integrated surface surveillance capabilities (i.e., Airport Surface Detection Equipment – Model X; ASDE-X), which can provide the precise location of an aircraft on the airport surface to controllers in the tower. Because these systems use a combination of advanced capabilities, they are cost prohibitive for most airports, leaving over 450 towered airports in the United States without any such surveillance system. As a result, these unequipped airports are not able to take advantage of potential safety benefits. The international market has noted similar challenges.

The objective for this research is to develop a block occupancy-based surface surveillance concept and prototype display using inexpensive sensors (such as magnetic sensors), installed in existing taxiway and runway light enclosures, for surveillance input. Under this concept, runways and taxiways on the airport surface are divided into operationally relevant blocks, and sensors are used at the block boundaries to monitor aircraft and ground vehicles entering and exiting these blocks. As a target moves on the taxiways and runways, the sensor detects an entry into or an exit out of a block, the surveillance system identifies the occupancy status of each block, the status of the block is sent to the tower, and a user interface presents this status information to the controllers (see Figure 9 for an example display). Researchers validated

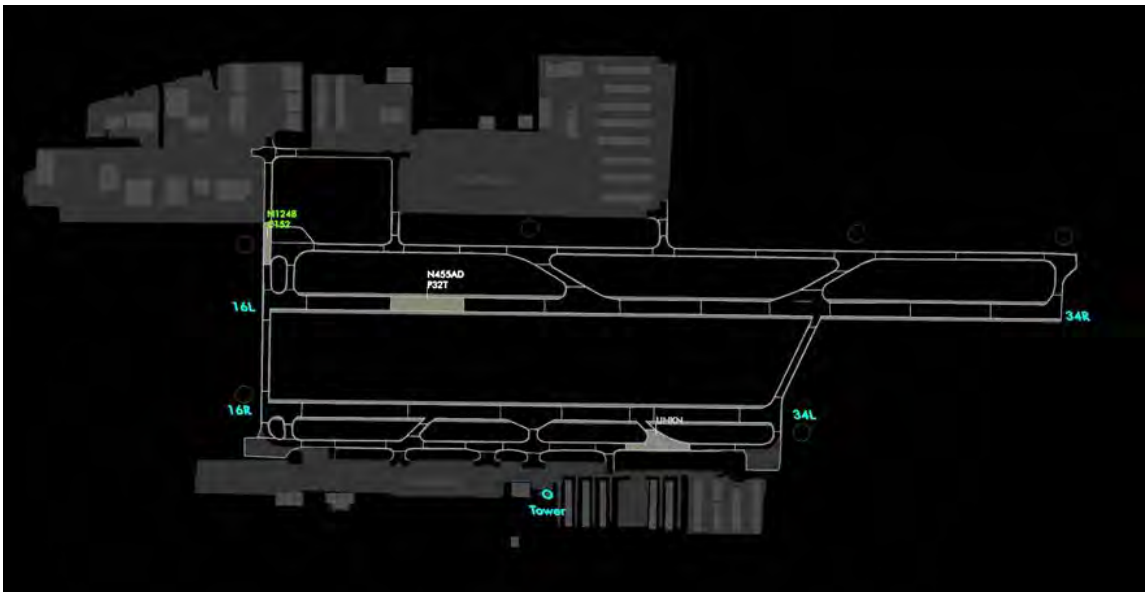


Figure 9: Prototype block occupancy controller display

this concept with controllers through human-in-the-loop (HITL) simulation, and data shows that it improves controller situational awareness and the safety of surface operations.

In FY 2013, MITRE identified and acquired candidate magnetic sensors, developed a small sensor network, and collected field data with ground vehicles in a parking lot and with small aircraft at a non-towered airport. Collected data were then successfully integrated into newly developed algorithms designed to take the raw sensor signals, filter noise, derive block occupancy, and display the occupied block on the prototype display. Findings from these tests indicate that sensor range of the candidate sensor technology is limited for small aircraft, so MITRE is identifying and examining alternative sensor capabilities for this concept. In FY 2014, MITRE intends to continue field testing at Manassas Regional Airport (MNZ) with a temporary and localized installation. (CAASD)

Research Study on Selected Categories of Software Assurance Approaches:

Advancement of new tools and technologies used in aircraft software development and new methods to safely assure the use of these new technologies when integrated onboard an aircraft have led the FAA to completed an in-depth research study on selected categories of software assurance approaches to determine the merits and drawbacks and to identify safety issues and propose mitigation strategies. The approaches considered in this effort included alternative hazard analysis and model-based specification. Researchers focused efforts on a set of safety analyses suggested by the Society of Automotive Engineer's S-18 and EUROCAE's WG-63 Committees in AIR 6110. The FAA developed specification templates for the core parts of the System Architecture Virtual Integration's (SAVI) Virtual Integration Process (VIP) process. Researchers developed several models to test the VIP process, conducted consistency checks on models, and performed safety analyses. The research indicated the SAVI process eliminated and mitigated a considerable number of errors early in the system development process while achieving safety goals and providing efficiencies in verification. The FAA anticipates that the sponsor will use the results of this research as additional guidance and to update training material for designated engineering representatives. (Digital Systems Safety)

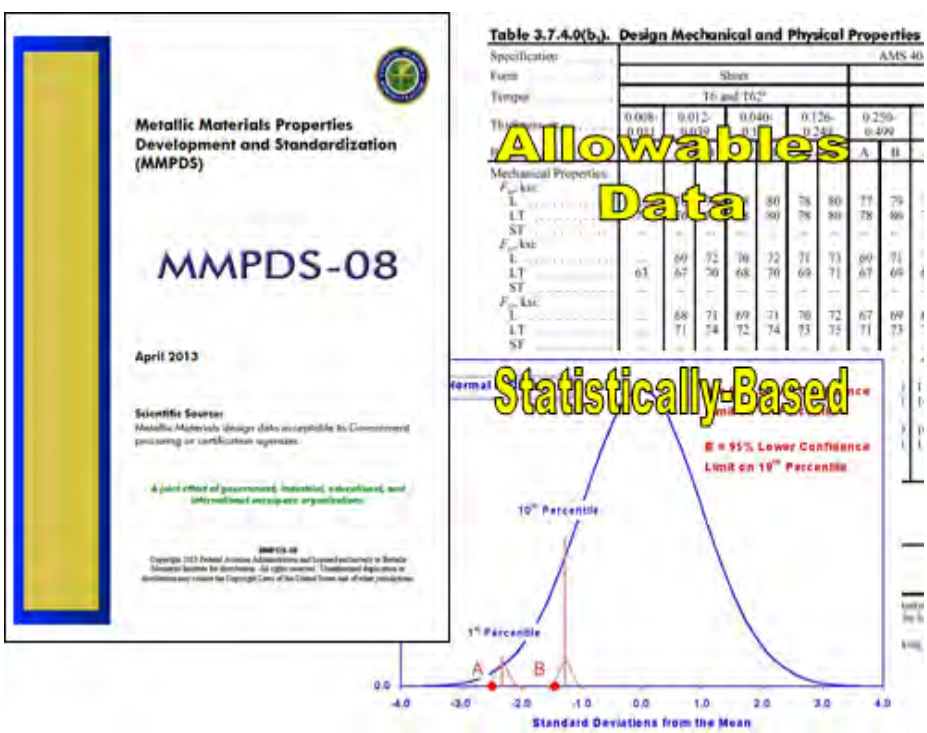
Ice Pellet Allowance Times:

The FAA completed a study of clean airfoil models with uncontaminated and contaminated de-icing fluids. This effort was necessary to verify procedures used to determine allowance times for operations in ice pellets, including ice pellets mixed with other forms of freezing or frozen precipitation. Ice pellet allowance times are based on observations of flow off and fluid failure as well as examinations of the lift curve. Since there are no holdover times for ice pellets (they cannot yet be simulated well enough in a cold chamber), this work is crucial to airline operations in ice pellet conditions. (Aircraft Icing)

Metallic Materials Properties Development and Standardization (MMPDS):

The Metallic Materials Properties Development and Standardization (MMPDS) is an effort led by the FAA to continue the Handbook process entitled *Metallic Materials and Elements for Aerospace Vehicle Structures* (MIL-HDBK-5). This handbook is recognized internationally as the most reliable source for verified design allowables needed for metallic materials, fasteners, and joints used in the design and maintenance of aircraft 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 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 (GSG), industry stakeholders in the Industry Steering Group (ISG) and profits derived from the sale of Handbook and derivative products. In pursuit of this goal, the FAA released the commercial version of the MMPDS-08 in April 2013. There has been a substantial upgrade to the Handbook with the addition of seven new metallic materials and tempers; consisting of a new steel alloy, various 2XXX series aluminum alloys and tempers, a new magnesium alloy, and an aluminum-nickel-bronze alloy. Additionally, legacy analysis was performed on 7075-T6, T62, bare and clad sheet and plate using current production data. The FAA upgraded or revised many other material sections, with a substantial update made to the analysis and example section for mechanically fastened joint allowables. The FAA distributes the MMPDS-08 Handbook and derivative products that provide data that satisfies material strength requirements for aircraft certification and continued airworthiness. (Continued Airworthiness Program)



Advanced Nondestructive Inspection (NDI) Methods:

The FAA's Airworthiness Assurance NDI Validation Center (FAA-AANC) has applied 15 advanced nondestructive inspection (NDI) methods to a set of solid laminate test panels to assess each method's capability and reliability. NDI technologies tested include advanced ultrasonic imaging using phased arrays, a variety of thermal imaging methods, microwave, and x-ray backscatter methods. Results from these tests produced probability of detection (POD) and false call data that can be compared with current existing NDI methods, such as pulse echo ultrasonics, to show the increased inspection capabilities of the advanced technologies. Data from this series of experiments has already assisted airframe manufacturers to develop procedures using advanced ultrasonic imaging, which will appear in their NDI manuals. (Continued Airworthiness Program)

Fire Extinguishing Agent Distribution and Fire Extinguishment Tests in an FAA-owned Boeing 747SP Aircraft Engine:

A multi-year project compared the ability of a particular solid aerosol fire extinguishing agent to Halon 1301, as used in an aircraft engine fire-extinguishment system. The final piece of the project is a series of eight tests conducted to ensure the acceptable performance of the solid aerosol fire extinguishing agent, its proposed design criteria, and its associated concentration analyzer. The test results indicated that this particular solid aerosol fire-extinguishing agent and its proposed design criteria likely would not perform comparably to Halon 1301.

The tests occurred in the number-2 Pratt & Whitney JT-9D engine on an FAA-owned Boeing 747SP, see Figure 10, located at the FAA Technical Center, which also included external ancillary equipment necessary for this testing. A team composed of FAA personnel and contractors from the Fire Safety Branch, FAA staff from the Transport Airplane Directorate and the Seattle Aircraft Certification Office, the Boeing Commercial Airplane Company, and Kidde Aerospace and Defense accomplished the build-up, testing, reviews, and attendant decision-making as progress occurred. The Fire Safety Branch maintained and operated the 747SP aircraft engine and ancillary systems, excluding all associated with the fire-extinguishment system. Kidde Aerospace and Defense provided and serviced the complete fire-extinguishment system and maintained and operated the associated concentration analyzer.

During the test article build up, researchers designed, fabricated, and installed systems external to the aircraft engine. They provided the engine fire zone with a forced ventilation flow, simultaneous spray, and pool fire threats based on turbine fuel, fire-extinguishing agent storage and delivery, and numerical and optical telemetry that monitored and recorded the local environment during testing. Additional electrical circuits were installed that allowed remote control of these systems during test completion. Researchers made minor modifications to the engine compartment, which minimized differences between tests conducted with the engine running and those conducted with the engine out, which promulgated an assessment of a requisite new concentration analyzer associated with the solid aerosol's use. With the completion of the test article, personnel operated the aircraft engine for a desired duration from

the aircraft flight deck, while other personnel in the adjacent site control room on the ground operated the forced ventilation supply equipment, prepared and ignited simultaneous spray and pool fires as needed, and prepared and discharged the engine fire-extinguishment system. Figure 11 shows examples of pool fire imagery in the engine fire zone during the solid aerosol injection and migration.

A series of tests were conducted that provided information for subsequent review and decision-making. Six tests were fire-extinguishing agent distribution tests that captured the performance of the agent injection system and the concentration analyzer. The FAA accomplished three tests during an engine run as well as three without, but immediately followed an engine run. The team considered the collected information and decided to continue forward, as the performance of the concentration analyzer did not solely discriminate according to engine operating status, that being a main concern. The final two tests were fire extinguishment tests conducted in a thermally "hot" engine fire zone with a static engine. The intensity of the fire threats were first assessed with the discharge of a pressurized quantity of nitrogen stored in the fire-extinguishing agent bottle. The injected nitrogen did not extinguish the fires, thus the fire threats were considered sufficiently intense. Knowing an acceptable challenge existed, the second test occurred to assess the performance of the solid aerosol fire-extinguishing agent and its proposed design criteria. The injected solid aerosol did not extinguish the fire threats.

During a number of meetings, team members offered several hypotheses to better understand the undesired outcome of the real engine fire extinguishment test with the solid aerosol fire extinguishing agent. All were plausible, but were divided between either needing to better understand the behavior of the solid aerosol fire-extinguishing agent or the fire threats using Halon 1301. Testing concluded because the industry component of the team desired to further investigate the behavior of the solid aerosol fire-extinguishing agent. (Fire Research and Safety)

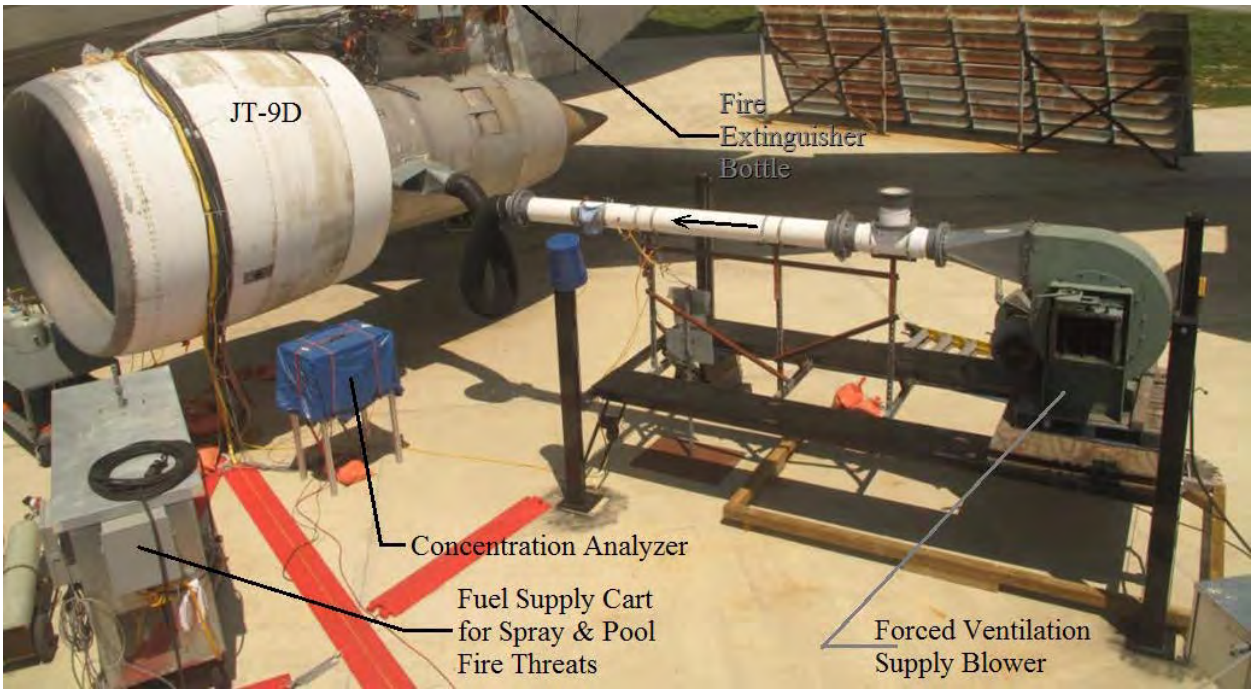


Figure 10: The FAA-owned Boeing 747SP engine fire test site

Figure 11: Pool fire imagery in the engine fire zone during the solid aerosol injection and migration

Full-scale Aircraft Fire Tests with Bulk Shipments of Lithium-ion Batteries:

A series of fire tests were conducted in the FAA Boeing 727 freighter test article to establish the hazards presented by bulk shipments of lithium-ion batteries. These tests represent a culmination of research conducted by the FAA to characterize the flammability hazard associated with the use, handling, storage, and shipment of lithium-ion batteries. Previous small-scale tests have documented the fire hazards of lithium-ion cells experiencing thermal runaway, including case temperature, auto ignition temperature, flammable electrolyte ignition, and explosive pressure. Also, in a typical bulk shipment cardboard box, it was determined that a single cell in thermal runaway produces enough heat to cause other nearby cells to also go into thermal runaway. This process propagates through all the cells within the box as well as to adjacent boxes, until all cells in the shipment have been consumed. Halon 1301, the fire suppressant used in all passenger aircraft cargo compartments, is ineffective in stopping the propagation of thermal runaway, though it does suppress the ignition of released electrolyte and prevents fire from spreading to other combustibles. This research has been the basis for two Safety Alerts for Operators (SAFO): 09013: Fighting Fires Caused by Lithium Type Batteries in Portable Electronic Devices (PED) and 10017: Risks in Transporting Lithium Batteries in Cargo Aircraft.

The bulk shipment of lithium-ion cells is permitted on both passenger and cargo aircraft. The involvement of lithium batteries is suspected in recent accidents resulting in the loss of two Boeing 747 cargo aircraft. Thus, there was a need to characterize the flammability hazard associated with a large shipment of lithium batteries in a realistic aircraft environment. To that end, the FAA Fire Safety Branch instrumented a Boeing 727 freighter aircraft to run full-scale fire tests with lithium batteries. Bulk shipments of lithium batteries can number in the tens of thousands. For the purpose of these tests, the FAA chose 5,000 cells.

Researchers configured the aircraft to simulate in-flight emergency conditions by manipulating interior airflow settings. Researchers chose two cargo storage locations: the main deck Class E compartment, and the forward lower Class C compartment. Class E compartments, found on all freighter aircraft, rely on smoke detection, decompression, and oxygen starvation to control a fire. Class C compartments, found on all passenger aircraft as well as some freighters, have both detection and active fire suppression (Halon 1301).

Researchers conducted three tests in each location. For comparison, the first test in each location consisted of 5,000 mixed non-lithium cells, including nickel cadmium, nickel metal hydride and alkaline, all AA size. Researchers exposed these cells to an adjacent fire as the ignition source. The second test used 5,000 lithium-ion 18650 cells, again exposed to an adjacent fire source. The last test used 5,000 lithium-ion 18650 cells with a simulated thermal runaway as the ignition source (Figure 12). All cells were in the original shipping cartons and boxes as received.

Class E Compartment results included the following:

- Mixed non-lithium cells with adjacent fire ignition — the adjacent fire ignited the fiberboard shipping cartons. This slowly developing fire eventually generated enough smoke to obscure the compartment. The cells did not contribute to the fire. There was minimal damage to the aircraft cargo liner, moderate ceiling temperatures. There was no smoke penetration in the flight deck.
- Lithium-ion (Li-ion) with simulated thermal runaway — the cells in thermal runaway generated enough heat to ignite the fiberboard cartons, which in turn ignited the released electrolyte. The fire gradually escalated, generating a large amount of smoke that soon penetrated and completely obscured the flight deck. The fire consumed most of the oxygen in the compartment, reducing the intensity. However, as oxygen infiltrated the compartment, the intensity increased. This cycle would have continued until fire consumed all cells, but researchers terminated the test by dousing the flames with water. Significant damage occurred to the compartment.
- Li-ion with adjacent fire ignition — the adjacent fire ignited the fiberboard shipping cartons. This in turn heated the lithium-ion cells, causing them to go into thermal runaway. The burning cartons ignited the released cell electrolyte. At this point the fire characteristics and aircraft hazards were indistinguishable from the previous test.

Class C Compartment results included the following:

- Mixed non-lithium cells with adjacent fire ignition — the adjacent fire was ignited and began to spread to the cartons containing the mixed cells. Halon 1301 was discharged upon smoke detection. This suppressed the fire preventing further fire spread. No smoke spread into the flight deck or main deck compartment.
- Li-ion with adjacent fire — the adjacent fire again spread to the cartons containing the lithium-ion cells. Halon 1301 suppressed the fire preventing fire spread. No cells became involved. No smoke spread into the flight deck or main deck compartment.
- Li-ion with simulated thermal runaway — the simulated thermal runaway device caused adjacent cells to enter into thermal runaway as well. This ignited the cartons and electrolyte. Halon 1301 was discharged upon smoke detection, suppressing the open flames. Thermal runaway continued to propagate throughout the shipping carton and spread to adjacent cartons. The rate of propagation increased with time. Researchers terminated the test with water. There was no smoke penetration into the flight deck or main deck compartment.

The conclusions of this study include the following:

- Li-ion batteries in bulk shipments pose a more serious threat to the aircraft than other more common battery chemistries.
- Li-ion fires in Class E compartments can do significant damage to the aircraft and can generate enough heat and pressure to force smoke into the flight deck.
- Class C compartments equipped Halon 1301 can suppress the open flames from a lithium-ion fire and prevent smoke penetration into the flight deck, but cannot stop the propagation of thermal runaway.
- The buildup of unburned hydrocarbons from the released electrolyte may pose a flash fire or explosion threat when the compartment is opened.

(Fire Research and Safety)

Figure 12: Post fire, 5,000 lithium-ion cells

Safe Human Exposure Criteria for Halon Discharge in a Small General Aviation (GA) Airplane:

Guidance for the safe use of hand extinguishers in AC 20-42D,[1] *Hand Fire Extinguishers for Use in Aircraft*, provides discharge limits to keep halocarbon extinguishing agents safely below the adverse effect level. Peak arterial blood concentrations predicted for an exposed person should not exceed a target arterial blood concentration (considered the threshold for safe use).[2]

[1] FAA AC 20-42D, *Hand Fire Extinguishers for Use in Aircraft* (Jan. 2011).
[2] Richard E. Lyon, and Louise C. Speitel, *Guidelines for Safe Use of Gaseous Halocarbon Extinguishing Agents in Aircraft*. FAA Report DOT/FAA/AR-08/3 (Aug. 2009).

Human arterial blood concentration histories are determined from the Halon 1211 gas concentration histories using a simple kinetic model,[3] developed by FAA personnel, which has been shown to provide good agreement with physiologically based pharmacokinetic modeling (PBPK).[4]

The guidance in AC 20-42D is based on the assumption of instantaneous perfect mixing in a ventilated aircraft cabin. Actual halocarbon gas and arterial concentrations may be lower than predicted at the nose level of a seated or standing passenger due to stratification of the heavier-than-air agent and exhaust at the floor-level air return ducts, or higher than predicted at locations in the aircraft near where the agent is discharged.

A stratification/localization multiplication factor (MF) can be applied to the perfect mixing concentration to increase the allowable AC-20-42D safe use weight of agent to account for stratification/localization. This would allow the use of effective extinguishers that might otherwise be prohibited because of safety concerns. For example, higher Halon 1211 extinguisher charge weights than those based on peak arterial perfect mixing concentrations are expected to be safe due to a long history of safe use of Halon 1211 extinguishers in small aircraft compartments.

Retrospective studies were conducted of Cessna 210C Halon 1211 discharge tests for an empty aircraft[4] and an aircraft loaded with 4 mannequins and baggage.[5] The aircraft was positioned in a wind tunnel (profile is shown in Figure 13). Three ventilation conditions were included in the analysis, all with a 120 mph wind tunnel air speed: overhead vents open, all vents open and all vents closed. The air change time for the Cessna 210C tests were determined to be 1.16 minutes for the empty aircraft with overhead vents open. Cessna 210C test data selected for analysis included two discharge targets: under the instrument panel, copilot's side and the copilot's seat.

This retrospective analysis determined the arterial concentration histories from the agent gaseous concentration histories using Halon 1301 kinetics, and determined the stratification/localization multiplication factors for Halon 1211 (Figure 14). Figure 14 also shows the theoretical perfect mixing concentration histories with and without ventilation, calculated based on the weight of the agent discharged and the air change time of the compartment, taking into account the measured cabin ventilation rate.

The ratio of the predicted peak arterial blood concentration, obtained from assuming perfect mixing in a ventilated compartment to the test-based predicted peak arterial blood concentrations, provides a stratification/localization multiplication factor for each test and each

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[3] Richard E. Lyon and Louise C. Speitel, A kinetic model for human blood concentrations of gaseous halocarbon fire extinguishing agents. *Inhalation Toxicology, 22*(12–14), pp. 1151–1161 (Dec. 2010).
[4] J.E. Demaree et. al., *Extinguisher Agent Behavior in a Small Aircraft*. FAA Report DOT/FAA/CT-83/30 (Jan. 1984).
[5] J.E. Demaree et. al., *Halon Extinguisher Agent Behavior in a Ventilated Small Aircraft*. FAA Report DOT/FAA/CT-86/5 (June 1986).

gas sampling position. Considering this data, one can select a multiplication factor that can be applied to the currently recommended maximum Halon 1211 concentrations to provide higher safe concentrations of Halon 1211. The resultant multiplication factors appear in Figure 15. For example, the multiplication factor for the nose level of a seated pilot was 2.2 when discharged under the instrument panel on the co-pilot's side and 2.1 when the agent was discharged at a the copilot's seat. (Fire Research and Safety)

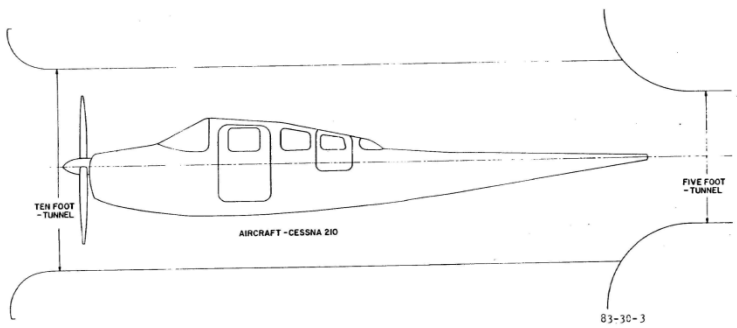

Figure 13: Wind tunnel profile with Cessna 210C

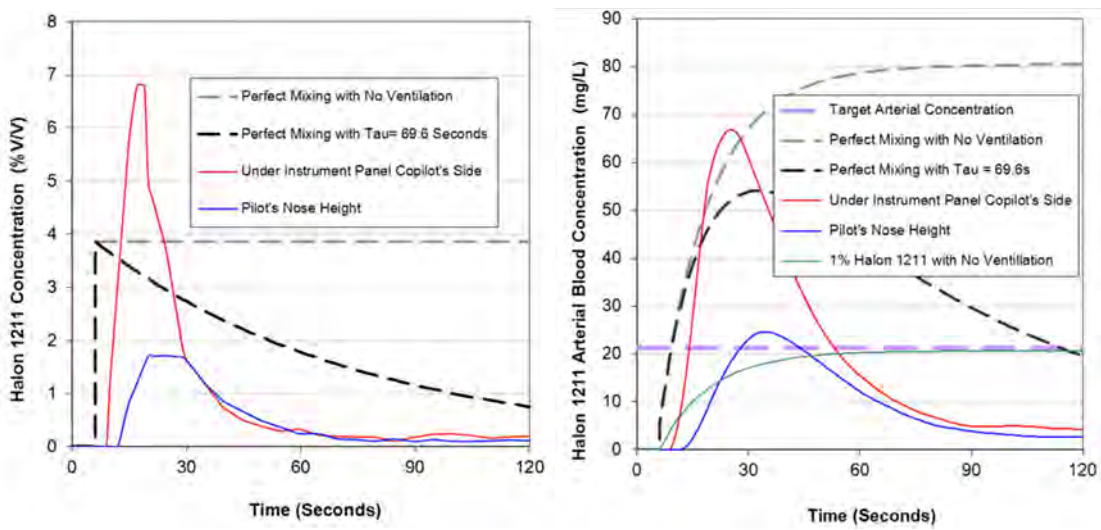

Figure 14: Halon 1211 gaseous and arterial blood concentration histories at pilot's nose level.

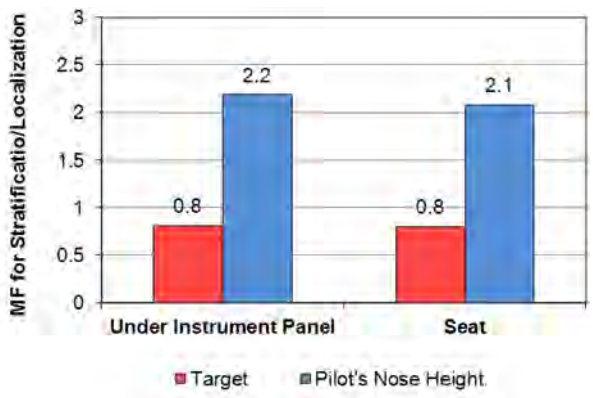

Figure 15: Multiplication factors for stratification/localization at pilot's nose level.

Development of a Flame Propagation Test Method for Composite Structure:

Technological advances in materials science have led to the increased use of composite materials for primary structures in commercial airframes. Carbon fiber composites are ideal for aerospace applications due to their increased strength, lower density, and better corrosion resistance than traditional aircraft aluminum. Nearly every major transport-category aircraft manufacturer is currently using or has plans to use carbon fiber composites for fuselage skins and structures. Current Federal Aviation Regulations do not require flammability testing for aircraft fuselage skins or structural members, as all transport airplanes up until now have been constructed from aluminum, which will not burn or propagate flames when exposed to a fire in an inaccessible area of the cabin. In recent years the FAA has been working to increase the fire worthiness of materials located in inaccessible areas, including insulation, ducting, and electrical wiring, striving to enhance in-flight cabin safety. Modern transport airplanes constructed from composite materials will inherently have a significant amount of composite material in inaccessible areas, potentially posing a threat to in-flight cabin safety. To certify an aircraft with a composite fuselage, the manufacturer must demonstrate that the composite materials will provide the same level of safety as an aluminum-constructed aircraft when exposed to an in-flight fire. To date, this has been done through Special Conditions imposed by the FAA, where the applicant submitted a test plan to the FAA for review, performed testing and analysis specific to their design, and provided the results to the FAA, who then determined whether the composite material posed a greater safety hazard than aluminum.

To standardize the certification process for composite aircraft, a study was undertaken to develop a laboratory scale test method to determine the flame propagation of structural composite materials. The test method was designed to correlate to an intermediate scale test simulating a (realistic) moderately severe fire impinging on the inboard side of the aircraft skin. An intermediate scale test rig was constructed to simulate an inaccessible area in an aircraft cabin with the ability to interchange the test panels in order to study various composite materials. The FAA evaluated a variety of materials, including aerospace and non-aerospace woven laminates, unidirectional laminates, and carbon/epoxy-honeycomb sandwich panels. Other materials tested included glass-fiber reinforced vinylester, glass-cloth epoxy resin, and a baseline aluminum

panel. The standard hidden fire source was a polyurethane foam block spiked with a small amount of heptane to promote uniform, consistent burning. The simulated hidden area was insulated with ceramic fiberboard to retain heat produced from the burning foam block and direct it toward the test panel. Panel temperatures were recorded during each test with thermocouples located on the inboard-side of the test panels to quantify the progress of the flame along the panel surface. Video was recorded to study the duration and intensity of panel burning, and a post-test measurement of the burn area was recorded (see Figure 17 for examples). Materials were ranked according to burn length and burn time after foam block extinguishment.

The FAA Technical Center's Fire Safety Branch designed, constructed, and tested a lab-scale flame propagation test apparatus (see Figure 16). The apparatus consists of a 710-watt, 2 ¾" diameter radiant coil furnace mounted vertically and opposite a 6-by-12-inch composite test sample. A 6-flamelet propane-air pilot burner impinges on the lower portion of the test sample for 50 seconds, and then is removed. The sample is then allowed to burn while still exposed to the radiant heat flux emitted by the coil furnace. The burn time beyond pilot flame removal is recorded as well as post-test measurements of burn length and burn width. Multiple test apparatuses were constructed and validated with a series of machine-to-machine comparative tests. Reproducibility was confirmed by testing all apparatuses in different laboratories. The final phase currently underway is the delivery of apparatuses to the major airframe manufacturers to validate the performance in a different geographic location. The final test parameters and pass/fail criteria will be confirmed through the test method's task group in the International Aircraft Materials Fire Test Working Group. (Fire Research and Safety)

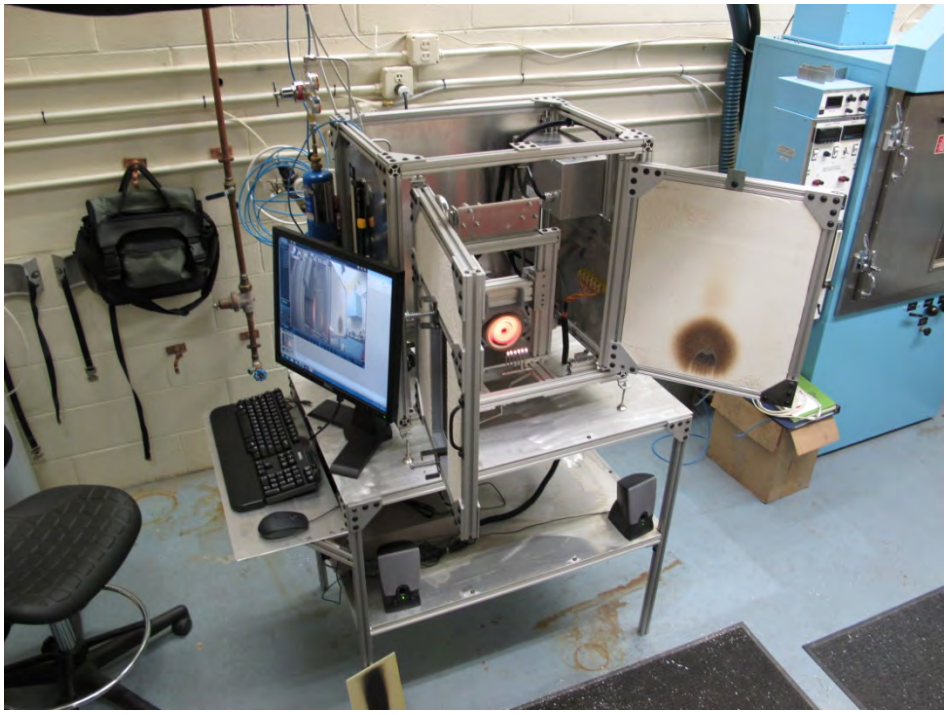

Figure 16: Flame propagation test apparatus

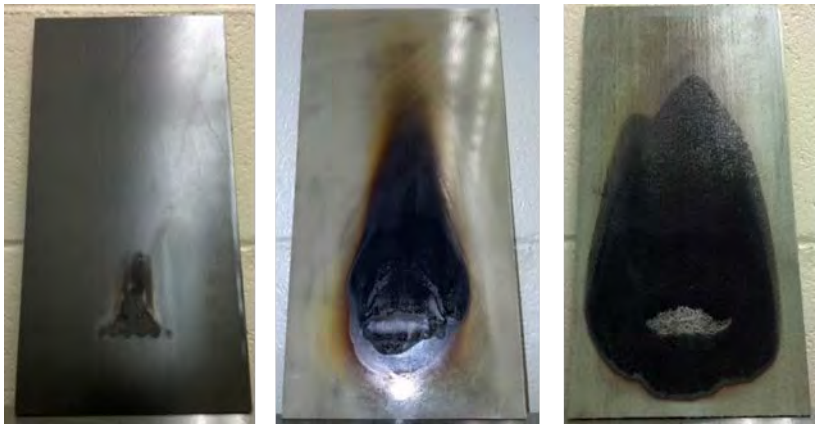

Figure 17: Post-test comparison of burned areas for aerospace carbon/epoxy (left), industrial-grade glass/epoxy (center), and glass/vinylester (right)

Extinguishing Lithium-Ion and Lithium-Metal Batteries:

Lithium and lithium-ion batteries exist in many consumer personal electronic devices (PEDs). The batteries sometimes overheat and create a fire and/or explode. When a single cell in a battery pack undergoes a condition of uncontrolled internal heating and rapid temperature rise called thermal runaway, its heat output causes other cells to do likewise. The propagation of thermal runaway and the resultant fire may be controlled if the correct extinguishing agent is used.

The objective of this study was to compare the effectiveness of fire extinguishing agents for extinguishing lithium-metal and lithium-ion battery fires and terminating the cell-to-cell propagation of thermal runaway.

Researchers conducted tests in a 64 cubic foot test chamber with a sealable door. Staff first conducted quantitative tests to compare the ability of "streaming" extinguishing agents, used primarily in handheld extinguishers, to cool a hotplate. The average temperature drop, measured by five surface thermocouples, quantified the effectiveness of the agent's ability to cool. Water and other aqueous extinguishing agents were the most effective coolants and they increased in effectiveness with increased volumes. The non-aqueous agents were essentially ineffective and showed a smaller increase in effectiveness with increased volumes (see Figure 18(a)).

Next, researchers performed fire tests with exposed lithium-ion and lithium metal cells to determine the capability of different agents to extinguish a small battery fire and prevent thermal runaway propagation. Researchers placed five cells side-by-side in an insulated holder and initiated thermal runaway in a single cell with a cartridge heater. Researchers conducted tests four times with lithium-ion cells and seven times with lithium-metal cells to verify that thermal runaway would consistently propagate without the presence of an extinguishing agent. Once verified, researchers applied streaming agents with a handheld extinguisher from the distance suggested on the extinguisher bottle and liquid agents were poured on the battery fire using a 500 mL water bottle. These results also showed that aqueous extinguishing agents were most

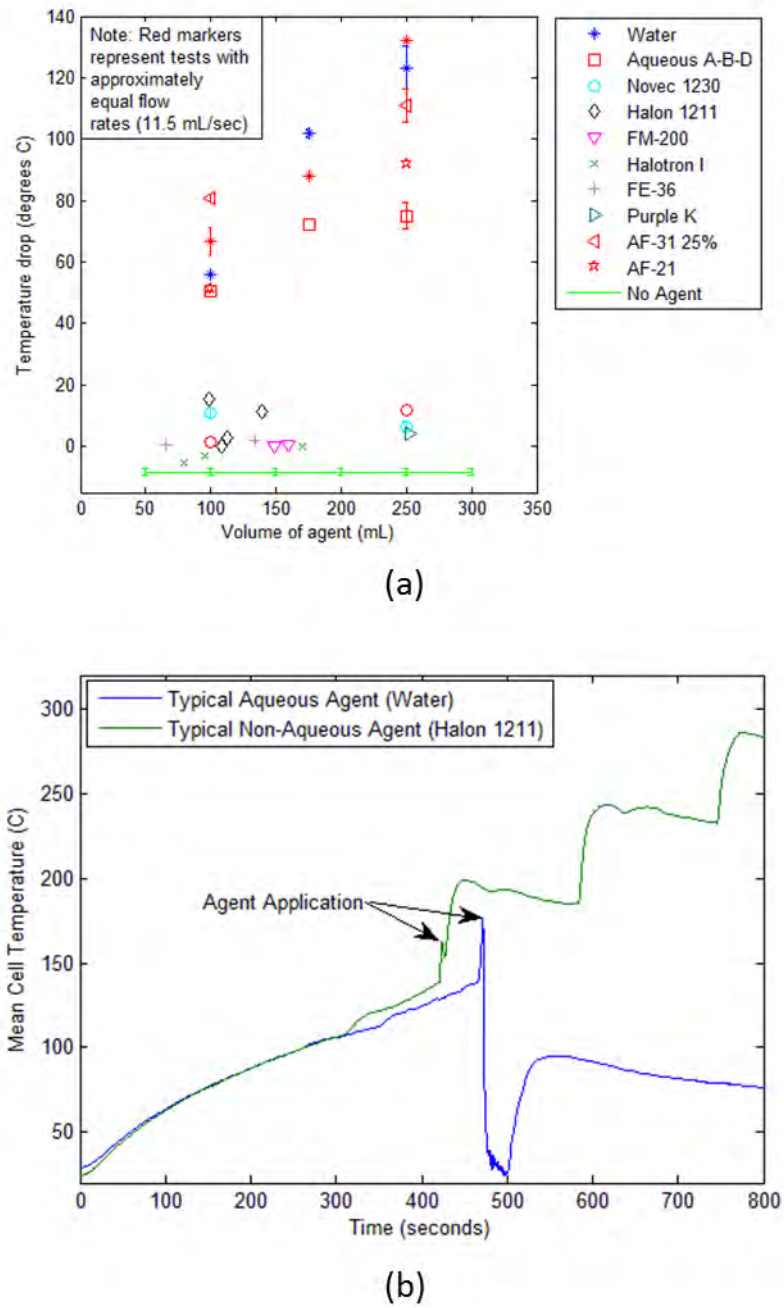

Figure 18: (a) Temperature drop of a hot plate from extinguishing agents; (b) temperature plot of the extinguishment of lithium-ion batteries in thermal runaway for verification of hot plate tests

effective at halting thermal runaway propagation (see Figure 18(b)). The gaseous agents were most effective at extinguishing the electrolyte fires.

There was a significant variation in the behavior of thermal runaway among various identical lithium-metal cells. The cells would usually do one of the following: (1) vent from melted holes in the cell, (2) leak plastic and lithium, or (3) eject their contents. The contents that leaked and ejected were usually burning, but on some occasions they did not burn, especially if an ignition source had not materialized.

On occasion, cells would explode and terminate thermal runaway propagation. The propagation would terminate because hot internal battery components would eject away from the exploded cell and reduce the available heat that could transfer to the next cell.

In summary, the tests showed that the extinguishing agents containing water were most effective at preventing thermal runaway propagation for small numbers of lithium-ion and lithium metal cells and that the effectiveness increased with increased volumes. The streamed agents showed less effectiveness at preventing propagation and a smaller increase in effectiveness with an increased volume. (Fire Research and Safety)

Design Assessment of Reliability with Inspection (DARWIN®):

The most recent version of the Design Assessment of Reliability with INspection software code (DARWIN® 8.1) developed by Southwest Research Institute was released September 2013 and provides several new capabilities for rotor designers and analysts.

The first capability involves automation of inspection assignments for application to autozoning. The autozoning feature allows the analyst to assign inspection regions directly to the FE model geometry. Inspection definition has been consolidated into a single "Inspection Events" menu for specification of inspection methods including POD curves, timetables (schedules), and regions (geometry). This capability greatly simplifies the inspection definition process and provides a consistent framework for zones that are created both manually and via autozoning. Automation of the fracture model, zone creation, and inspection assignment processes reduces the human time and judgment that were previously required for risk assessment of materials with inherent anomalies.

In contrast to inherent material anomalies that can occur anywhere, surface damage typically occurs at key component features, such as holes, blade slots, and turned surfaces. Advisory Circular (AC) 33.70-2 provides guidelines for assessment of hole features and these guidelines are subsequently supported by previous versions of DARWIN®. The FAA and the Aerospace Industries Association (AIA) Rotor Integrity Sub Committee (RISC) are currently developing an approach for risk assessment of blade slots that involves creation of zones along the leading edges and surfaces of a slot. To support this effort, DARWIN® 8.1 now includes a new capability for creating zones on surfaces and edges of three-dimensional (3D) FE model geometries. This capability enables the analyst to import and view complex 3D FE blade slot models and to select individual FE faces or edges for inclusion in zones. It also supports surface damage anomaly distributions that are defined in terms of surface area or length (for application to FE surfaces and edges, respectively) that are currently under development by RISC.

Prior versions of DARWIN® included a capability for superposition of residual stresses associated with surface treatments with service stresses associated with two-dimensional (2D) FE model geometries. For DARWIN® 8.1, the surface treatment residual stress capability has been extended for use with 3D FE models. This enables the analyst to define manually a univariant residual stress gradient and to superimpose it with service stresses that are extracted along the crack path in 3D FE models. This new capability supports all of the univariant crack types that are currently available for 3D FE models in DARWIN®.

Finally, DARWIN® also includes a Fleet Assessment module that can be used for Continued Airworthiness assessments associated with FAA AC 39-8 - Continued Airworthiness Assessments of Powerplant and Auxiliary Power Unit Installations of Transport Category Airplanes. This module enables the analyst to use results from multiple DARWIN® runs to quantify risk factors and risk per flight values addressed in AC 39-8 for a fleet of aircraft. In previous versions of DARWIN®, risk values were reported on a component basis in which components that failed an inspection were removed from the population. However, aircraft fleet assessments are based on a population of aircraft in which components are replaced following a

failed inspection. DARWIN® 8.1 provides a new option for replacement of components that fail inspections to support fleet assessments in compliance with AC 39-8. The initial version supports replacement of an identical component following a failed inspection to quantify the additional risk associated with components that are replaced following an inspection.

The figures below illustrate some of the enhancements. Figure 19 shows how DARWIN® 8.1 can now assign inspections directly to the finite element (FE) model geometry. This enables automated assessment of risk with inspection for inherent anomaly materials. The image in Figure 20 shows a new capability for creating zones on surfaces and edges of 3D FE model geometries in support of AIA RISC development of a future FAA Advisory Circular (AC) for Blade Slot Assessments.

These enhancements map directly to future ACs planned by the FAA's Engine and Propeller Directorate (ANE). Benefits will accrue in the form of reduced risk of engine failures and fewer accidents, which in turn will lead to fewer injuries and fatalities. (Propulsion and Fuel Systems)

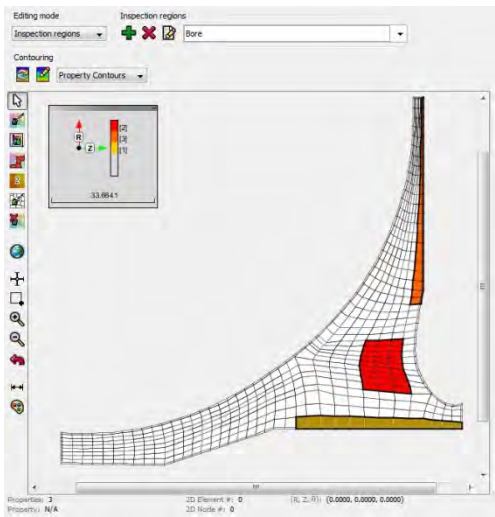

Figure 19: DARWIN® 8.1 can now assign inspections directly to the FE model geometry.

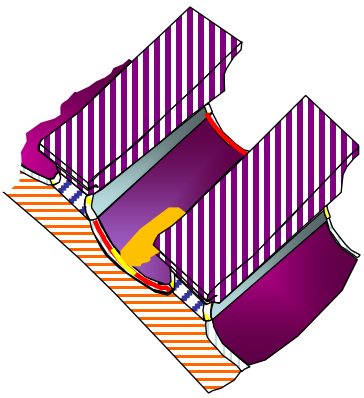

Figure 20: This image shows a new capability for creating zones on surfaces and edges of 3D FE model geometries.

Guidance for Automatic Dependent Surveillance – Broadcast (ADS-B) enabled Cockpit Display of Traffic Information (CDTI):

The FAA developed two significant documents that contain human factors guidance for Automatic Dependent Surveillance – Broadcast (ADS-B) enabled Cockpit Display of Traffic Information (CDTI) certification and operational approval. The first report, *The Usefulness of the Proximate Status Indication as Represented by Symbol Fill on Cockpit Displays of Traffic Information*, documented the results of experimental research with over 100 corporate and airline pilots, and found no advantage for the proximate status indication as represented by symbol fill, only a disadvantage. The second report, *Use of Color on Airport Moving Maps and Cockpit Displays of Traffic Information (CDTIs)*, documents issues related to color, which have been identified on current airport moving maps that show traffic information and Cockpit Displays of Traffic Information (CDTIs). This document also compiles FAA regulatory and guidance material, industry documents, and human factors research recommendations, which address the use of color. Both reports are intended to support the update of RTCA DO-317 Minimum Operational Performance Standards for Aircraft Surveillance Applications System, and FAA AC 20-172A, Airworthiness Approval for ADS-B in Systems and Applications. (Flightdeck/Maintenance/System Integration Human Factors Program)

Synthetic Vision Systems and Enhanced Flight Vision System (SVS/EFVS) Testing:

Synthetic Vision Systems and Enhanced Flight Vision System (SVS/EFVS) technologies have the potential to provide additional margins of safety for aircrew performance and enable operational improvements for low visibility operations in the terminal area environment with equivalent efficiency as visual operations. To meet this potential, the FAA conducted research for effective technology development and implementation of regulatory standards and design guidance to support introduction and use of SVS/EFVS advanced cockpit vision technologies in NextGen operations. Researchers delivered a report covering a fixed-base pilot-in-the-loop simulation test conducted at NASA Langley Research Center that evaluated the use of SVS/EFVS in NextGen low visibility approach and landing operations. Twelve crews flew

approach and landing operations in a simulated NextGen Chicago O'Hare environment. Various scenarios tested the potential for using EFVS to conduct approach, landing, and rollout operations in visibility as low as 1,000 feet runway visual range (RVR). In addition, the FAA tested SVS to evaluate the potential for lowering decision heights (DH) on certain instrument approach procedures below what can be flown today. Expanding the portion of the visual segment in which EFVS can be used in lieu of natural vision from 100 feet above the touchdown zone elevation to touchdown and rollout in visibilities as low as 1,000 feet RVR appears to be viable as touchdown performance was acceptable without any apparent workload penalties. A lower DH of 150 feet and/or possibly reduced visibility minima using SVS appears to be viable when implemented on a Head-Up Display, but the landing data suggests further study for head-down implementations. (NextGen - Air Ground Integration Human Factors)

Human Factors Issues Present in Current RNAV Operations:

The FAA completed analysis of Area Navigation (RNAV) approach and departure procedures in support of the AJI NAV LEAN team. In an effort to better understand the potential impact of increased RNAV usage, the FAA conducted a human factors safety assessment to identify key human factors issues present in current RNAV operations. The analysis found several key causal factors related to RNAV procedure design, controller-pilot communication, automation systems, and track deviations. Specific human performance concerns and mitigation strategies for each causal factor were developed. These results should drive requirements associated with implementation of future RNAV procedures. (ATC/Technical Operations (TO) Human Factors)

Air Traffic Control Tower Alerts Standard:

The FAA delivered the draft of FAA HF-STD-008 *Air Traffic Control Tower Alerts Standard* to the Program Management Organization Service Unit. The Program Management Organization's Specialty Engineering Team (AJM-352) sponsored research to develop a standard for alerts that will support development and acquisition of air traffic control systems in the tower cab. Alerts with consistent functionality, meaning, and presentation minimize distraction and workload. The standard specifies functional requirements, alert human interaction characteristics, and threshold levels for development of systems that use alerts to capture human attention in the tower cab. (ATC/TO Human Factors)

Jet Upset Recovery Training:

The FAA and human factors researchers integrated existing guidance, best practices, and other research information for jet upset/loss of control. This collection included causal and contributing factors, and identification of recommendations for training to mitigate jet upset in all phases of a potential event. Additionally, researchers developed a taxonomy defining training priorities and documented training objectives and outcomes in air carrier operations. Results of this research are intended to support the FAA in developing a new AC on upset recovery training as well as provide data to support revisions to AC 120-109, *Stall and Stick Pusher Training*. The

research will also support development of future guidance material for the design of systems, procedures, and training. (Flightdeck/Maintenance/System Integration Human Factors)

Human Factors Guidance for Automatic Dependent Surveillance – Broadcast (ADS-B):

The FAA completed research providing human factors guidance for Automatic Dependent Surveillance – Broadcast (ADS-B) enabled CDTI certification and operational approval. The second report (completed in FY 2013), entitled *Use of Color on Airport Moving Maps and Cockpit Displays of Traffic Information (CDTI)* documents issues related to color, which have been identified on current airport moving maps that show traffic information and CDTI. The report also compiles FAA regulatory and guidance material, industry documents, and human factors research recommendations, which address the use of color. The report is intended to support update of RTCA DO-317 *Minimum Operational Performance Standards for Aircraft Surveillance Applications Systems*, and FAA AC 20-172A, *Airworthiness Approval for ADS-B in Systems and Applications*. (Flightdeck/Maintenance/System Integration Human Factors)

Flight Deck Displays and Controls:

The FAA and its human factors researchers completed final coordination with sponsors for developing a report entitled *Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls*. This document is intended for FAA Flight Test Pilots, Engineers, and Human Factors Specialists who work in the field doing hands-on evaluations of avionics. It will serve as a single comprehensive source for human factors regulatory and guidance material related to flight deck displays and controls, and will facilitate identification and resolution of human factors issues with these systems. Chapters address key human factors/pilot interface issues seen across multiple FAA Aircraft Certification projects including display hardware, depiction, and organization of electronic information elements and features (e.g., symbology, labels, and use of color), considerations for alerting, controls, design philosophy, workload, human error, and automation. Appendices provide a variety of sample checklists, testing scenarios and procedures, key reference lists, and "gold star" human factors research reports, which have proven to be useful to both the FAA and industry representatives who evaluate and approve flight deck displays and controls. (Flightdeck/Maintenance/System Integration Human Factors)

Controller Pilot Data Link Communications:

The FAA and human factors researchers completed the NextGen integrated air and ground HITL simulation referred to as "Flight Crew and Air Traffic Controller Interactions when Conducting Interval Management Utilizing Controller Pilot Data Link Communications." The majority of pilots and controllers found the integration of the NextGen capabilities of Interval Management (IM) and Controller Pilot Data Link Communications (CPDLC) acceptable. Controllers seemed to have more difficulty with traffic with a mix of aircraft equipage for IM than they did for a mix of aircraft equipage for CPDLC. Both pilots and controllers found the procedure for accepting

an IM clearance to work well for CDPLC. However, some concern was expressed for using the same procedure for voice communications. Both pilots and controller preferred CPDLC over voice communications. However, both recognized that voice is still necessary for urgent instructions, such as some IM terminations.

Results also indicated that the necessary messages were available for IM as tested, and the CPDLC performance requirements (i.e., Required Communication Performance [RCP180]) were achieved. CPDLC also reduced the time both controllers and pilots spent on the voice frequency. Overall, pilot and controller responses indicated that the IM clearance was well phrased but that shortening it would improve acceptability. The FAA intends for the results of this research to provide scientific and technical information, including recommendations, for use by certification and flight standards specialists in the FAA Aviation Safety Organization. The Aviation Safety Organization is charged with developing regulatory guidance to enable approval of new flight deck avionics and functions. The research will also assist the Air Traffic Organization's ADS-B and DataComm program offices, and will provide information necessary for approval of flight deck procedures that operators propose to achieve NextGen capabilities. (NextGen - Air Ground Integration Human Factors)

Effects of Weather Presentation Symbology on General Aviation (GA) Pilots:

The Weather Technology in the Cockpit (WTIC) program studies the use of new weather technologies and presentations to improve pilot situation awareness and safety. Currently, there are no FAA or industry standards for the presentation of weather information in the cockpit, which can result in symbology variations among vendors and increases the potential that a system may provide ineffective or misleading information. The current project explored the effects of cockpit weather-presentation symbology on GA pilot weather avoidance, weather system usage, and cognitive workload. Twenty-five volunteer instrument-rated GA pilots participated in HITL simulations at the FAA William J. Hughes Technical Center (WJHTC). The volunteers flew a single-engine GA simulator under Visual Meteorological Conditions (VMC) and Instrument Meteorological Conditions (IMC) using three different weather presentation symbologies. The underlying weather data were identical in the three presentations, but each used different symbols and colors (See Figure 21 below). The weather presentations were based on three commercially available symbology sets. In addition to a moving geographical terrain map and aircraft position symbol, each weather presentation contained precipitation information, a meteorological report, significant meteorological information, and lightning information. The study collected a variety of human factors and system performance data, including pilot deviations to avoid weather, controller-pilot voice communications, altitude and heading changes, visual scan patterns, and cognitive burden.

The three weather presentation conditions showed no differences in keeping a safe distance from precipitation, communications, or altitude and heading changes. However, the three conditions led to demonstrably different pilot behaviors in weather-related deviations, visual scanning, and cognitive workload. Based on the weather presentation, the pilot groups chose different deviation routes from origin to destination. For the visual scanning behavior, we found group differences in scan patterns that included an increased number of fixations and saccades on the weather presentation and cockpit glass display. Future studies will examine whether these

differences in pilot behavior lead to operationally important differences in system performance. (NextGen – Weather Technology in the Cockpit (WTIC))

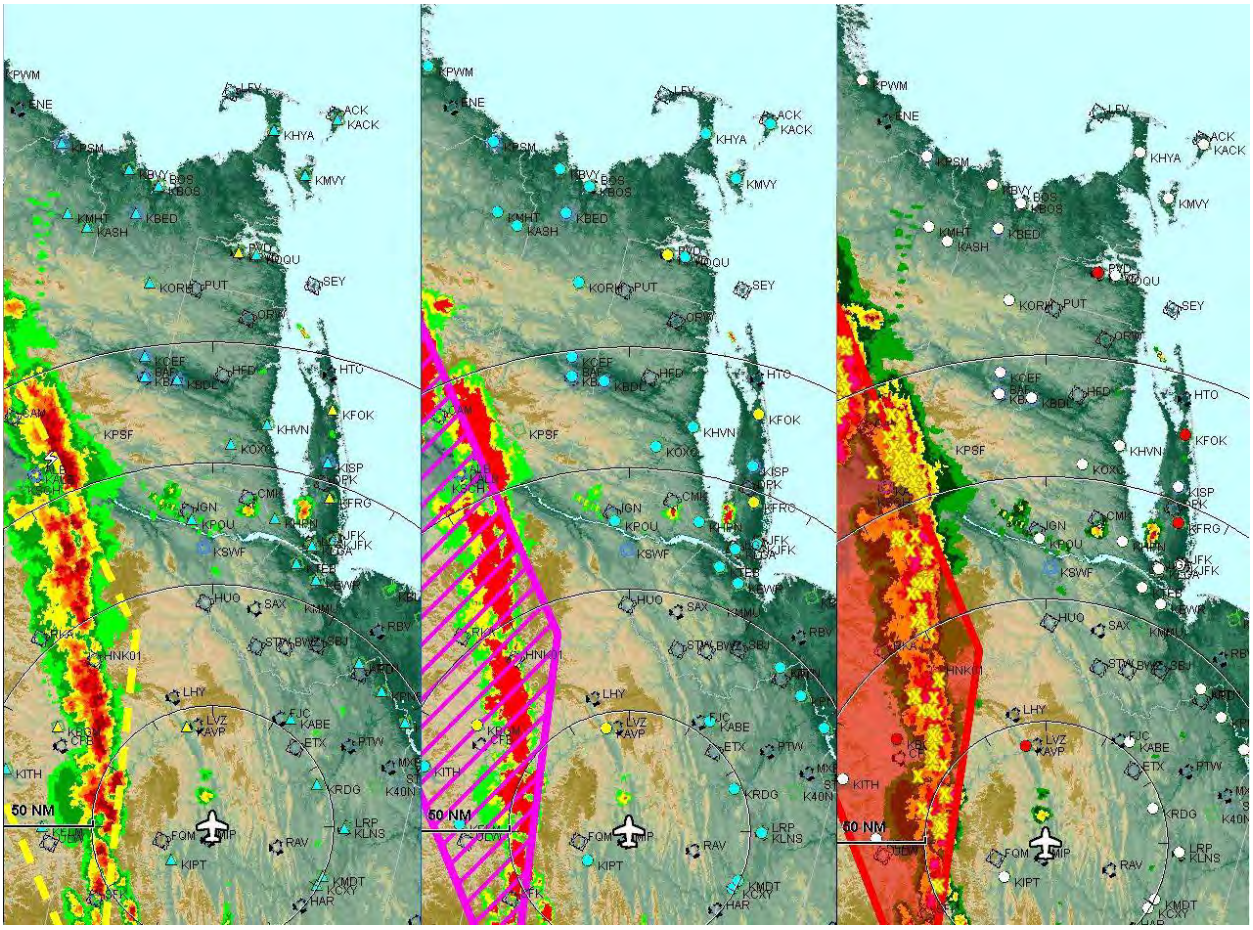

Figure 21: Three weather symbology designs used in the study.

Automation Reliability Meta-Analysis and Conflict Probe Reliability Analysis:

Research was done to empirically determine a level of conflict detection accuracy for the En Route Automation Modernization (ERAM) Conflict Probe that would be acceptable for display on the radar controller side (R-side) and to assess the probe's observed accuracy in relation to that criterion. FAA engineering research psychologists performed a series of analyses to assess the following two questions:

1. Is it possible, based on the existing human factors literature, to define a minimum level of decision-support automation accuracy required to improve joint human-automation performance?

   Research in human factors and human-automation research shows that decision-support tools with a reliability level below 0.65 do not improve joint human-automation performance. That is, when the tool is less reliable than that value, the human operators

perform just as well alone as they do using the tool. For the en route ATC conflict probe, reliability is calculated as the number of correctly detected conflicts plus the correctly rejected encounters divided by the total number of encounters. Unfortunately, many publications' studies of conflict probe use sets of encounters (i.e., the denominator) which controllers do not consider to be potential conflicts. That is, if the closest point of approach between two aircraft is several multiples of the minimum required separation, controllers do not consider the two to be an operationally significant pair. The result is an inflated reported reliability value (higher than 0.90) that gives a misleading impression of how reliable the tool is. Until an operationally relevant encounter set is created, it is not possible to determine if the en route conflict probe exceeds the 0.65 reliability level. To provide the FAA with the tools to create such an operationally relevant encounter set, an interactive, online survey has been created that will determine what types of encounters are truly relevant to en route controllers.

2. How well, according to appropriate accuracy metrics, can the Conflict Probe function of ERAM predict aircraft-to-aircraft conflicts?

   Research shows that a metric that is less sensitive to a large number of correct rejections is the Positive Predictive Value (PPV). The PPV is easily explained to a layperson, because it is the ratio of the correct detections of a conflict and the total number of alerts. Currently, the en route conflict probe - excluding conflict probe alerts for uncleared portions of the trajectory (also known as muted alerts) - has a PPV of approximately 1:10. That is, for every correct detection of a conflict, the system will generate nine false conflict probe alerts. Muted alerts account for approximately half of all false conflict probe alerts; therefore, the PPV based on all alerts is approximately 1:20. The ATO has decided that it will no longer notify controllers of muted alerts because so many of them are false, potentially resulting in a reduction of 50% of all false alerts. Under Trajectory Based Operations - Separation Management - Modern Procedures research, modification to conflict probe adherence bounds and algorithmic improvements in the en route conflict probe have further reduced the number of false alerts. The resulting PPV based on the remaining alerts is about 1:5.

The researchers conducted a meta-analysis of 12 studies from the human factors literature, studying the effect of imperfect automation on system performance. This analysis quantified the relationship between several accuracy metrics and the corresponding automation effect size (i.e., performance of a human-automation system, as compared to the human operating without an automation aid). The automation reliability metric (overall percent correct) exhibited a statistically significant positive relationship with effect size. We found a crossover point of 0.65 reliability, with automation accuracy greater than this value likely resulting in performance benefits. This is similar to the value obtained by other researchers using a different methodology. Other metrics commonly used to measure the benefits of automation were also explored, including hit and false alarm rates from signal detection theory (SDT), and Positive Predictive Value (PPV), an operationally meaningful metric commonly used in clinical work, which indicates what proportion of reported alerts are valid. None of the other metrics showed reliable relationships with the performance benefit realized from the automation.

The first accomplishment of this research is that rather than using a subjective rejection of integration of conflict probe on the radar display, the agency now has a reliability requirement that it can use to determine if the conflict probe decision support tool will result in an improvement in human-automation performance. When used with an operationally relevant aircraft-to-aircraft encounter set, the reliability measure will not only be able to provide evidence that a conflict probe enhancement performs as well or better than the legacy version, but will also show if the enhancement will result in an improvement in combined human-automation performance. The second accomplishment is that PPV - rather than reliability - can be used as a simpler method for explaining and comparing conflict probe performance. (ATC/TO Human Factors)

Self Separation: Human Factors Evaluation of Conflict Probe Location and Format:

The Self Separation program seeks to guide decisions about possible future modification to the En Route Automation Modernization (ERAM) system used in en route air traffic control. The current study investigated the characteristics of conflict probe notifications. A conflict probe projects aircraft positions into the future and notifies controllers when the potential for a separation violation exists. In the current system, conflict probe information is presented only to the Data Controller, known as the D-side. The study examined whether conflict probe information should also be presented to the Radar Controller, known as the R-side as well as how it should appear. Volunteer en route controllers completed simulation scenarios at the WJHTC. The scenarios included moderate to high-traffic levels and varied where and how the conflict probe information appeared: (a) the current list-based presentation on the D-side only, (b) the list-based presentation on both the R-side and the D-side, and (c) the list-based presentation on both the R-side and D-side plus a new presentation in the aircraft data blocks on the R-side.

Two other test conditions used a modified conflict probe algorithm that presented notifications differently depending on whether the aircraft trajectories were predicted to come within six nm of one another within the next six-minute period or not. In both of these conditions, notifications were presented on both the R-side and D-side displays. However, in one condition, only the most imminent alerts were presented on the R-side. In addition, the formats used to present the information differed between the two conditions. One condition used color-coding to indicate whether the conflict was predicted to occur within the next six minutes (red) or not (yellow), and the other condition used flashing to indicate whether the conflict was predicted to occur within the next six minutes (flashing) or not (steady state). The findings showed no significant differences across test conditions for the basic ATC capacity, efficiency, and safety measures. Eye-tracking data also did not reveal differences across the test conditions. With respect to the conflict probe notifications, R-side controllers selected and viewed more notifications when the conflict probe algorithm presented only the most imminent notifications. The participants' subjective impressions also indicated that they found it useful to provide conflict probe notifications on the R-side display, but only when the most imminent notifications were presented. The participants preferred having the notifications presented in the data block rather than in a list and preferred color-coding of the notifications rather than flashing. Based on these results, providing conflict probe information for more imminent alerts in the data blocks of

aircraft on the R-side display appears useful for en route radar controllers. (NextGen – Self Separation Human Factors)

Staffed NextGen Tower Human-in-the-Loop Camera Integration Evaluations:

The Staffed NextGen Tower (SNT) concept entails a shift from the current model of tower operations that relies primarily on the out-the-window view to a model that places greater or total reliance on surveillance to provide tower control services. The SNT concept has been evaluated as both a supplemental and contingency concept. For example, the FAA expects that SNT may be able to increase capacity at night or during periods of inclement weather when impaired visual conditions might otherwise lead to delays or reduced airport access levels. Such a shift may also enable controllers to perform remote operations from a ground-level facility for contingency operations. In the current study, engineering research psychologists from the WJHTC attempted to determine what role cameras might play in augmenting surveillance displays in an SNT environment. The researchers also examined whether cameras with alerting logic would increase controller situation awareness of off-nominal events. The results showed that when an aircraft attempted to land with its wheels up, the controllers were able to consistently detect the off-nominal condition using the cameras and could not detect these events relying solely on surveillance displays. Other off-nominal conditions were generally detected using the surveillance display or the audible alerts, and not by using the camera views. For example, when an aircraft failed to conform with its taxi instructions, controllers successfully identified the off-nominal using only the surveillance display, which is an indication that the controllers did not need cameras or alerts to detect this event. However, when alerting was available, the means of detection were split between the surveillance display and the alerts, indicating that the controllers did use the alerts when they were available. This study demonstrates the potential usefulness of cameras in specific conditions for possible future SNT implementations. The feedback received from controllers during the study regarding camera coverage, display configuration, and control functionality will guide the development of the camera user interface for future SNT studies. (NextGen – ATC/TO Human Factors (Controller Efficiency and Air Ground Integration))

Aviation Safety Information Analysis and Sharing System (ASIAS):

The FAA expanded the Aviation Safety Information Analysis and Sharing (ASIAS) system to GA domain and started expanding ASIAS to the rotorcraft domain. For the GA domain, the FAA developed the National General Aviation Flight Information Database (NGAFID), which is an information system to collect, archive, and disseminate Flight Data Monitoring (FDM) parameters recorded in GA aircraft operations. FDM allows for proactive assessment and mitigation of risks in GA operations. The NGAFID currently contains FDM data collected from the Cessna 172 aircraft fleets of the University of North Dakota and Embry-Riddle Aeronautical University. The NGAFID also has the capability to monitor essential exceedances with trending on the following: G-loads (longitudinal, lateral, and vertical); airspeed (min/max); excessive bank angle; excessive pitch angle; maximum altitude; maximum oil temperature; oil pressure (min/max); maximum revolutions per minute; minimum fuel quantity; and maximum cylinder head temperature (CHT). For the rotorcraft domain, through partnerships with the GA COE

(PEGASAS), industry partners, helicopter operators and manufacturers, avionics manufacturers, and other stakeholders, the FAA has established a research methodology and framework for Rotorcraft ASIAS that will be able to efficiently and effectively collect, provision, and analyze FDM data from multiple sources. The research team also completed preliminary analysis of simulated FDM data parameters and detected several flight parameter exceedances via a data-driven approach and started to examine the baseline state of helicopter FDM. (System Safety Management)

Electrical Infrastructure Research Team Study:

The Electrical Infrastructure Research Team (EIRT) study tested and evaluated six representative architectures for airfield lighting infrastructure that can convey power to LED fixtures more efficiently and with improved capability than the present 6.6 amp circuit. The architectures evaluated by the FAA included three developed by industry, one from a former FAA research effort, and two that were the result of a current FAA research project. Activities included an investigation and an extensive testing phase at the WJHTC Test Bed, followed by evaluation of the results by the EIRT team data. The EIRT team saw similarities in the architectures, and two main categories of architectures with common characteristics emerged: Vault Centric Architecture and Fixture Centric Architecture. Vault Centric Architecture is an airfield lighting architecture that directly controls the fixture intensity from the power source in the vault.. The Series PWM and Series Sinusoidal are vault centric. This architecture requires that the current delivered to the fixture is uniform and well controlled to provide uniform intensity control. Circuit conditions or layout can impact the distribution of power with this architecture, but the fixtures cannot compensate this effect. Fixture Centric Architecture is an airfield lighting architecture where fixture intensity is controlled by the fixture. The Smart Series, Smart Parallel, ASK, and FSK architectures are fixture centric. This architecture decouples the fixture intensity from the circuit current or voltage. The desired fixture intensity is conveyed to the fixture using either simple or advanced communication techniques. Fixture intensity performance is the most precise, supporting virtually any practical dimming ratio and not directly affected by circuit conditions, unless the conditions prevent communication to the fixture or prevent sufficient power from reaching the fixtures. The recommendations identified to date are based on the small scale testing conducted. Further steps involve large scale validation testing on the series vault centric and fixture centric architectures to further refine the architectural design and address any issues that could not be validated in the small scale environment. This will include development of prototype hardware and instrumentation, and the installation of the resulting refined candidate systems in a representative airport environment to provide exposure to real world conditions. (Airport Technology Research Program – Safety)

NextGen Flight Deck Human Factors Considerations:

Although data communications (DataComm) is one of the FAA key technologies supporting the transition to NextGen, human factors experts have anticipated potential implementation challenges. For example, DataComm equipment may not be integrated with flight management systems (FMS). The crew will be required to read the DataComm messages, interpret them,

make decisions with respect to the flight, and then make the appropriate FMS input. The time required for such actions might preclude use of DataComm in certain flight regimes and operating domains. Even when DataComm and FMS flight deck systems are fully integrated, four-dimensional (4D) trajectory clearances with multiple waypoints and required times of arrival (RTA), and complex Dynamic Required Navigation Performance (DRNP) clearances could pose challenges to the flight crew. There is significant concern that textual clearances for complex 4D trajectory information may be difficult for pilots to interpret quickly and without error. This study addressed the challenge by evaluating concepts for alternative flight deck displays with graphics, hybrid text and graphics, and other formats that could be integrated with existing navigation displays and with new DataComm displays. (NextGen - Air Ground Integration Human Factors)

ASIAS Innovations: Traffic Alert and Collision Avoidance System (TCAS) Simulator:

To aid in the tracking and trending of Traffic Alert and Collision Avoidance System (TCAS) Resolution Advisory (RA) activity in the NAS, the ASIAS program has developed a tool that merges National Offload Program (NOP) radar surveillance data with a TCAS II Version 7.0 logic simulator. The purpose of a TCAS logic simulator is to determine which aircraft equipped with TCAS (ownship) would have received a TCAS RA due to proximity to another aircraft called an intruder. An intruder aircraft does not have to be TCAS-equipped. The TCAS II logic simulator pulls radar track data from the NOP sensors and performs a pair-wise track comparison between any pair of aircraft where at least one is known (or assumed[6]) to have a TCAS II system.

NOP data is secondary surveillance radar data for all transponder-equipped aircraft within sensor radar range that is recorded, collected, and archived at FAA facilities. NOP radar data is recorded, collected and archived for both Terminal Radar Approach Control (TRACON) and Air Route Traffic Control Center (ARTCC) facilities, but the TCAS logic simulator only uses the TRACON radar data because the ARTCC radar data is sampled at a rate of approximately 12 seconds, which can lead to data quality issues. To obtain good results from the TCAS logic simulator, the TRACON NOP radar data is smoothed and re-sampled at a 1Hz frequency.

The TCAS simulator uses an algorithm that assesses four parameters and TCAS alarm thresholds to determine when two aircraft were close enough to result in a TCAS RA. To have a TCAS RA, both a range threshold and a vertical threshold have to be exceeded. The TCAS logic simulator approximates TCAS behavior, and therefore cannot confirm or refute RA scenarios with perfect accuracy. The TCAS II Version 7.0 logic simulator tool was used to analyze NOP

[6] The Code of Federal Regulations (CFR) Title 14 Part 121.356 requires TCAS II logic on any turbine-powered aircraft with a maximum take-off weight of at least 33,000 pounds or any passenger aircraft with more than 30 seats. The radar data specifies the aircraft type for each track, and that information is cross-referenced with a database to determine which aircraft are required by the CFR criteria to be TCAS II equipped. The TCAS simulator assumes that all radar tracks on aircraft types that are required by the CFR to be TCAS II equipped are TCAS II equipped.

data collected between August 1, 2010, and May 28, 2013, resulting in over 270,000 simulated TCAS RA event records.

The ASIAS Program has also developed the TCAS Exploration Dashboard (TED), a tool for the discovery of potential safety vulnerabilities within the NAS. TED was built using Tableau® software and leverages the results in the TCAS logic simulator database. TED joins each TCAS RA event with other data sources available to MITRE, including weather, runway, procedure, and Air Traffic Safety Action Program (ATSAP) text reports. TED has user-defined filters and can calculate the TCAS RA event rate based on the chosen filters. Using the location of each TCAS RA event, TED creates visual hotspot maps to show areas with a high number of TCAS RA events. The hotspot maps are filterable by date, airport, procedure, runway, and altitude, among other parameters.

The TCAS logic simulator has been integrated into the Terminal Area Route Generation and Traffic Simulation (TARGETS) capability to give users the ability to check if any two tracks were close enough to receive an RA; Figure 22 shows TCAS RAs predicted by the TCAS logic simulator. ASIAS is currently developing a capability to take two procedures and to determine if there is a flight scenario involving the two procedures that could cause a TCAS RA. This approach gives a prospective safety view on potential future issues and can be used to collaborate with airspace and procedure designers to alleviate safety risks. (Safety System Management)

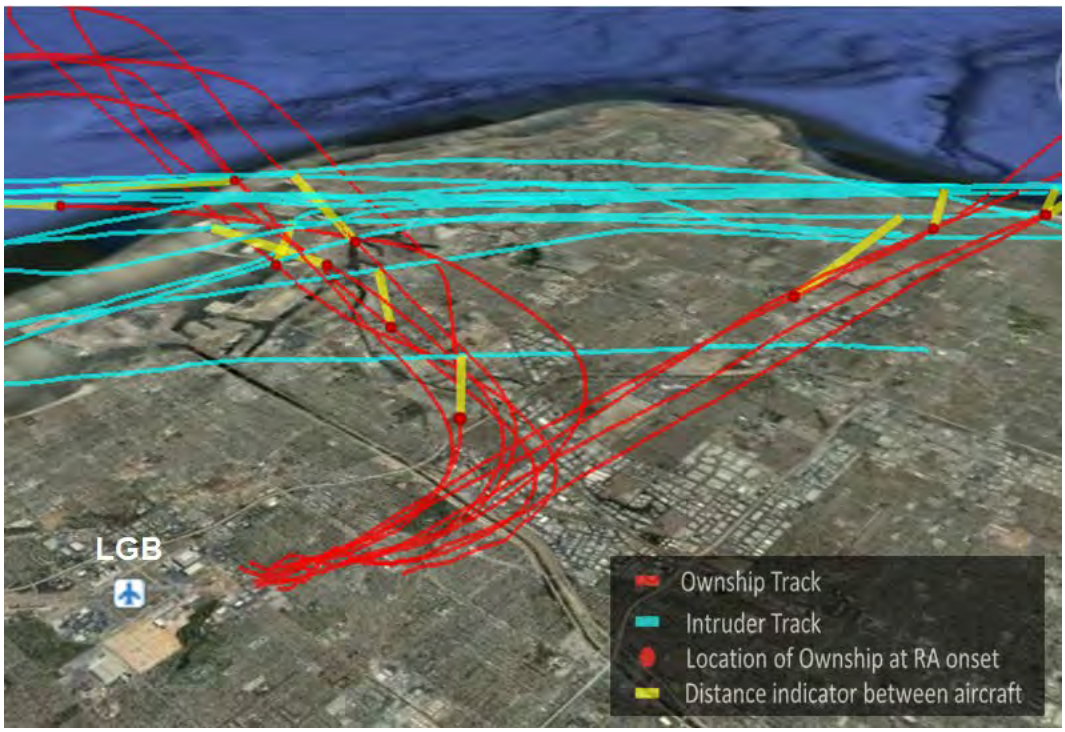

Figure 22: TCAS RAs near LGB, as predicted by TCAS logic simulator using NOP data

Safety System Management for CFR Part 141 Pilot School:

The FAA has issued a notice of proposed rulemaking to require CFR Part 121 operators to establish a Safety Management System (SMS). SMS is a formalized and proactive approach to managing safety risks, which includes an organization-wide safety policy, formal methods of identifying, analyzing, and mitigating hazards, and an organization-wide emphasis on promoting a safety culture. SMS for air operators is comprised of four key components: Safety Policy, Safety Risk Management (SRM), Safety Assurance, and Safety Promotion. These components help Part 121 air carriers effectively integrate formal risk control procedures into normal operational practices thus improving safety for all U.S. Part 121 operators. The FAA estimates the cost of the SMS proposed rule is $390 million, while estimated benefits total $470 million.

While SMS is underway in the commercial aviation, this program is not yet widespread in GA. There are many reasons for this, not the least of which is the complexity and heterogeneous nature of the GA sectors.

The University of North Dakota (UND), through the COE for General Aviation Research (CGAR), conducted research to examine the feasibility of designing and implementing a SMS for a CFR Part 141 Pilot School (Part 141). The goal of the research was to design and implement a Part 141 SMS program based on existing FAA guidance for FAR Part 121 air carriers and Maintenance Repair and Overhaul Operations. Considerations were given to the various levels of complexities associated with large and small Part 141 operators.

The resulting report provides detailed information and guidance on how to establish and implement an effective Part 141 SMS program. The report also includes the following documents to assist a part 141 certificate holder in developing the SMS framework:

- SMS Part 141 Preliminary Gap Analysis
- SMS Part 141 Detailed Gap Analysis
- SMS Part 141 Implementation Plan Tool
- Generic SMS Manual for a Part 141 Pilot School
- Generic SMS Risk Management Tool
- Safety Assurance Tool
- Proposed changes to the 14 CFR Part 141 Pilot Schools

Based on this research, UND has developed and implemented a SMS program for its flight training program. Currently there are only four Part 141 pilot schools voluntarily implementing an FAA recognized SMS. However, the University of North Dakota Aerospace Department is currently the only Part 141 pilot school to achieve Level 3 status (Levels go from 1 to 4) from the FAA National SMS Program Office. The SMS levels indicate progress of an organization in achieving SMS objectives. Level 3 implies that the school has a fully functioning SMS that has processes in place that are proactive, i.e., looks at potential future risks. UND Aerospace at Phoenix has successfully transitioned its single-engine fleet to Cessna 172s in 2013 using the SMS program developed based on the SMS for Part 141 research. Figure 23 shows a student pilot doing a preflight check. (Safety System Management)

Figure 23: A student pilot is going through the preflight checklist at UND Aerospace's Phoenix location.

Unmanned Aerial Systems (UAS) Program — Communication Research:

The FAA conducted research to determine acceptable time-critical low latency response times for UAS control systems with low levels of autonomy. Researchers modeled and simulated UAS control architectures to assess its ability to safely manage the trajectory of an unmanned aircraft during critical phases of flight, despite potential delays between control station control inputs and aircraft responses. Results of the first HITL simulation indicated that UAS pilots experienced more difficulties with control latencies over 494 miles; that pilots rated aircraft handling as "inadequate" in crosswinds with 750 miles control latency; and that, as control latency increased, (1) aircraft deviated more from traffic pattern during takeoffs, but did not deviate more from runway centerline on landings; (2) pilot rudder inputs increased significantly; (3) force at touchdown increased; and (4) pilots indicated need for more go-arounds. This information will support the UAS Integration Office during the development of the Communications and Control Minimum Operational Standards.

A study was conducted to assess UAS communication and delay values associated with step-ons. The UAS Integration Office needed to determine the maximum acceptable communication delay between the air traffic controllers and UAS pilots during the associated step-on(s) communication process. Results indicated that one-way communication delays should be less than 400 ms for both manned and unmanned aircraft. This information will support the development of the Communications and Control Minimum Operational Standards currently under development by RTCA Subcommittee 228. The outcome of this research supports development of voice communication performance requirements concerning step-on(s).

The FAA completed a task to study UAS during contingency situations, such as lost link. Existing data from prior FAA UAS studies was collected and reviewed for use in developing simulations. The UAS Integration Office needs to examine UAS specific contingency operations in various classes of airspace and the associated impacts to safety and efficiency of the NAS. This research will contribute to the identification of standards for ATC while handling UAS under abnormal flight conditions. Identification of acceptable procedures during contingency operations will lead to development of UAS operating standards. (Unmanned Aircraft Systems Research)

Aviation Weather Demonstration and Evaluation Services:

The WJHTC Weather Engineering and Evaluation Branch designed and implemented the Aviation Weather Demonstration and Evaluation (AWDE) Services Concept and Product Assessment Capability in FY 2013. This capability is a highly configurable user/software/hardware assessment space with multiple user workstations, servers, storage arrays, and presentation platforms. Both weather and aircraft data are collected for use in assessments as appropriate.

The AWDE Concept and Product Assessment Capability allows the FAA to perform initial assessments of new and emerging aviation weather concepts and capabilities with end-users and in collaboration with developers from aviation weather research laboratories and industry. Assessments target usability, integration issues and preliminary analyses of NAS operational impacts as appropriate. Outputs from AWDE contribute to defining preliminary requirements, validating research, and identifying realistic alternative solutions for NextGen's aviation weather concepts and capabilities. AWDE Services are comprised of the following:

- Defined approach for cost estimation, planning, and conduct of demonstration and evaluation services
- Access to SMEs in HF, Meteorology, Engineering, Computer Science, and CM
- Ability to access, archive, and retrieve weather data
- Flexible, managed laboratory environment with connectivity to multiple laboratory environments

AWDE Services is currently assessing new concepts in the areas of Weather Technology in the Cockpit, Turbulence, and Emergency Management Services weather platforms. (Weather Program)

Avoiding In-Flight Icing Conditions:

According to NTSB data, in-flight icing causes more than 25 accidents annually, with more than half resulting in fatalities and destroyed aircraft. Annually, this equates to more than $100 million in injuries, fatalities, and aircraft damage. To address this problem, the FAA's Aviation Weather Research Program (AWRP) developed the Current and Forecast Icing Products (CIP and FIP) which provide more accurate and timely diagnoses and forecasts of atmospheric

conditions leading to ice accretion on aircraft during flight. After transitioning to the National Oceanic and Atmospheric Administration (NOAA), CIP and FIP were implemented operationally on the Web-based Aviation Digital Data Service (ADDS) at the NOAA Aviation Weather Center (AWC) in Kansas City.

In FY 2013, the Weather Program upgraded the CIP and FIP algorithms to meet NextGen requirements of a High Resolution diagnoses and forecast of atmospheric conditions conducive to aircraft icing. The upgraded algorithms, also known as CIP/FIP High Resolution (HiRes) improve the horizontal and vertical resolution and extend the forecast from 12 hours to 18 hours with a goal of further enhancing safety of flight and meeting NextGen requirements. A Quality Assessment and Technical Review Panel were conducted to assess the scientific validity and goodness of the new HiRes products, and a Safety Risk assessment is planned. Figure 24 sows a a plot of HiRes CIP data. Finally, an evaluation and demo of operational relevancy and suitability is being conducted at the AWC Testbed. CIP/FIP HiRes are anticipated to become available to NAS Users on operational ADDS by the end of the 4th quarter of FY 2014.

These automated algorithms gather real-time information from numerous data sources including satellites, radars, weather models, surface stations, and pilot reports, and determine the probability of encountering icing, its expected severity, and the likelihood of large droplet icing conditions. These capabilities are especially beneficial to commuter and GA aircraft without ice protection and those that fly at relatively low altitudes, less than 24,000 feet, where they are more likely to encounter atmospheric conditions conducive to icing. In addition to availability on ADDS for NAS users, CIP and FIP are also used by NWS forecasters to prepare FAA mandated forecast products. (Weather Program)

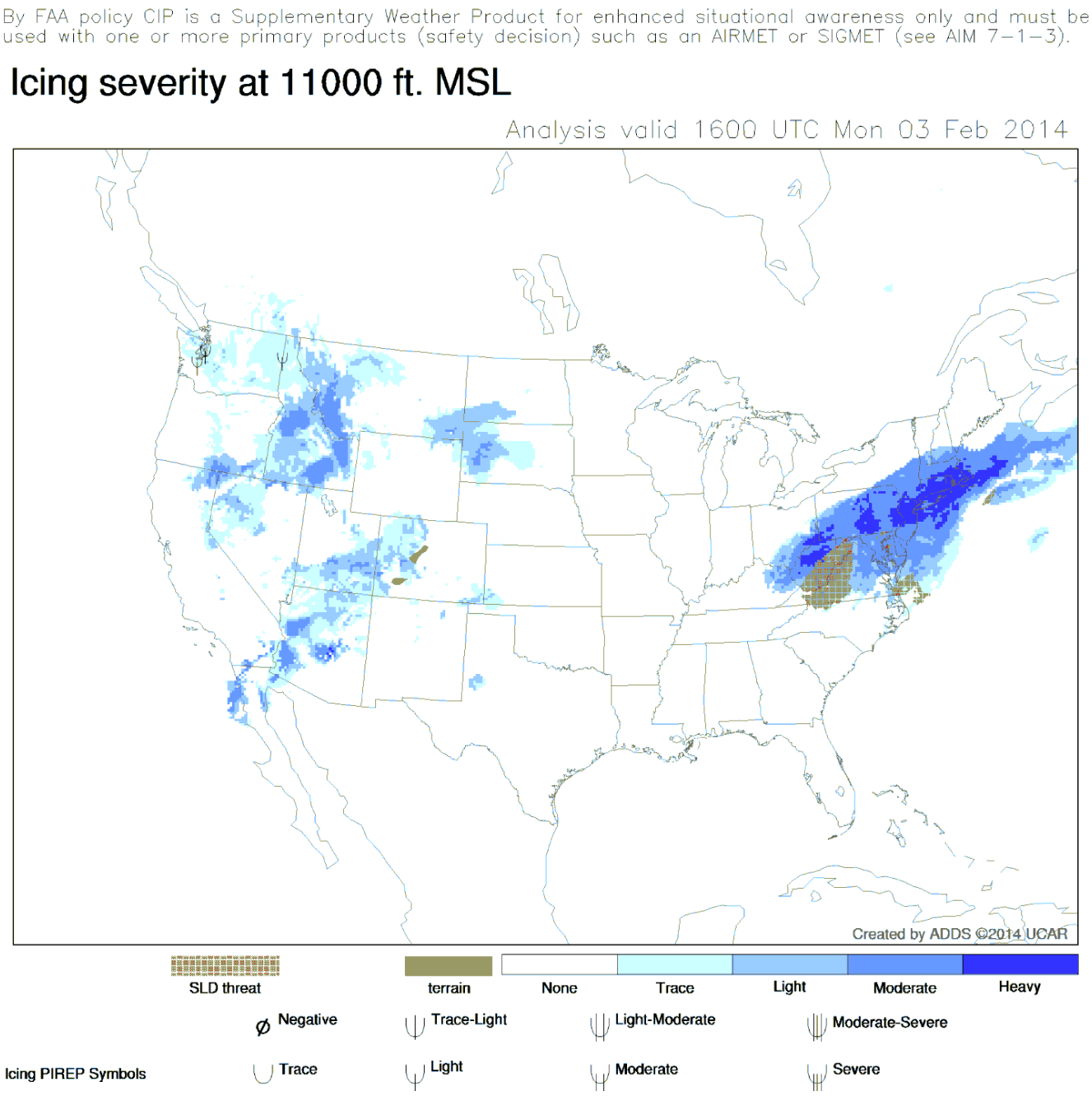

Figure 24: HiRes CIP showing severity

<u>WTIC Aeronautical Information Services and Meteorological Data Link Services Modeling Analysis:</u>

The availability of highly reliable, high-throughput, and low-cost wireless aircraft connectivity is growing rapidly. Ground-based technologies and systems have far outstripped airborne capabilities in both speed and sheer breadth of available functionality. Certification and approval techniques for airborne systems and capabilities have remained reactionary to the demand rather

than leading the way. Due to the rapid advances in digital data exchange technology it is a challenge to maintain up-to-date standards and guidance. Analyses were done to support the ongoing standardization activities in RTCA Special Committee 206 (SC-206) to develop Aeronautical Information Services (AIS) and Meteorological (MET) Data Link Services.

The FAA developed three data link models using the OPNET simulation tool to illustrate the quantitative phase of the process developed within SC-206 for determining suitable delivery methods for current and future AIS and MET applications and uses. The first model developed was a generic satellite communication (SATCOM) in the K_u frequency. The use case transmitted data from aircraft (downlinked) to characterize the atmospheric conditions. The second model was a generic terrestrial air-to-ground (A/G) model based on Code Division Multiple Access (CDMA) 2000 Evolution-Data Optimized Revision A Standard (Third Generation Cellular). The use case also downlinked data to characterize the atmospheric conditions. The third model developed was a generic SATCOM in the K_u frequency for AIS and MET ground-to-aircraft (uplink) use case. In this use case, the flight crew establishes a contract to receive automatic AIS and MET updates from the ground, based on the specified contract criteria. Figures 25 and 26 illustrate the data link models.

The model descriptions, use cases, and analyses are included in the RTCA document entitled *Aeronautical Information Services (AIS) and Meteorological (MET) Services Architecture Delivery Recommendations*. The results of these analyses will enable greater flexibility for the review and operational approval of systems delivering AIS and MET data services to aircraft cockpits. (Weather Technology in the Cockpit)

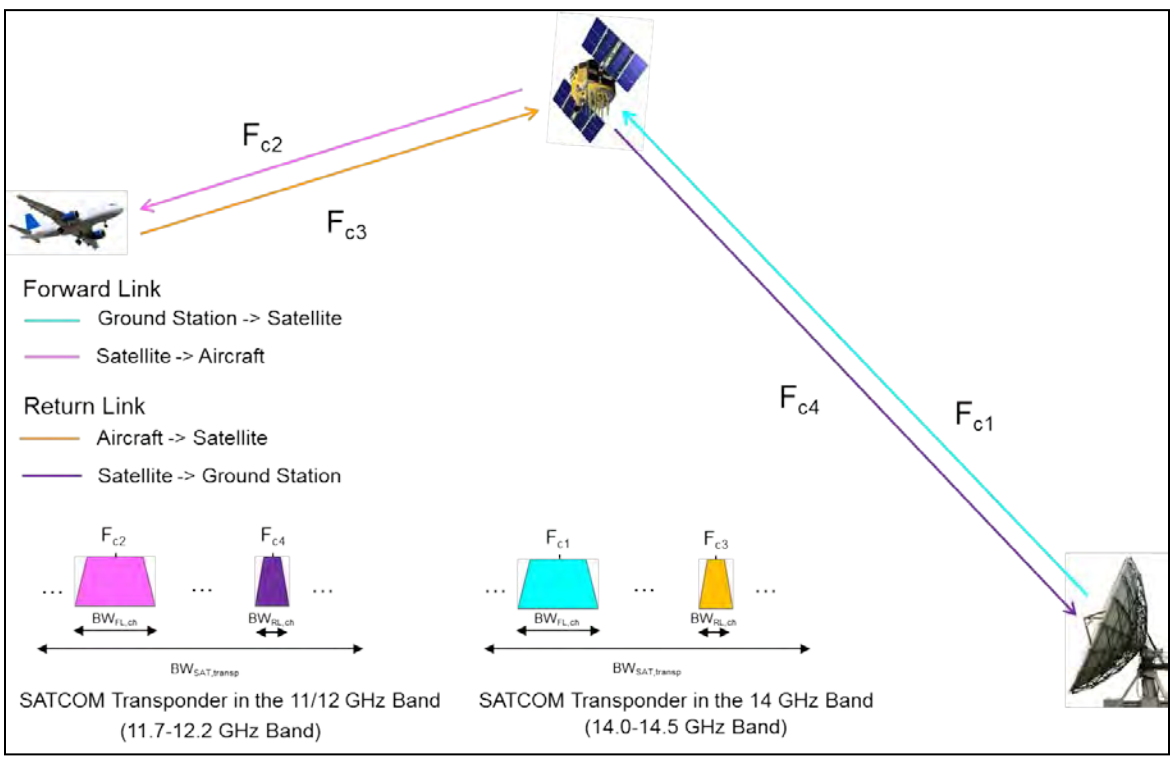

Figure 25: Model 1 and 3 illustration of SATCOM links as K_u-band

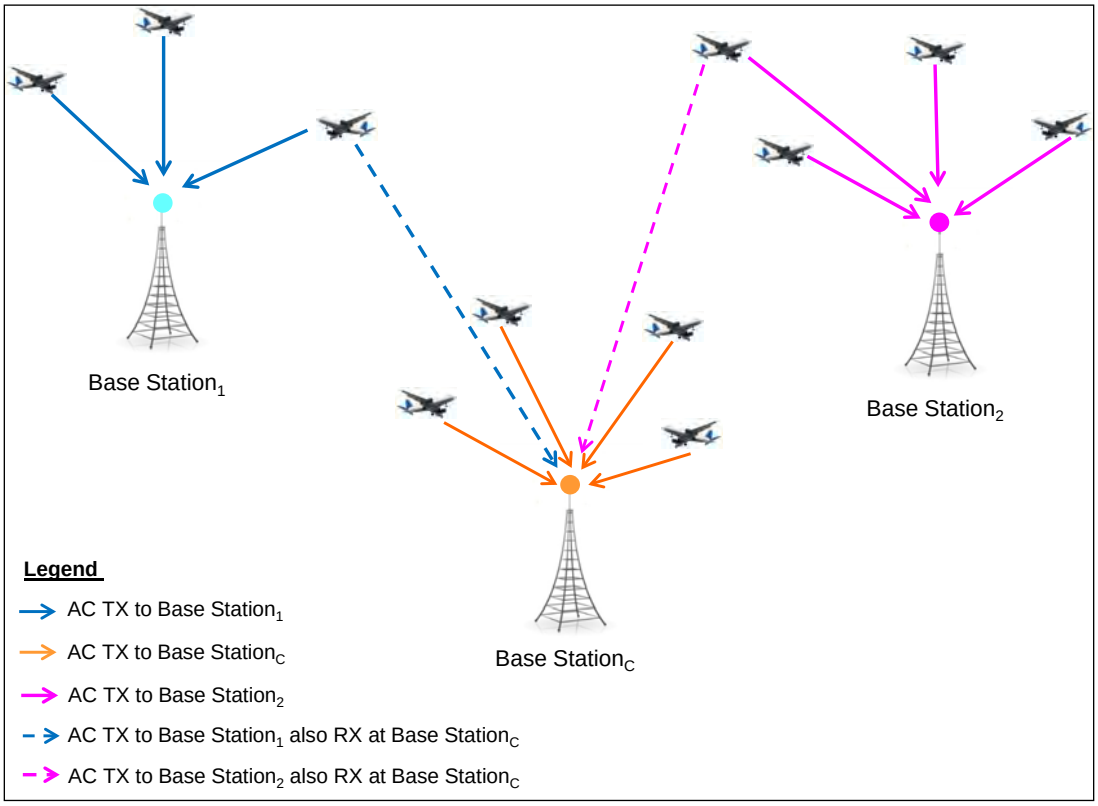

Figure 26: Model 2 illustration of CDMA concepts for A/G communications

R&D Principle 2 – Improve Efficiency

Systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve access to and increase capacity and efficiency of the nation's aviation system.

Re-Categorization of Wake Turbulence Categories Program:

The Re-Categorization of Wake Turbulence Categories Program (RECAT) is an ongoing international effort to safely reduce and standardize minimum wake turbulence separation distances. This is a group effort led by the FAA with many research partners, including the European Organization for the Safety of Air Navigation (EUROCONTROL), the Department of Transportation (DOT) John A. Volpe National Transportation Systems Center, The MITRE Corporation (MITRE), North West Research Associates (NWRA), and others. The RECAT team is pursuing a comprehensive engineering and analysis effort to better quantify the required wake separation between various aircraft types. This will lead to an improvement in current U.S. and international wake separation standards with expected overall capacity improvements. MITRE's overall role is to complete technical analyses to support RECAT team considerations and decision-making for the definition of separation standards, RECAT implementation, and RECAT benefits analyses.

RECAT is a three-phase international effort that will incrementally advance toward the availability of dynamic, pairwise wake separation standards for any combination of leader/follower aircraft types. In RECAT Phase I, based on completed engineering and scientific analysis of 61 of the most common International Civil Aviation Organization (ICAO) aircraft types, an updated wake separation matrix was derived with 6 wake classes of aircraft. Under RECAT Phase II, ongoing engineering and scientific analysis will further refine the results from Phase I and extend them to address the large majority of worldwide aircraft types by percentage of operations. RECAT Phase II is an international effort that will allow individual Air Navigation Service Providers (ANSPs) to optimize their implementation for increased benefits. RECAT Phase II will establish static wake separation distances for all leader/follower combinations of aircraft types. RECAT Phase III will later provide the ability to incorporate dynamic information, primarily environmental, into the separation requirements for leader/follower pairs, resulting in further separation reductions when conditions are favorable.

The implementation of RECAT Phase I at the first key site, Memphis International Airport (MEM), occurred on November 1, 2012, through the issuance of JO 7110.608. The FAA Wake Program Office asked MITRE's CAASD to perform an initial benefits analysis of arrival and departure operations at MEM to depict the operational impact of new separation standards under RECAT Phase I. Separation reductions enabled by RECAT at MEM were expected to provide the opportunity to reduce separation between some arrival and departure aircraft pairs, leading to increased departure and arrival throughput, increased departure and arrival capacity, and reduced

departure taxi times, especially during the heavy demand periods that occur during FedEx operations.

CAASD conducted a first look analysis comparing pre- and post-RECAT operations shortly after RECAT implementation, provided monthly analysis updates, and delivered a final report that examined the 12 months before and the 9 months after RECAT implementation. Metrics examined for both departures and arrivals included separation distances, capacity, and throughput. Researchers also analyzed departure taxi times. Additionally, heavy demand FedEx operational periods received separate analyses from other operational hours. Finally, analyses comparing these metrics during IMC and VMC provided comparisons for arrival metrics where the option of visual separations maintained by pilots potentially influenced separation distances. Key findings included:

- MEM realized significant departure benefits from the outset of RECAT Phase I implementation during FedEx operations in terms of decreased separation, increased throughput, increased capacity, and decreased taxi times. Figure 27 demonstrates the increased departure throughput rates in the post-RECAT period.
- FedEx arrival push benefits were more modest in the period of analysis, but demonstrated continued improvement throughout the nine months after implementation, including decreased separation during both IMC and VMC operations.
- In contrast to FedEx push operations, other hours of operation saw few or no benefits from the RECAT implementation, primarily due to the lack of demand.

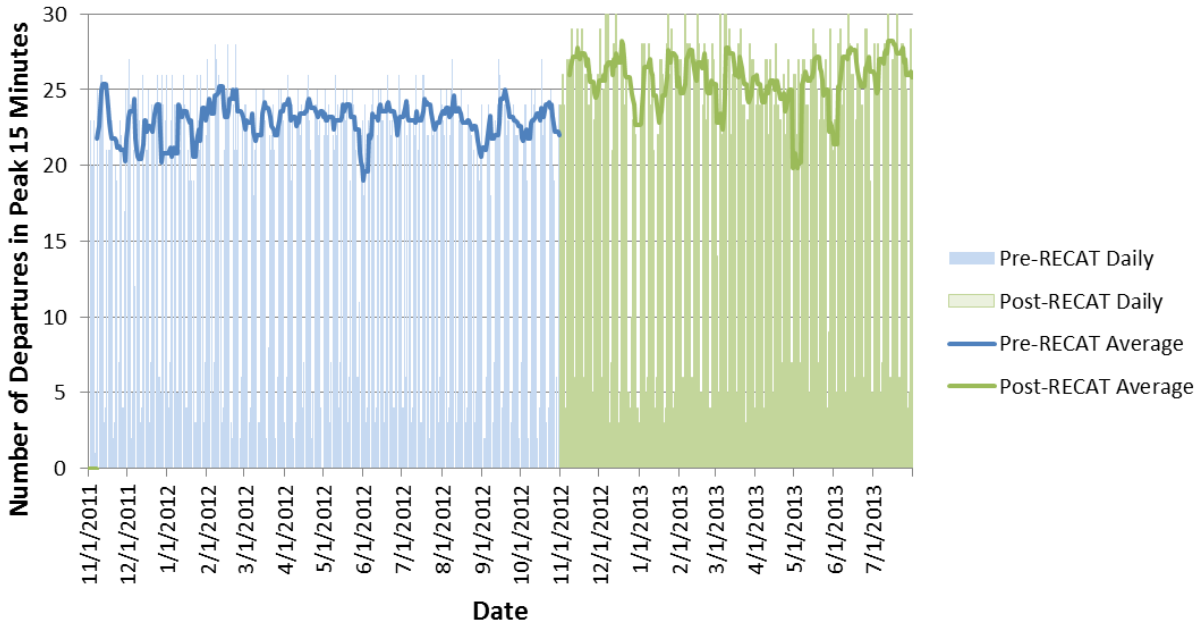

Figure 27: FedEx pre- and post-RECAT 15-minute peak departure rate

The RECAT Phase I implementation at MEM received significant praise from the FAA and industry as a NextGen success story. CAASD's first look, recurring, and final analyses provided key quantitative evidence to support claims of improved operational performance due to RECAT. Additionally, CAASD's continuous efforts to coordinate internally and externally with various groups performing related analyses ensured the delivery of a consistent RECAT benefits story. (CAASD)

Departure Metrics Development:

In FY 2013, CAASD conducted research to develop next-day metrics for the FAA that measure airport departure efficiency so the FAA can identify performance issues and make improvements to increase efficiency. Based on FAA feedback, the research focused on the following three areas:

1. Develop methodology to detect airport taxi-backs, which are departing flights that return to the gate after having started the taxi-out phase, on a next-day basis.
2. Explore possible metrics to measure departure efficiency on a next-day basis.
3. Improve performance thresholds for daily metrics so the correct "outlier" days are identified for in-depth review; ideally, these thresholds should take into account factors that are not under FAA control, such as weather.

The FAA has identified taxi-backs as a high priority metric requiring daily review at the Air Traffic Control System Command Center (ATCSCC). Prior to this task, the main source of taxi-back data was the Department of Transportation's Airline Service Quality Performance (ASQP) dataset. The ASQP taxi-back data is delayed by six weeks and only includes domestic scheduled flights by air carriers with one percent or more of total domestic scheduled service passenger revenues. Using ASDE-X data, MITRE developed an approach to detect taxi-backs on a next-day basis for five airports selected by the FAA: Hartsfield-Jackson Atlanta International (ATL), Newark Liberty International (EWR), John F. Kennedy International Airport (JFK), La Guardia Airport (LGA), and Chicago O'Hare International (ORD). This information is being transferred daily to the FAA at 5:00 AM Eastern Time. A comparison of the taxi-backs detected by MITRE's algorithm to the ASQP taxi-backs showed that MITRE's taxi-back detection algorithm reports twice as many cases or more than ASQP; this is partly due to fact that ASQP does not cover all the carriers. Moreover, in some instances, MITRE's algorithm detects taxi-backs for ASQP carriers not reported in ASQP.

MITRE explored the development of the inter-departure spacing metric, which is the time between subsequent departures on a runway, to measure the efficiency of departure operations on the runway on a daily basis. The metric was calculated for two airports, JFK and LGA, for July 2012. The FAA also developed a metric that measures departure flow efficiency using a methodology that is similar to that used for the FAA's Terminal Arrival Efficiency Rate metric. Researchers developed the metric for two selected airports, ATL and Seattle-Tacoma International Airport (SEA), and recorded the metric for a period of almost 2 years (August 2011–June 2013).

The metric selected for the performance threshold improvement task was taxi-out time, which is used to track and manage departure performance at an airport. On a daily basis, the FAA's ATCSCC daily metrics report (Figure 28 shows a typical FAA ATCSCC report.) is reviewed by the ATCSCC Systems Efficiency Group, Manager of Tactical Operations, and Traffic Management Officers, and it shows the average daily taxi-out time compared to a performance threshold based on 3-year historical averages for the same day of week, and does not take into account factors that are not under the FAA's control, such as weather. MITRE conducted statistical analysis to improve taxi-out time performance thresholds by removing (normalizing) the impact of weather, season, and original demand using historical data from 2010 to 2012. This analysis was conducted for the 29 Core airports, excluding Honolulu International (HNL), which did not have the weather impact data, and the results were applied to determine performance thresholds for March 2013. A comparison of the taxi-out times for LGA, March 18–19, 2013, which were days that the airport experienced several hours of IMC weather, showed that even though the taxi-out times exceeded their performance thresholds, they did not exceed the MITRE calculated adjusted thresholds, which accounted for the bad weather. Routine use of an adjusted threshold approach could save the FAA time and resources by helping to identify the truly anomalous events (events where actions could be improved) that the FAA should focus on, versus events that are mostly due to factors that are out of the FAA's control. (CAASD)

Facility	OPSNET Operations	Cancellations Departures / Arrivals	Diversions	Ground Stop Events / Minutes	Airborne Holding Events / Minutes	Taxi Out 90-119 / 120-179 / 180+ / Taxibacks	Completion Rate
ATL	2251	100 / 140	0	0 / 0	0 / 0	0 / 0 / 0 / 10	87.94
BOS	762	120 / 103	2	0 / 0	0 / 0	0 / 0 / 0	75.71
BWI	588	37 / 40	2	0 / 0	0 / 0	0 / 0 / 0	85.07
CLT	1309	50 / 53	1	0 / 0	0 / 0	0 / 0 / 0	91.65
DCA	748	74 / 82	0	0 / 0	0 / 0	0 / 0 / 0	80.93
DEN	1374	67 / 93	1	0 / 0	1 / 44	0 / 0 / 0	87.53
DFW	1846	41 / 56	2	0 / 0	0 / 0	0 / 0 / 0	93.74
DTW	536	316 / 324	3	0 / 0	0 / 0	2 / 0 / 0	38.17
EWR	930	126 / 151	1	0 / 0	5 / 73	0 / 0 / 0 / 0	69.60
FLL	713	19 / 28	0	0 / 0	0 / 0	0 / 0 / 0	89.96
HNL	860	5 / 3	0	0 / 0	0 / 0	0 / 0 / 0	98.48
IAD	737	78 / 88	1	0 / 0	0 / 0	0 / 0 / 0	73.33
IAH	1214	58 / 85	0	0 / 0	0 / 0	0 / 0 / 0	85.83
JFK	849	107 / 112	0	0 / 0	0 / 0	0 / 0 / 0 / 8	77.00
LAS	1363	19 / 20	2	0 / 0	0 / 0	0 / 0 / 0	95.07
LAX	1563	41 / 45	1	0 / 0	0 / 0	0 / 0 / 0	94.25
LGA	879	122 / 131	2	0 / 0	0 / 0	0 / 0 / 0 / 11	75.96
MCO	780	27 / 30	2	0 / 0	0 / 0	0 / 0 / 0	91.35
MDW	413	97 / 96	0	0 / 0	0 / 0	0 / 0 / 0	59.83
MEM	744	33 / 41	4	0 / 0	0 / 0	0 / 0 / 0	51.19
MIA	1169	21 / 21	1	0 / 0	1 / 80	0 / 0 / 0	95.37
MSP	1060	64 / 90	2	0 / 0	0 / 0	0 / 0 / 0	82.32
ORD	1230	603 / 636	0	0 / 0	0 / 0	0 / 0 / 0 / 14	43.92
PHL	1056	60 / 78	1	0 / 0	0 / 0	0 / 0 / 0	85.39
PHX	1152	26 / 31	2	0 / 0	0 / 0	0 / 0 / 0	93.60
SAN	422	13 / 18	0	0 / 0	0 / 0	0 / 0 / 0	91.30
SEA	804	5 / 8	1	0 / 0	1 / 19	0 / 0 / 0	97.88
SFO	1077	26 / 26	1	0 / 0	3 / 70	0 / 0 / 0	94.84
SLC	853	11 / 10	1	0 / 0	0 / 0	0 / 0 / 0	96.55
TPA	500	19 / 19	2	0 / 0	0 / 0	0 / 0 / 0	90.55
Total	29782	2385 / 2658	35	0 / 0	11 / 286	2 / 0 / 0 / 43	81.76

Taxi-backs

Figure 28: FAA ATCSCC report

Paired Approach Concept of Operations (CONOPS):

CAASD has been exploring a procedure called paired approaches for closely spaced parallel runways. Closely spaced parallel runways are runways that are separated laterally by less than 2,500 feet. About 50 percent of the top delayed airports in the NAS have such runways. When weather conditions are excellent, a closely spaced parallel runway pair can accommodate about 60 aircraft an hour. When the weather is less than excellent, the acceptance rate is reduced by half. The paired approach procedure solves this problem by using recent NextGen technology. It envisions the aircraft in the pair to be equipped with ADS-B out capability, a key NextGen capability, and the trail aircraft to be equipped with ADS-B-In. With this capability, the paired approach procedure enables the equipped aircraft to have access to an airport with closely spaced parallel runways when others may be holding on the ground due to less than excellent weather conditions.

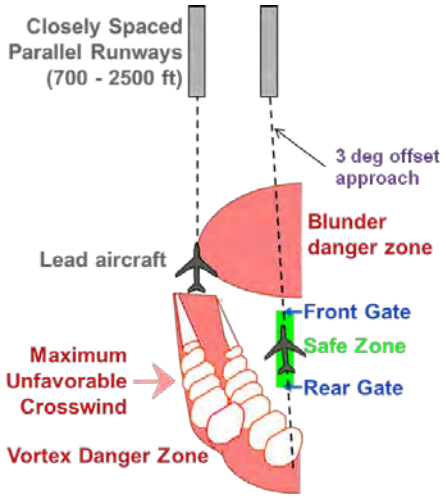

Figure 29: The Paired Approach Procedure

Because of the proximity of the two runways and their approaches, the concern in the paired approach procedure is to assure that the pair is safe both in the rare event of an aircraft deviation (or blunder) and from each other's wake. The procedure guarantees safety with respect to these concerns by requiring and enabling the aircraft to maintain a specified relative position with respect to each other within a safe zone. See Figure 29.

Figure 30: Cockpit Display Tools for the Paired Approach Procedure

Over the last two years CAASD was able to demonstrate that the paired approach procedure could be supported by the current ADS-B rule that requires all aircraft in the NAS to be equipped with ADS-B out by 2020. CAASD also showed that the current navigation systems on airplanes could support it and that the paired approach procedure recovered at least 75 percent of the capacity of the airport in good visual conditions, enabling it all the way down to Category I weather minima. In other words, the procedure would enable the airport and the users to do in less than ideal meteorological conditions what they now do in ideal visual conditions. Finally, CAASD conducted pilot and controller HITL simulations in the MITRE labs that showed that the procedure was acceptable to both the pilots and the controllers. Figure 30 shows cockpit display tools for the procedure.

The paired approach procedure requires wind forecast algorithms on the ground for ATC. These can be built on systems now available and requires no other ground automation. It is applicable at 38 airports including 12 of the top 30 delayed airports in the NAS. Based on the results of the analyses and studies, the FAA is now planning to deploy this capability in the pre-2020 period. (CAASD)

Arrival-Departure Runway Integration Scheduler (ADRIS):

At airports where there is a dependency between arrival and departure operations, airport capacity can be lost due to inefficient spacing of arrival aircraft. Departure capacity may be lost due to insufficient arrival spacing, and arrival capacity may be lost if arrivals are being spaced

farther apart than is required for the current departure situation. In addition, under current operations, arrival gaps are often provided when there are no aircraft waiting to depart.

These inefficiencies are primarily seen at airports with same runway and crossing runway operations. At these airports today, approach controllers provide an agreed upon static spacing interval between arrivals to ensure there is sufficient room to depart aircraft. The interval typically does not consider the inter-departure spacing requirements, the types of aircraft departing, or whether there are actually aircraft waiting to depart. Failure to consider these factors can lead to inefficient spacing for arrivals and a reduction in airport throughput.

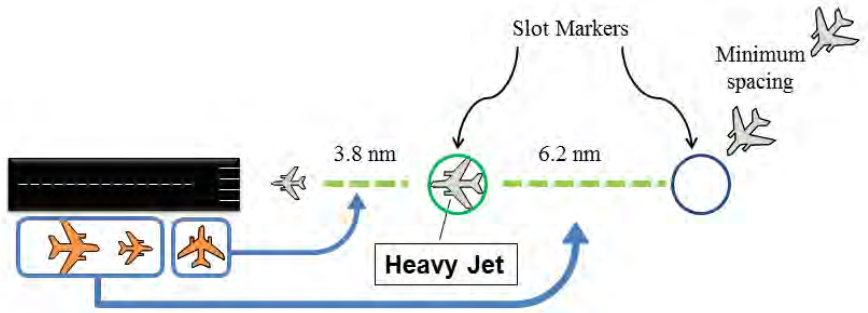

Figure 31: Arrival-Departure Runway Integration Scheduler (ADRIS)

Increasing efficiency at core airports is one of the FAA's primary goals. Research into an automated integration of arrival and departure schedules is targeted at improving efficiency through increased runway throughput. An innovative solution to this problem has been developed in the MITRE Aviation Integration Demonstration and Experimentation for Aeronautics (IDEA) Laboratory. Expected departure time, departure runway occupancy time, departure queue length, and aircraft type information are gathered. At the same time, the aircraft location, number of arriving aircraft, controller-determined sequence, speed, heading, type aircraft, arrival runway occupancy time, deceleration characteristics, and other information about the arrival aircraft are collected. An algorithm determines the most efficient inter-arrival spacing required to accommodate the aircraft scheduled to depart and provides spacing cues to the arrival controller in the form of guidance circles named slot markers, along the final approach course. The controller vectors the arrivals into the slot markers. The spacing of the circles employs a special time-based interval that also considers the runway occupancy time of the arrival and departure aircraft. When there are no departures waiting, the approach controller is provided guidance to use the minimum required spacing. A research prototype (the Arrival/Departure Integration Scheduler, illustrated in Figure 31) of this runway integration scheduler capability has been developed on a mock-up Standard Terminal Automation Replacement System (STARS) display in the IDEA Lab.

In FY 2013, two HITL simulations were conducted using the Arrival/Departure Integration Scheduler research prototype. This prototype runs in MITRE's Aviation IDEA Laboratory on a mock-up STARS display. The research assumptions for the first HITL included: (1) participants

will vector accurately and "hit" slot markers; (2) participants will reduce spacing when minimum spacing guidance is provided; and (3) presenting participants with slot markers will reduce overall participant workload. Results show that when presented with slot marker guidance, controllers were able to vector aircraft to comply with that guidance, improve throughput, and keep workload impacts to a minimum. It was also noted that the ADIS prototype was intuitive to learn.

Analysis of data collected during the first HITL pointed to necessary changes in the design of the prototype interface. These changes included guidance that is more precise and an enhanced arrival and departure list for the controller. The results of the second HITL show that the prototype design changes yielded spacing that was more precise, improved throughput, and had no significant workload impacts. (CAASD)

Human Factors Evaluation of Pointing Devices Used by Air Traffic Controllers:

The trackball currently used in en route air traffic control has been in the field for nearly 20 years and has been an effective pointing device overall. However, with the introduction of many new systems, the existing trackball may not be flexible enough to provide controllers with all the interaction capabilities they will need in the future. Although most information technology systems outside of ATC employ some form of mouse as the pointing device, there are human factors concerns that changing to a mouse for ATC may lead to lower controller performance and may lead to an increase in musculoskeletal disorders (MSDs), such as carpal tunnel syndrome. The current study explored the viability of changing pointing devices in the en route ATC environment. Current and recently retired controllers volunteered to participate in a HITL simulation at the WJHTC. FAA engineering research psychologists monitored the controllers' behavior, operational performance, and physical workload using electromyographic (EMG) equipment as the controllers used the current en route trackball, an alternative trackball, a specialized ergonomic mouse, and a standard commercial mouse. The researchers found that controllers preferred the standard mouse and current en route trackball to all other devices, and that they controlled traffic successfully using both. They found no significant physiological indications that any of the devices under evaluation had the potential to result in musculoskeletal disorders under typical conditions. Finally, the researchers found that controllers were more accurate and significantly faster using the standard mouse than using other devices. Considering these factors, the standard mouse appears to be a more appropriate pointing device for future ATC systems than the existing trackball. Figure 32 shows an En Route ATC workstation with samples of different pointing devices. The current en route trackball appears in the lower right. (ATC/TO Human Factors)

Figure 32: En route ATC workstation with samples of different pointing devices

Unmanned Aircraft Systems (UAS) Comprehensive Plan:

As required by the FAA Modernization and Reform Act of 2012, the U.S. Secretary of Transportation has submitted the Unmanned Aircraft Systems (UAS) Comprehensive Plan to Congress. The Joint Planning and Development Office (JPDO) developed the Plan to provide a domestic framework for the safe and timely integration of UAS into the NAS. It details a multi-agency approach and emphasizes the need for close coordination with the NextGen transition to satellite-based technologies and new operational procedures. JPDO collaborated with the NextGen partner agencies, including the Departments of Transportation, Commerce, Defense, and Homeland Security, NASA, and the FAA as well as industry to develop the UAS Comprehensive Plan, which includes six national goals and eight objectives that reflect the partner agencies UAS mission needs. The Plan also highlights other important topics for safe integration, such as UAS Research and Development, UAS Test Ranges, and the Small UAS Rule. (JPDO)

FY 2013 JPDO UAS Integration Report:

This report summarizes two key efforts — the Initial UAS Activity Alignment and the Initial UAS R&D Gap Analysis — performed by the JPDO during FY 2013. The Initial UAS Partner Agency Activity Alignment identified milestones, using data from NextGen partners, to represent critical R&D activities that support each of the UAS National Objectives (ref. the UAS Comprehensive Plan). These timelines provide stakeholders with an executive view of the UAS initiatives each agency is performing to meet the Objectives for achieving UAS integration. The FY 2013 initial UAS R&D Gap Analysis identified subjects that are not adequately addressed by ongoing or planned UAS integration R&D projects. R&D needs not met by the work identified in the inventory of UAS R&D constituted the gaps. This work represents an important step toward establishing a coordinated set of research priorities to guide NextGen planning and implementation with respect to UAS integration. (JPDO)

Optimized Route Capability (ORC):

The ORC assists with trajectory and flow management functions in a metroplex environment by optimizing airspace and route configurations based on demand and capacity constraints. This is done by monitoring current operating conditions (e.g., traffic volume, airspace availability, weather forecasts, and staffing levels), and using this information to develop, when needed, alternative route structures and airspace allocations. The FAA completed an ORC Functional Analysis in October 2012, which they used to form the basis of an initial Concept of Operations and preliminary Operational Requirements document. The FAA completed these documents in June 2013.

The ORC concept ultimately seeks to streamline the coordination and collaboration process for the selection and implementation of reroutes in a metroplex environment. The ORC will monitor the demand and capacity forecasts within the metroplex environment and generate optimal airspace and routing configurations that consider impact beyond the immediate and adjoining ATC facilities. The ORC will provide tools to assist with the coordination and collaboration between upstream and downstream facilities on the route selection and implementation in way that allows for timely and seamless implementation of route configuration changes.

Since many traffic flow adjustments often involve the redistribution of traffic flows outside the purview of a single ATC facility, the ORC will be able to coordinate with other facilities (e.g., share the same information and optimization plans), ensuring that the recommended changes in traffic route selection do not have any negative impacts on either upstream or downstream operations. In addition, the ORC will assess the optimal timing for the initiation and termination of airspace configuration changes.

The ORC concept will enable a smoother and more efficient transition of the NAS from its current highly structured configuration into the more flexibly configurable system proposed by the NextGen concept. It will work within this transitional framework to leverage all of the additional routing options that NextGen offers (e.g., RNP routing and OPDs) so the optimal

routing solutions it generates may be properly assessed, efficiently coordinated, and successfully implemented at the optimal time. In addition to this, the ORC is expected to streamline the coordination and collaboration efforts needed to enact changes to routing and airspace structures further enhancing the efficacy of the entire process. (Operations Concept Validation Modeling)

Remote Operations at Non-Towered Airports (RONA):

On March 28, 2013, the FAA prepared a Mission Analysis on non-towered airports, and conducted a Shortfall Analysis on Enhanced Services and ATC Services at Non-Towered Airports. Current Instrument Flight Rules (IFR) operations at some non-towered airports are inefficient for both the FAA and stakeholders. IFR operations at non-towered airports can require extensive ATC coordination between the Center and the local TRACON (if one exists). If surveillance coverage exists, this compounds the problem. If multiple IFR flights arrive at a non-towered airport with little to no surveillance, only one aircraft can land at a time. The following aircraft cannot be cleared to land until air traffic receives confirmation by phone or other means that the landing aircraft arrived and has cleared the active runway. Following aircraft must remain in holding until they receive a clearance to land from air traffic control. This is called a "one-in-one-out" operation. This operation can significantly reduce throughput and cause operators to accrue excessive flight time and mileage, which consumes more fuel and increases harmful emissions.

Figure 33: Non-towered airport operational context

Efforts are currently underway to provide surveillance at several non-towered airports through the use of wide-area multilateration and Automatic Dependent Surveillance – Broadcast (ADS-B). Additionally, several additional low-cost technologies are under development to provide surveillance at these airports. Improved surveillance, along with modified ATC procedures, will improve operations at these airports. For this effort, the FAA partnered with the Surveillance

and Broadcast Services (SBS) office to develop an operational concept and procedures for remote towered operations at currently non-towered airports, see Figure 33. Activities through FY 2015 could include safety analysis around surveillance requirements as well as a field demonstration. (Operations Concept Validation Modeling)

Space Vehicle Operations (SVO):

Since 1988, the FAA has licensed or permitted nearly 250 commercial launch and re-entry operations. As these operations have been conducted at a relatively low frequency and mostly from Federal ranges, they have until recently received little attention from other NAS stakeholders. During these operations, the FAA ensures that the safety of the NAS is maintained by temporarily closing relatively large volumes of airspace. The size, location, and duration of these planned closures correspond to the type of vehicle operated, the planned trajectory, and the duration of the operational window. In some cases, these closures can span hundreds of miles and last for several hours.

The Obama administration's space policy commits the nation to rely solely on launch vehicles designed, manufactured, and operated by private aerospace companies. Successful SpaceX missions to the International Space Station (ISS) exemplify this paradigm shift from government-sponsored space operations to commercial space operations. There are many indications that this is a market that will expand and grow in many new directions. Currently, eight licensed spaceports support commercial space transportation, with a similar number in the planning stages. Corporations, individuals, and state and local governments are investing heavily in the development of commercial space vehicles and supporting infrastructure.

Current FAA capabilities for managing space vehicle operations consist of processes that were sufficient for traditional launch and recovery activites of the past, but are not scalable to anticipated space activity projected during the NextGen timeframe. The current, highly manual process that involves closing large areas of the NAS does not scale to a substantial increase in the frequency and location of space vehicle operations. Future commercial space operations, vehicles, and launch and recovery locations will challenge the FAA's ability to maintain safety and effiency.

NextGen SVO represents a new vision for air and space traffic management in the NAS. Using new technologies, capabilities, and procedures, SVO will ensure the NAS safely and efficiently handles the increasing variety and frequency of space operations while minimizing delay and environmental impacts.

As part of the foundational research for the SVO concept, the FAA conducted a SVO Focus Group in December 2012. Participants included ATC and ATCSCC subject matter experts as well as experts from the FAA's Office of NextGen (ANG) and Commercial Space Transportation (AST). The group discussed operational and technical scenarios, concepts, and procedures for handling routine space vehicle operations in the NAS; and identified shortfalls in current operations. Operational Assessments were completed on April 30, 2013. The FAA

incorporated the results of the Focus Group into a subsequent SVO shortfall analysis report on June 5, 2013.

	SVO Operational Phases		
	Planning	Real-Time Operation	Post-Operation
Key Shortfall Categories	4D Trajectory Analytic Support, NAS-SVO Trajectory Harmonization	4D Trajectory Automated Real-time Vehicle Tracking & Surveillance	4D Trajectory Data Availability, Measures of Performance, Analytic Support
	Contingency Management Debris Simulation Modeling, "What-if" Decision Support including Convective Weather	Contingency Management Automated Interfaces, Debris Threat Modeling, Vehicle Health Monitoring	Contingency Management Data Availability, Measures of Performance, Analytic Support
	Mission Management Shared Situational Awareness, Communication Latency, Ripple Effects Modeling	Mission Management Communication Latency, "What-if" Decision Support, Human Factors/Safety	Mission Management Data Availability, Measures of Performance, Analytic Support
	Spaceports Licensing Simulation Modeling, rough order of magnitude estimates	Spaceports Operations Consistency, Weather Automation & Standard Procedures	Spaceports Data Availability, Measures of Performance, Analytic Support

Tools & Procedures
Analytic Tools, Decision Support Tools, "What-if" Simulation Tools, Impact Modeling Tools, Weather Tools, Spaceport and Post-Operation Metrics and Best Practices

Figure 34: SVO operational phases, key shortfall categories

The shortfall analysis highlighted the NAS improvements necessary to safely and efficiently handle increasing launch and recovery activities. Key shortfalls include the following: lack of decision support tools for modeling and planning operations; lack of real-time surveillance of space vehicles; lack of a real-time debris response capability; communications latency amongst stakeholders; and the significant size and duration of airspace closures for space activity. The shortfall analysis concluded that NextGen represents a unique opportunity for the FAA to evolve its approach to airspace management of space vehicles and keep pace with the projected demand of this emerging industry. Figure 34 summaries the SVO operational phases and key shortfall categories. (Operations Concept Validation Modeling)

Trajectory Operations Concept of Operations:

In June 2013, the FAA completed a Trajectory Operations (TOps) Concept of Operations document. The TOps Concept represents a fundamental shift of ATM from vector-based control to trajectory-based management of aircraft. The FAA expects this shift to take place in all domains of flight operations, including pre-flight planning, surface, arrival and departures, enroute, and oceanic. In today's high-density domestic airspace, air traffic management is characterized by a reliance on manual execution of tasks that are shaped by the limitations of current NAS technology. For example, during high density operations in the arrival domain, enroute air traffic controllers may receive assistance from automation tools, such as the Traffic Management Advisor , to aid in the timely delivery and sequencing and spacing at a given ARTCC or TRACON meter fix. Controllers tactically issue vectors to aircraft to maintain

separation and achieve the appropriate delay for metering to the fix. Controllers rely on their experience and cognitive ability to execute these tasks with little or no assistance from ground automation. On the flight deck, the flight crew receives and executes manually the vector clearances issued by the controller. The issuing and execution of vector-based clearances is

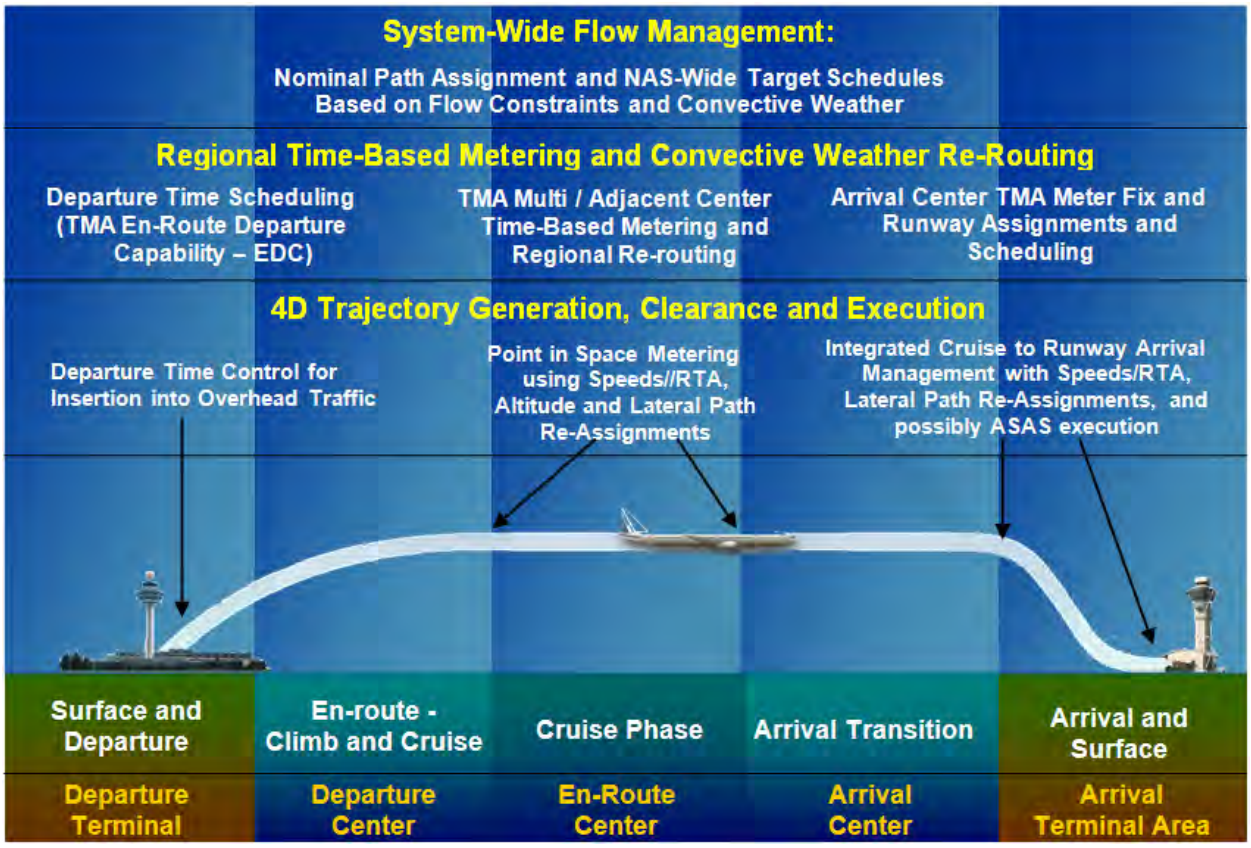

Figure 35: System-wide Flow Management: Nominal Path Assignment and NAS-wide Target Scheduled Based on Flow Contraints and Convective Weather

often times operationally inefficient in terms of fuel savings and workload. NextGen plans include the development of new ground and flight deck automation along with the increased use of currently available automation (i.e., aircraft flight management systems) to facilitate the transition from vector-based clearances to trajectory-based clearances. Trajectory operations move the NAS from a less efficient manual and tactical operation to a highly efficient strategic and automated operation. (Operations Concept Validation Modeling)

Flow Based Trajectory Management (FBTM):

The FAA conducted research to examine the impact of improved departure time predictions on Ground Delay Programs (GDPs) and the look-ahead time and percent improvement of the departure time estimate needed to realize cost savings. Decision-makers can use the results of

the study to understand the benefit trade-offs between different data sources that may provide improved departure time predictions through NextGen improvements. On December 2012, the FAA identified and analyzed network attributes for NextGen trajectory negotiations and completed an updated version of the FBTM research management plan and fast time analysis of traffic flow management departure predictability.

Inaccurate predictions of departure times are often thought to be the biggest source of error in the Traffic Flow Management System (TFMS). Flight Status Monitor (FSM) uses departure time predictions to project demand at the destination airport and these demand projections are used as a basis for determining when a GDP is needed, resulting in an Expect Departure Clearance Time (EDCT) being issued to the aircraft to meet the arrival slot. If the departure time assumed by TFMS is not accurate, then a slot may be saved for an aircraft that the aircraft cannot meet. These unfilled slots due to errors in the departure time predictions represent missed opportunities to deliver enough aircraft to match airport capacity. The FAA conducted the study to validate the hypothesis that errors in departure time predictions contribute to unused capacity or lost slots and to determine the percentage improvements and look-ahead times needed to reduce this loss.

The NextGen Advanced Concepts and Technology Development Directorate, Concept Development and Validation Branch led the study and the John A. Volpe National Transportation Systems Center conducted the research. While improved departure time predictions may benefit multiple tools and systems, this study focused only on the benefits to GDPs. Researchers used the Volpe Airport Arrival Simulation Model to determine the effect on cost of improving the prediction of departure times. The model mimics the FSM in calculating GDPs and researchers used actual GDP data from 2011 to test the hypotheses. The study focused on the top-8 delay airports, which accounted for 95 percent of delays for all GDPs. Three GDPs from 2011 for each airport were chosen for study for 24 GDPs. For each GDP, 2,000 simulations were conducted for each case to determine the impact of look-ahead times (LAT), which is how long before departure the prediction improvement occurs, and the percent improvement in the prediction error. In total, researchers conducted 2,688,000 simulations.

The study confirmed the hypothesis that improvements in departure time predictions could yield significant cost savings to the user community from reduced GDP delays. The following chart depicts the results, with the lines representing different percentage improvements at the various LATs. Although the maximum cost savings is not practically achievable, the results suggest that improvements at longer look-ahead times (potentially from data supplied by the user community) would yield significant benefits. The FAA will complete a follow-on study in FY 2014 examining the estimated benefit of improved departure time predictions based on assumptions of LAT and percentage improvement that various NextGen technologies could potentially realize. (Operations Concept Validation Modeling)

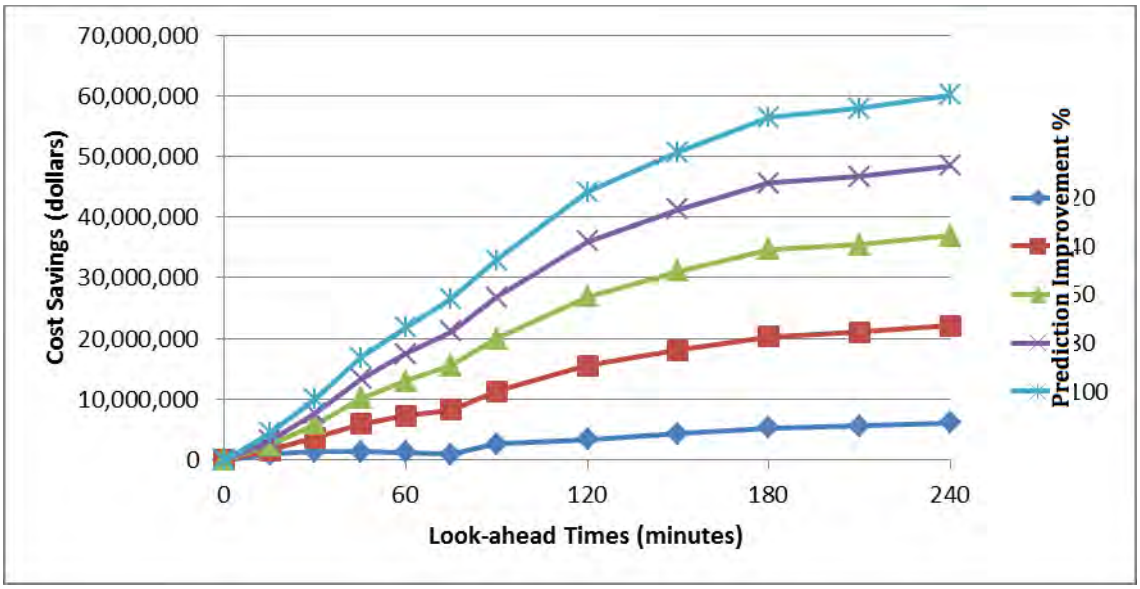

Figure 36: Cost savings with increased look-ahead times

Unmanned Aircraft Systems (UAS):

The FAA is in the process of safely accelerating UAS integration into the NAS, based on Congressional direction set forth for 2015. FY 2013+ activities are focused on continued concept exploration and refinement via SME panels with ATC and UAS experts. The FAA delivered Version 2.0, of the ConOps for UAS Integration into the NAS, in October 2012; the document will be incorporated into the congressionally mandated comprehensive plan for UAS. The FAA will also support the development of lower-level UAS concepts as required based on these analyses. The FAA will develop and refine operational requirements throughout the analysis. Updates to the UAS ConOps Version 2.0 will be made as required based on feedback from both the internal and external stakeholder communities. (Operations Concept Validation Modeling)

Wake Standards for New Aircraft Designs:

The FAA completed paper and initial modeling analysis in determining the needed aircraft-to-aircraft wake mitigation separations for the new Airbus A-350 series aircraft, scheduled for initial operations in the summer of 2014. The European Aviation Safety Agency (EASA) is the lead international organization for proposing the wake separation standards for the A-350 aircraft and the FAA will review in FY 2014 the more detailed safety case EASA will provide for that aircraft and determine the wake separations that will be used in the NAS for the A-350. (Wake Turbulence)

Analysis of Airports for Characteristics Allowing Reduction of Required Wake Separations between Aircraft:

Analysis and procedure review at San Francisco International Airport (SFO) and at Newark Liberty International Airport (EWR) resulted in the approval of FAA Order JO 7110.308 CHG 3. The Order specifies revised leader/follower-specific runway pairs and new approach geometries for the closely spaced parallel runways (CSPR) at these airports, enabling up to a 50 percent increase in CSPR landing throughput capacity. Before these changes, weather conditions would have restricted the use of the CSPR to that of a single runway approach operation. San Francisco began use of the procedure at the end of September 2013.

The FAA developed capacity enhancing wake turbulence mitigation procedures and associated Safety Risk Management Document and supporting analyses for the Phoenix and Las Vegas airports' CSPR. Approval (FAA Order JO 7110.308 CHG 4) for the use of the procedure and approach geometry at these airports is expected in FY 2014. This analysis and approval will include the use of RNAV (GPS) approaches as a part of the mitigation solution. (Wake Turbulence)

Development of NextGen Wake Procedure and Decision Support Tool Concepts:

The FAA completed the transition of the crosswind-based wake mitigation air traffic control decision support tool (DST) concept development from the use of the discontinued National Weather Service (NWS) Rapid Update Cycle weather forecast model to the more capable NWS Rapid Update (RAP) weather forecast model. Researchers modified ongoing DST concept development to take advantage of the improved performance of the RAP.

The FAA completed detailed statistical crosswind versus wake transport for the approach and departure corridors for airports that are candidates for the Wake Turbulence Mitigation Single runway decision support tool. (Wake Turbulence)

Determination of Statistical Wake Encounter Frequency/Severity:

The FAA completed validation testing of an aircraft flight data recorder screening tool that detects likely wake encounters (minor or less impact) that occurred during an aircraft's flight. Approximately 60,000 flight data recorder datasets for one aircraft type and 10,000 datasets of another aircraft type were examined by the screening tool and results from the screenings are promising in terms of detected potential wake encounters (minor or less impact). During FY 2014, the FAA will adapt the screening tool for use in flight recorder datasets of several more aircraft types. Researchers analyzed the results of the flight data recorder screenings and will use these results to help establish the statistical frequency of wake encounters (minor or less impact) occurring in today's operating environment. (Wake Turbulence)

Develop Models, Databases and Data Sources:

This year saw the evaluation of a low profile, person portable LIDAR-based wind profilers as augmentation instrumentation for the wake data collections sites near the Boston Logan International Airport (BOS) and the John F. Kennedy International Airport (JFK). The evaluations showed that the wind profilers performed as desired and will be permanently integrated into the wake data collection sites, with potential movement of one of the wind profilers to the wake data collection site near San Francisco International Airport (SFO). The profilers were also evaluated for their ability to detect and track wakes generated by aircraft. Due to the profiler's low profile, it was deployed under the approach path of a runway and was able, upon initial examination of collected data, to measure an important parameter of wakes generated by landing aircraft.

The FAA reached an agreement with the National Research Council Canada for the collection of wake transport data for aircraft traveling at their cruise altitude and speed. These data will be used to validate wake transport and decay models currently developed for use near the ground that must be modified to analyze proposed NextGen Era air traffic control wake encounter mitigation procedures for use with trajectory based operations. (Wake Turbulence)

Implementation of New 6 Category Wake Turbulence Separation Standards at Memphis International Airport (MEM) and Louisville International Airport (SDF):

The last change to wake turbulence separation standards occurred in 1994 when the B757 was put into its own wake separation category. Since then, the fleet mix has changed significantly and the understanding of wake behavior has grown due to major efforts by Volpe National Transportation Systems Center, FAA, and EUROCONTROL. The enhanced understanding of wake behavior has led to the development of safe, more runwaythroughput efficient, 6 Category wake separation standards for use by the FAA in separating aircraft in the airspace near to an airport. The new 6 Category standards were used in ATC operations at MEM starting on November 1, 2013, and were implemented by FAA at SDF on September 9, 2013.

The change in separation standards at MEM has led FedEx, which operates 230 arrivals and departures at MEM daily, to state that it is likely adding a new runway to MEM. FedEx's reported average taxi times are down 3 minutes, taxi-out delays were down 75 percent, and ramp tower delays were down 35 percent. For arrivals, FedEx reported their aircraft were spending 2–6 fewer minutes in terminal airspace. Since the September 2013 introduction of the 6 Category wake separation standards at SDF, United Parcel Service has seen similar, but not as dramatic, benefits in their operations at SDF.

The new standards will be implemented at additional airports in FY 2014 and FY 2015. (Wake Turbulence – Re-Categorization)

Framework for the Leader/Follower Pair-Wise Static aircraft wake mitigation separation Standards:

In FY 2013, FAA and EUROCONTROL jointly developed an initial set of wake separation standards that consider the wake generation and wake upset risk of approximately 115 different aircraft types. In FY 2014, these separation standards will be optimized to provide the maximum potential runway throughput efficiency while maintaining safe aircraft-to-aircraft wake mitigation separations. It is expected in FY 2015, the Leader/Follower wake separation standards will be given to the ICAO Wake Study Group for their analysis and approval. (Wake Turbulence – Re-Categorization)

WTIC Flight Deck Weather Avoidance Decision Support:

Weather-related disruptions account for 70 percent of the delays in the NAS. A key component of NextGen is to assimilate observed weather information and probabilistic forecasts into the decision process of flight crews and air traffic controllers. Research has developed a system that will display weather forecast information on the flight deck using weather predictions from the Corridor Integrated Weather System (CIWS) and the Convective Weather Avoidance Model (CWAM). The system would support flight crew weather decision-making. A 2½ D presentation for CIWS and CWAM and a 3D visual presentation for CIWS were developed. results showed that pilots could take advantage of long-range predicted weather forecasts in performing en route weather avoidance. The advantages gained by using the CIWS and CWAMs in the cockpit was that pilots collaborated with ATC on flight paths to avoid adverse weather in a strategic manner (and with more predictable requests), which enabled more efficient planning by ATC versus cockpit-originated tactical deviation requests. Additional research is planned to determine what information to present and the best way to display it. The two presentations were compared and the two formats performed about the same, although subjective evaluations rated the 3D presentation as preferable.

This research supports the NextGen mid-term goal of reducing the number of deviations originating from the cockpit due to adverse weather. The products developed in this research provide decision aids that enable pilots to re-route for weather with increased efficiency.. If research results continue to be positive, the program will make recommendations for standards for incorporating forecasts and probabilistic weather in the cockpit by around 2020. Figures 37 and 38 below provide screen shots of the two presentations used in this experiment. (Weather Technology in the Cockpit)

Figure 37: Screenshot of 3D CIWS presentation

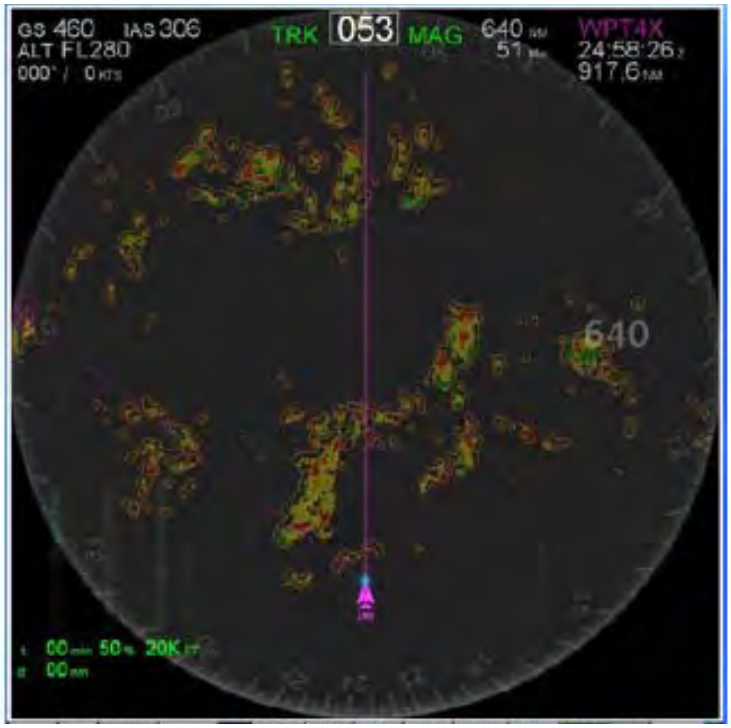

Figure 38: Screenshot of 2½ D presentation of CIWS and CWAM

Understanding of Uncertainty in Weather Information and Products:

NAS decision-makers typically rely on a mix of deterministic and probabilistic convective weather forecasts. Absent from this suite of available forecast information, however, is critical insight into the inherently uncertain nature of weather information. To mitigate this uncertainty, numerous NextGen documents envision the use of probabilistic weather forecasts in the NextGen era.

The FAA assessed how convective weather forecast uncertainty information is used in today's NAS to support ATM decisions. Interviews and discussions with ARTCC, TRACON, tower, and Command Center personnel as well as Center Weather Service Unit (CWSU) meteorologists, weather information providers, airline personnel, and weather researchers, identified the following observations on the current use of convective weather forecast uncertainty in ATM decisions:

- NAS users and weather information providers understand that all convective weather observations and forecasts contain uncertainty, but frequently use weather information as if it doesn't contain uncertainty.
- NAS ATM users do not fully understand how to use convective weather information that includes uncertainty for decision-making in the NAS.
- Providers of NAS convective weather information do not fully understand how weather information that includes uncertainty is used for decision-making in the NAS.
- NAS users and weather information providers do not have the same understanding of terms used to express convective weather uncertainty.

Table 1 – Differences in Convective Weather Uncertainty Terms between NY CWSU Meteorologist and NY ARTCC Traffic Management Unit (TMU) User

NY CWSU Convective Weather Uncertainty Term (probability Severe Weather Action needed)	NY CWSU Meteorologist Probability	NY ARTCC TMU User Probability
Not Expected	0%	0%
Possible	>0%-<50%	50%
Probable	50%-90%	100%
Expected	95%-100%	100%

Table 1 is a good example of how weather providers and ATM users do not have an equivalent understanding of terms used to express convective weather uncertainty. Although the New York CWSU meteorologist uses a specific term (Possible, Probable, etc.) associated with a distinct probability or probability range (50%-90%, 95%-100%, etc.) to communicate the convective weather uncertainty, the NY ARTCC TMU user understands these terms using a singular

probability value (0%, 100%, etc.). This can result in TMU personnel giving too high a probability to a convective weather forecast and thus may be too strict in selecting Traffic Management Initiatives (TMIs) in anticipation of convective weather.

The study verified a systemic issue with the use of convective weather information in ATM decision-making, not an indication of negative performance by TMU or CWSU personnel. The study also revealed that TMU personnel use a variety of trial and error methods and biases in their weather decision-making. Because these are an intrinsic component of human intuition, they must be taken into account for any new weather products and decision tools developed and implemented, especially during the transition to NextGen when humans will still be making primary operational decisions. By teaching operators to recognize biases in their decision-making, and providing weather products listing ranges of possible outcomes for users to consider, better decisions can be made to improve efficiencies during convective weather events.

Additional research is underway to identify a pathway from today's use of non-standard and unsophisticated convective weather forecast uncertainty information to a level needed to meet NextGen requirements for full integration of automated probabilistic weather information into ATM decisions. (Weather Program)

R&D Principle 3 – Reduce Environmental Impacts

Systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will reduce aviation's environmental and energy impacts to a level that does not constrain growth

NAS-Wide Environmental Impact Assessment for NextGen:

Environmental impacts of aviation are under increasing global scrutiny and need to be addressed along with operational performance when assessing proposed changes to the NAS. There are well-established methods and metrics for evaluating system-wide operational and environmental performance. However, tradeoffs among performance objectives are not well understood because of lack of integration across models and differences in modeling assumptions. Combining these analysis capabilities requires forming linkages across two distinct modeling domains. In FY 2013, MITRE research was aimed at bridging the gap between air traffic simulation tools and environmental models and developing key capabilities to incorporate environmental metrics in future NextGen benefits assessments. See Figure 39. While the models used in this research were *systemwide*Modeler and the FAA's Aviation Environmental Design Tool Version 2a SP1 (AEDT), the methods and software developed can be applied to other tools.

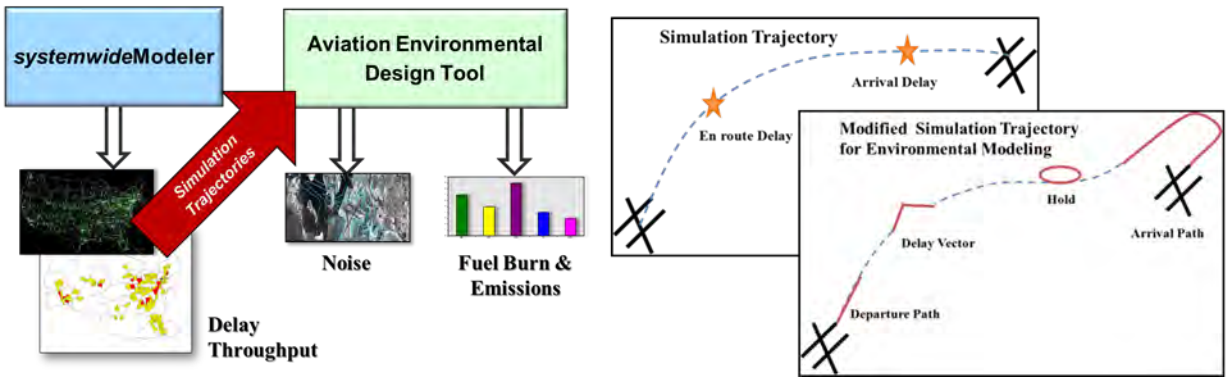

Figure 39: Harmonizing inputs, assumptions, and trajectory representation across models

Key challenges associated with integrating simulations and environmental models include harmonizing trajectory fidelity requirements, aligning other modeling assumptions and inputs, such as aircraft types and airport data, and developing software to support large environmental studies. Trajectory fidelity can vary both in the en route and terminal domains across the modeling domains of interest. Simulation tools often express delay incurred by a flight simply as time absorbed at a particular point in the airspace system, without calculating a realistic aircraft maneuver. Also, NAS-level simulation tools such as *systemwide*Modeler do not incorporate details of arrival and departure procedures in the terminal area close to the runway. Environmental models, on the other hand, require detailed flight paths that explicitly express

delay absorption maneuvers, wherever taken, and accurately represent flight trajectories in the terminal area with respect to geographical location and altitude.

This research modifies *systemwide*Modeler trajectories by incorporating delay maneuvers, such as speed changes, vectors, and holds to represent simulation predicted delay. Additionally, *systemwide*Modeler trajectory definition in the terminal area was enhanced by appending higher resolution flight paths, such as radar track data or proposed procedures onto simulation trajectories. Another step in the integration process involves mapping *systemwide*Modeler aircraft type and airport data to appropriate inputs for AEDT. Finally, a prototype software tool was developed that transforms simulation tool outputs into appropriate input formats for AEDT. This tool was developed such that it could be used with a wide range of models or radar track data and could efficiently handle large datasets required for NAS-wide studies.

Research products include an integrated analytical capability using *systemwide*Modeler and AEDT, prototype AEDT study generation software, and documentation of methodology and software including a conference publication in 2013 at the *AIAA Aviation 2013 Conference*. A notional study of the operational and environmental performance impacts of NextGen airport capacity improvements was undertaken to demonstrate the methods developed. Figure 40 below illustrate delay and fuel burn savings resulting from airport capacity improvements in the notional case study mapped to ARTCCs. Darker shades of blue indicate a reduction in flight time or fuel burn whereas the grey colors indicate almost no change.

The prototype environmental study generation software was shared widely within MITRE as well as with the FAA and their vendor to support other simulation tools or radar track data. Some of the tools that the prototype software interfaced with include the FAA's System Wide Analysis Capability and the Total Airspace and Airport Modeler. In FY 2014, the prototype software will be further developed for the next version of AEDT, Version 2b, expected to be released in 2014. This research involved close collaboration with the FAA's OEE and the AEDT development team at the Volpe National Transportation Systems Center. (CAASD)

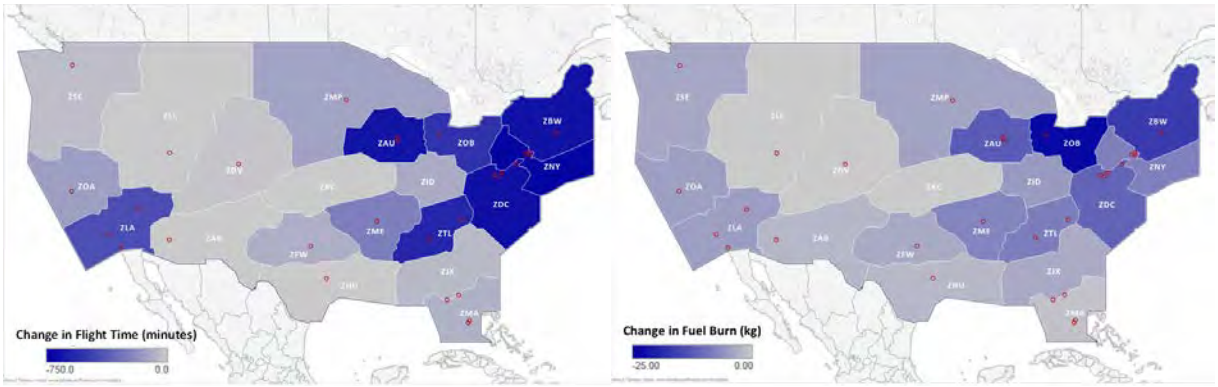

Figure 40: Notional results from a NAS-wide operational and environmental analysis of airport capacity improvements

Aviation Environmental Design Tool (AEDT):

AEDT is a software system that dynamically models aircraft performance in space and time to produce fuel burn, emissions and noise. Full flight gate-to-gate analyses are possible for study sizes ranging from a single flight at an airport to scenarios at the regional, national, and international levels. AEDT is currently used by the FAA to examine interdependencies and tradeoffs between aircraft-related fuel burn, noise and emissions in domestic and international analyses.

The first version of AEDT, version 2a, was released on March 21, 2012. AEDT 2a replaced the Noise Integrated Routing System (NIRS – regional noise analysis) upon release and is currently mandated to be used in place of NIRS to assess the environmental consequences of air traffic airspace and procedure actions. Information on purchasing and obtaining AEDT 2a is available at http://aedt.faa.gov/.

In 2014, AEDT version 2b will also become the next generation aviation environmental consequence tool, replacing the current public-use aviation air quality and noise analysis tools, the Integrated Noise Model (INM – single airport noise analysis) and the Emissions and Dispersion Modeling System (EDMS – single airport emissions analysis). AEDT 2b will also replace the NAS-wide and global policy analysis tools the Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA) and the System for Assessing Aviation's Global Emissions (SAGE), which are used for trends and policy development both at the national and international level. The FAA is actively developing and testing AEDT 2b at this time. (Environment and Energy)

Integration of AEDT with Airspace System Models:

The FAA has performed a considerable amount of work to date on meeting the NextGen Concept of Operations requirement to provide a mechanism for integrating environmental protection objectives in decision-making. The FAA's efforts have focused on establishing a framework to link models of air traffic management or air transportation operations to the AEDT, the next generation environmental consequences modeling tool. The two airspace system models selected for this integration included the Total Airport and Airspace Modeler (TAAM) and the System-Wide Analysis Capability (SWAC), which represent the extremes of the spectrum of modeling detail and their application.

The FAA targeted the first phase of the integration work toward understanding the differences between the TAAM and SWAC modeling domains and the development of a guidance document targeted specifically to the capabilities of AEDT 2a. The FAA delivered the resulting final document in 2013. The FAA designed this document to support operations and environmental modelers in bridging data and assumptions gaps to establish a successful workflow for the integration of the two modeling domains. During 2013, the FAA also began an initial effort to integrate TAAM and SWAC with beta versions of AEDT 2b. (Environment and Energy)

Noise Propagation Methodologies to Predict Surface Noise Levels:

One important factor to ensure accurate calculation of the number of people exposed to significant commercial aircraft noise in the United States is proper noise modeling. The FAA continues to conduct research to improve the noise propagation methodology, a key aspect of noise modeling, in the environmental modeling tools. The FAA has made great strides in improving the methodology through international collaboration and by advancing research. The FAA has worked with propagation experts in Europe to validate and compare current propagation methodologies within the U.S and across Europe. In addition, the international collaboration has led to the availability of data that can be used to validate emerging propagation methodologies and gave the FAA an opportunity to use mature propagation methodologies, validated with European models in the FAA environmental tools. In addition, collaboration with NASA has led to the opportunity to collect additional data that can be used to validate emerging propagation methodologies. The overall work in noise propagation, as documented in the noise propagation research roadmap, will continue to mature and be implemented into the FAA environmental models. These models are used for National Environmental Policy Act (NEPA) review, to complete Noise Exposure Maps under the FAA's Part 150 program, and to provide the FAA's annual noise exposure estimate, among other uses. The FAA achieved the following progress in 2013:

1. Investigated the effect of fast source motion and furthered numerical models to demonstrate the source motion effect for both ideal and realistic weather/ground conditions;
2. Continued the weather input data harmonization for noise modeling by leveraging the input parameters used in air quality models;
3. Started working with experts in European countries on model-to-model comparison and benchmarking; and
4. Planned and conducted a field noise measurement in Houston in conjunction and collaboration with the NASA Discovery-AQ flight measurement campaign. The field noise data — together with detailed aircraft trajectory and weather data — are undergoing analysis to yield a quality database for validating numerical models.

(Environment and Energy)

Health Effects of Aviation Noise:

The FAA NextGen implementation strategy is to reduce significant health and welfare impacts of aviation community noise in absolute terms, notwithstanding the anticipated growth in aviation. The FAA continues to conduct studies of long-term health impacts of noise exposure. The extent to which exposure to aircraft noise might increase the risk of adverse health impacts has not been thoroughly studied. Few studies of the relationship between aircraft noise and health risk factors have been conducted to date. They typically focus on a single geographical area and do not have sufficient statistical power. One of the ways to obtain a large sample study is to analyze the existing health cohorts retroactively. The Medicare program database was used by PARTNER to statistically examine the health impacts of aviation noise. The objective of this

project was to investigate whether exposure to aircraft noise increases the risk of hospitalization for cardiovascular disease in older people. Medicare is a large cohort, which covers the entire country, but includes only the older population. This study had other limitations, including lack of individual level health data in Medicare's database, low precision of retroactively constructed noise contours, and coarse ZIP Code-level resolution of socioeconomic data. Although this work found statistically significant association between exposure and risk of hospitalization for older people living near airports, further research should refine associations by investigating modifying factors at the airport or individual levels. The FAA is continuing to conduct research to investigate the possible link between cardiovascular health and aircraft noise. (Environment and Energy)

Quantification of Aircraft Contribution to Climate Change:

The Aviation Climate Change Research Initiative (ACCRI) program, initiated by OEE, has provided valuable information on the non-CO_2 climatic impacts of present-day aviation emissions as well as those for future (2050) aviation growth scenarios. The 3-year program, which was completed in FY 2013, involved 10 research teams with members from universities, the aerospace industry, and government agencies. The program examined a range of uncertainties and helped improve the understanding of how aviation affects the climate by combining observationally-based estimates of contrail and contrail-induced cirrus cover effects with modeling simulations. In addition, the program also helped identify five new mechanisms of aviation effects on climate, three pertaining to the improved understanding of atmospheric chemical effects initiated by aviation emissions and two pertaining to the non-linear effects of aerosols, such as sulfates and black carbon on existing and aviation-generated cirrus clouds. Further investigation is necessary to understand and characterize these impacts fully. The program also developed preliminary estimates of climate benefits of using alternative fuels. (Environment and Energy)

A Technique to Estimate Domestic U.S.-wide Effects of Aviation Emissions on Surface Air Quality:

One of the FAA's environmental goals is to reduce aviation-related air quality health effects. To quantify progress toward meeting this goal, the FAA developed a methodology to quantify and track year-to-year changes in health effects. Researchers used the methodology, based on the Community Multi-scale Air Quality (CMAQ) modeling framework, to examine the years 2005 and 2010. The background emissions from non-aviation sources and meteorology are standardized for use in the CMAQ modeling framework as these are important factors that can lead to considerable year-to-year variability. This approach quantifies the health effects due to aviation in a consistent fashion. While prior approaches had only included health effects due to particulate matter, a number of additional factors are included to estimate significant health effects. This methodology was used to estimate both premature mortalities and monetary damage for the years 2005 and 2010, and the FAA will use it to track the trajectory of health effects for current and future years. (Environment and Energy)

Direct Measurements of Aircraft Particulate Matter Data to Support Development of Internationally Approved Methodology:

Over the course of several years, the FAA has been leading the development of a method to measure particulate matter emissions from aircraft engines. The goal of the work is to develop an internationally approved methodology that could then be used as the basis for an international standard on particulate matter emissions. Over the last year, researchers built a sampling system to meet the requirements as specified by the SAE E31 subcommittee, and they used it to conduct back-to-back measurements with comparable systems built by researchers throughout the world. The testing of this system has been started as a joint activity with the Swiss Government, EASA, Transport Canada, among others, and it will continue into 2014. (Environment and Energy)

Analysis of Compatibility of Future Alternative Jet Fuel Pathways with Existing Aircraft and Infrastructure to Expand Feedstock Options for Sustainable Fuel Production:

In partnership with industry, the FAA continues to make significant progress toward the development and deployment of sustainable alternative jet fuels. Through the Commercial Aviation Alternative Fuels Initiative (CAAFI), the FAA facilitates information exchange among approximately 300 stakeholders from government, the aviation industry, fuel suppliers, agriculture industry and universities. Through the Continuous Lower Energy, Emissions, and Noise (CLEEN) Program, the FAA is facilitating fuel approval by conducting rig and engine tests of promising novel alternative jet fuels. The results from these tests are compiled into research reports that undergo peer review to determine if the fuel can be approved for use by ASTM International. Testing includes fuel property, material compatibility, engine rig, auxiliary power unit and turbine engine tests of multiple alternative jet fuels including fuels made from sugars, plant oils, waste greases, and waste gases from industrial sources. Results from the testing are crucial to the approval process for fuels used by commercial aviation. The FAA continues to work with the U.S. Department of Defense to jointly fund and accomplish much of this testing. In addition, work to produce novel alternative jet fuels was completed by three innovative alternative fuel companies funded by the FAA. Virent, Inc., Lanzatech, Inc., and Honeywell UOP delivered fuel samples and preliminary testing of those fuel samples was completed. Those and other fuels are being tested this year for performance, and the resulting data will support future fuel approvals. (Environment and Energy)

Environmental and Economic Sustainability of Future Alternative Turbine Engine Fuels:

Efforts have been ongoing over several years to quantify the environmental benefits, technological feasibility and economic costs of alternative jet fuels. This work has been conducted by the CLEEN Program and university researchers within the FAA COE program. Several efforts within this program will produce reports in FY 2014. In FY 2013, research under the PARTNER COE has shown significant potential for renewable jet fuels using novel biochemical and thermochemical pathways, such as advanced fermentation and aqueous phase processing, while pointing toward the potential for reducing the currently high production costs.

Research also indicated that biogeophysical effects from biomass cultivation might have a significant impact on the net climate footprint of alternative fuels. Work was also conducted and published that quantified additional sustainability metrics, such as the Energy Return on Investment of alternative jet fuels and freshwater and land requirements on a geospatially disaggregated basis. Finally, US efforts within ICAO CAEP were supported through analyses on differences in aviation biofuels regulation, and the development of methodologies for future biojet production potentials. (Environment and Energy)

Demonstration of Continuous Lower Energy, Emissions and Noise (CLEEN) Aircraft Technologies:

The CLEEN Program continues to make significant progress toward maturation and demonstration technologies that reduce aircraft fuel burn, emissions, and noise. Each of the five companies working under CLEEN achieved major milestones in 2013.

Boeing is working under CLEEN to develop a ceramic matrix composite (CMC) engine exhaust system that can withstand higher temperatures, reduce engine weight to improve fuel consumption, and accommodate acoustic treatments that reduce community noise exposure. Boeing completed ground testing of its Ceramic Matrix Composite (CMC) engine exhaust system in 2013 and plans to conduct a flight test of this technology on a 787 aircraft in 2014. Figure 41 shows the Boeing CMC engine exhaust nozzle installed on a Rolls-Royce Trent 1000 engine.

General Electric (GE) is developing the ability for aircraft trajectory synchronization between the aircraft FMS and the En Route Automation Modernization (ERAM) system to improve efficiency. The potential benefits of trajectory simulation include allowing accurate conflict detection far in advance of the conflicts occurring, with resulting fuel savings due to early conflict resolution measures being taken. GE conducted a demonstration of this trajectory synchronization capability in 2013. GE also completed engine modeling of technologies to achieve fuel burn reduction using FMS-Engine Integration. These technologies include Integrated Flight-Propulsion Control for synergistic optimization of the engine and aircraft; Adaptive Engine Control, which uses knowledge of aircraft state and engine health to optimize performance; and Integrated Vehicle Health Management, which uses knowledge of engine health to optimize aircraft performance and reduce fuel consumption.

Honeywell is developing a package of engine core technologies that will reduce engine fuel burn by increasing efficiency and reducing weight. Honeywell conducted component rig testing of a number of its technologies in 2013. Honeywell procured the hardware necessary to conduct engine ground tests of the technologies in 2014.

Pratt & Whitney is working on next generation ultra-high bypass ratio geared turbofan technologies that will reduce aircraft noise and fuel burn. Pratt & Whitney conducted preliminary, detailed design reviews in support of these fuel burn and noise reduction technologies for the geared turbofan. These technologies are being designed to be fit to a

demonstrator engine for testing. Additionally, wind tunnel testing of a scaled model of this engine is planned for further technology maturation.

Rolls-Royce is developing ceramic matrix composite (CMC) engine turbine blade tracks under the CLEEN Program. This technology will allow for reduced engine cooling, airflow and weight savings, reducing aircraft fuel burn. Rolls-Royce conducted engine ground testing of its CMC Turbine Blade Track technology in 2013. Rolls-Royce has planned additional ground testing in 2014. (Environment and Energy)

Figure 41: The Boeing CMC engine exhaust nozzle installed on a Rolls-Royce Trent 1000 engine.

Planning for Continuous Lower Energy, Emissions and Noise Phase II Activities:

The CLEEN Program was launched in 2010 as a 5-year NextGen effort to accelerate development and commercial deployment of environmentally promising aircraft technologies and sustainable alternative jet fuels. The CLEEN Program's successes to date have prompted the FAA to plan for a second phase of the program, CLEEN II, that would take place from 2015–2020 and would focus on new aircraft technology and alternative fuels projects to support advanced environmental goals. The FAA has completed several steps in preparation for CLEEN II, including conducting a Market Survey to gauge interest from industry and inform the FAA about technological options for potential maturation under CLEEN II, developing draft environmental goals for the program, publicly releasing a draft statement of work for public comment, and holding a CLEEN II Industry Day event to gather further industry feedback. These activities provided the FAA with valuable information on potential areas of work and industry areas of activity, both of which will help build a strong solicitation for a successful program. The FAA is working to obtain internal approval to move forward with the solicitation and expects to release the CLEEN II solicitation in the summer of 2014. (Environment and Energy)

NextGen Environmental Management System:

In FY 2013, the development of NextGen Environmental Management System (EMS) focused on three components: the Strategic Plan, Communications, and the Stakeholder Collaboration Program. The NextGen EMS Strategic Plan is being developed to articulate the FAA OEE research approach, and will draw high-level connections between OEE program areas and the environment and energy goals that were established in FAA's Aviation Environmental and Energy Policy Statement. For the Communications component, FAA developed a beta version of a website to provide a single information resource on aviation environment and energy. This website describes the challenges facing aviation, the role of the aviation community in addressing these challenges and how research programs and development of solutions being undertaken by the FAA contribute toward Aviation Environment and Energy goals. The beta website was designed, populated with content, and user tested. In addition, the initial concept and requirements for an information exchange portal to support the stakeholder collaboration program were developed. The FAA also worked with industry to begin development of the Stakeholder Collaboration Program, recognizing that achieving the Aviation Environmental and Energy Goals is dependent upon the input of all aviation stakeholders. In 2013, the FAA conducted initial industry outreach and market research, which identified a strong demand for a more formalized mechanism drive across industry collaborating on shared environmental challenges. As a result, the FAA launched an collaborative development program with the industry, which identified core aviation stakeholders (including representatives from air carriers, airports, manufacturers, and FAA) to work to develop a reward/recognition program that aims to help address complex aviation environmental challenges. Given the positive response from core group members, this program is expected to expand in 2014. (Environment and Energy)

Analysis to Support CO2 Standard-setting:

To support the development of an international aircraft CO_2 standard, the FAA's OEE has assessed CO_2 metric systems that can objectively and accurately reflect CO_2 emissions at the aircraft and fleet levels. The final CO_2 metric system will provide the technical basis of the international aircraft CO_2 standard, or CO_2 certification requirement. It is expected that such a CO_2 certification requirement will influence the development of future airframe and engine technologies in order to reduce fuel consumption and thus CO_2 emissions, which will have a long-term influence the operating fleet of commercial aircraft. FAA-OEE has been fully involved in the relevant national and international processes in order to understand how such a CO_2 certification requirement might impact system-wide level fuel consumption, aircraft CO_2 emission, and overall environmental and monetary cost-benefit scenarios. In particular, there is a continued strong need to investigate the extent to which the form of aircraft CO_2 certification requirements may influence future aircraft fleet development, evolution, and associated fleet wide CO_2 emissions.

The International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP) made great strides toward establishing a worldwide CO_2 standard by unanimously agreeing to a CO_2 metric system at the CAEP Steering Group meeting in July 2012. The FAA supported this process of developing the metric system, over the course of several years, by providing technical analyses to ensure sound decision-making. A motivating schedule has also been established for the CO_2 standard setting to occur at CAEP/10 in 2016. More recently, a set of 10 stringency options based on the agreed CO_2 metric system was agreed upon during the CAEP Emissions Working Group (WG3) meeting in September 2013, which was subsequently supported by the CAEP Steering Group in November 2013. Research continues to inform the FAA as well as the ICAO-CAEP process with technical insights on the challenges associated with the development and adoption of the CO_2 certification standard. Moving forward, this will require the need to assess the fleet-wide environmental implications, including system-wide climate cost, of the accepted metric system and initial set of stringency option scenarios. (Environment and Energy)

Delayed Deceleration Approaches:

In conventional descent and approach operations, aircraft often decelerate relatively early in their approach trajectory, as illustrated by the red region in Figure 42 below. This can occur for a number of reasons, such as air traffic control commanding early deceleration to give more time for spacing and sequencing traffic flows onto the final approach or due to slower traffic ahead in the arrival stream. Earlier deceleration is accompanied by deployment of high-lift devices, such as flaps, requiring higher engine thrust to counteract the resulting higher drag and giving rise to higher approach fuel burn, emissions, and noise. If a Delayed Deceleration Approach (or DDA) procedure is implemented, the increase in approach fuel burn, emissions, and noise can be avoided, since the aircraft speed is kept higher for a longer period during the initial stages of the approach. The aircraft remains in a cleaner aerodynamic configuration with associated lower fuel burn and emissions due to lower engine thrust requirements. The aircraft deceleration to the

standard stabilized final approach speed occurs later in the approach, but still in plenty of time to comply with current stabilization criteria such that safety is not adversely affected.

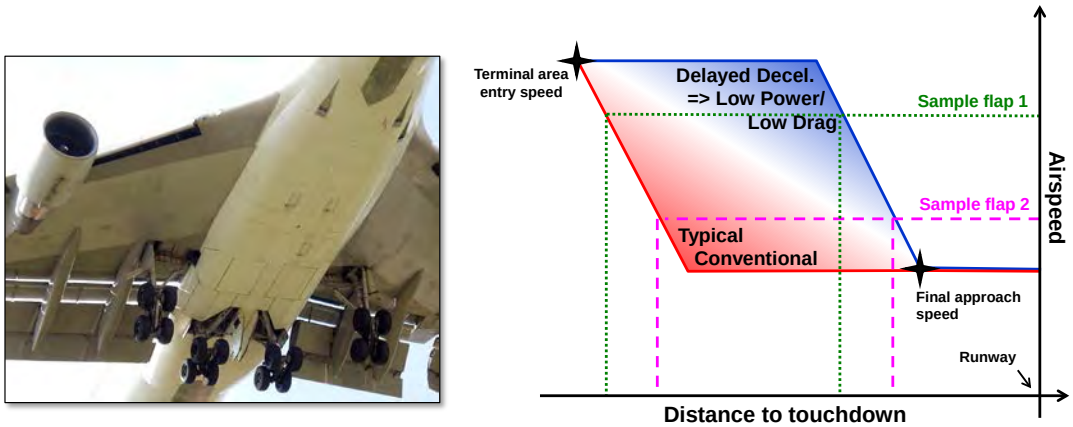

Figure 42: Delayed Decelearation Approaches

This operational mitigation is complementary to the widely-studied Continuous Descent Approach (CDA) procedure as the DDA focus is on the approach speed profile while the CDA focus is on the approach vertical profile. Since DDA has not been studied in as much detail as CDA, the initial work under this study analyzed the potential benefits and barriers to wider deployment of DDAs using Flight Data Recorder (FDR) data. This data offers visibility into many internal states of the aircraft highly relevant to this study, including fuel burn, airspeed, aerodynamic configuration, and engine power. FDR data from a set of commercial aircraft operations were analyzed for this study. Three aircraft types (A320, B577, and B777) flying 3° vertical profiles to isolate the effect of airspeed during the approach operation were analyzed using statistical summaries for fuel burn, airspeed, flap angle, and engine power. The flights with the lowest fuel burns were on the "high" side of the airspeed and flap setting profiles (i.e., delaying deceleration and flap deployment until later in the approach, consistent with the DDA philosophy) and maintained flight idle engine settings until the final approach. The flights with the highest fuel burn exhibited the opposite characteristics: they decelerated and deployed flaps earlier in the approach and had significantly higher engine power than flight idle. This study found a 30–37 percent fuel burn and $C0_2$ emissions reduction potential between the "average" and the ideal DDA profile for flights on three-degree flight path approaches from 10,000 feet to touchdown. Correlation analyses specifically identified airspeed and flap extension schedule as the main factors resulting in observed differences in fuel burn.

The primary objective of the FY 2013 DDA analysis was to characterize the approach speed profile characteristics of a range of US airports to identify barriers and opportunities for increased DDA usage to enable a fraction of the DDA savings identified above to become an operational reality. This required analysis of radar data from operations into the study airports over an extended period. A methodology was developed to characterize approach speed profiles and hence DDA opportunities from radar archives. In practice, there are barriers to implementation which may prevent increased DDA usage at some locations, but ongoing work is attempting to find opportunities for increased use of DDAs at suitable airports. (Environment and Energy)

Comparison of Industry Detonation Detection Equipment with FAA Referee Method:

The current FAA Advisory Circular for the determining the detonation margin requirements (AC 33:47 - Detonation Testing in Reciprocating Aircraft Engines) is significantly outdated and contains references to obsolete analysis methods based on extinct test instrumentation. The FAA Technical Center Aviation Fuel and Engine Test Facility (AFETF), in cooperation with the Coordinating Research Council Piston Fuels Group, developed and successfully balloted an ASTM International Standard Practice for detonation detection in aircraft engines. The method includes reference standards for equipment, installation, calibration, analyses algorithms, power settings, and engine operating testing conditions. To date, the engine and airframe original equipment manufacturers have diverged in their approach to detonation detection and a formal correlation to the FAA Technical Center ASTM referee method has not been performed. This correlation will inform development of a standardized detonation testing procedure to be used to evaluate all unleaded candidate fuels submitted to the Piston Aviation Fuels Initiative for the replacement of 100 low-lead (100LL) aviation gasoline.

Detonation testing using UL94 was completed. This work is significant since it is the first publically available data set that compares the performance of a high octane quality aviation alkylate currently in production to a fuel that does not contain lead. While the significantly reduced octane of UL94 may not make it suitable for many high performance aircraft, the testing shows the size of the fleet that could operate safely with no changes to aircraft materials, operating procedures or safety margins. The research will support the eventual balloting of a UL94 unleaded aviation alkylate standard specification at ASTM International. (NextGen – Alternative Fuels for General Aviation Program)

NextGen Environment Management System (EMS):

In FY 2013, the development of NextGen EMS focused on three components: the Strategic Plan, Communications, and the Stakeholder Collaboration Program. The NextGen EMS Strategic Plan is being developed to initially describe how FAA OEE programs, initiatives, and research activities provide a roadmap for achieving FAA-specific environment and energy targets that contribute to broader aviation environment and energy goals. In Phase 1, this strategic plan was designed and the programs and research efforts being conducted by the FAA OEE were consolidated. Phase 2 will expand the plan to include other relevant FAA programs. For the Communications component, FAA developed a beta version of a Website to provide a single information resource on aviation environment and energy. This Website describes the challenges facing aviation, the role of the aviation community in addressing these challenges, and the innovative programs being undertaken by the FAA contribute toward Aviation Environment and Energy goals. The beta Website was designed, populated with content, and user tested. In addition, the initial concept and requirements for an information exchange portal to support the stakeholder collaboration program was developed. FAA also worked with industry to begin development of the Stakeholder Collaboration Program, recognizing that achieving the Aviation Environmental and Energy Goals is dependent on the input of all aviation stakeholders. In 2013, the FAA conducted initial industry outreach and market research, which

identified a strong demand for a more formalized mechanism drive across industry collaborating on shared environmental challenges. As a result, the FAA launched a collaborative development program with the industry, which identified core aviation stakeholders (including representatives from air carriers, airports, manufacturers, and FAA) to work to develop a reward/recognition program that aims to help address complex aviation environmental challenges. Given the positive response from core group members, this program is expected to expand in 2014. (Environment and Energy – Environmental Management System and Advanced Noise and Emissions Reduction Program)

Acronym List

Acronym	Definition
0-9	
2D	Two-Dimensional
3D	Three-Dimensional
3D PAM	Three-Dimensional Path Arrival Management
4D	Four-Dimensional
A	
AC	Advisory Circular
ADDS	Aviation Digital Data Service
ADS-B	Automatic Dependent Surveillance – Broadcast
AEDT	Aviation Environmental Design Tool
ARTCC	Air Route Traffic Control Center
ASIAS	Aviation Safety Information Analysis and Sharing
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
ATL	Hartsfield-Jackson Atlanta International Airport
ATM	Air Traffic Management
C	
CAASD	Center for Advanced Aviation System Development
CACRC	Commercial Aircraft Composite Repair Committee
CAMI	Civil Aerospace Medical Institute
CDTI	Cockpit Display of Traffic Information
CFR	Code of Federal Regulations
CIP	Current Icing Product
CLEEN	Continuous Lower Energy, Emissions, and Noise
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COE	Center of Excellence
CSET	Composite Structural Engineering Training
CWSU	Center Weather Service Unit
D	
Data Comm	Data Communications
DSS	Decision Support System
DRNP	Dynamic Required Navigation Performance
E	
EDMS	Emissions and Dispersion Modeling System
EMS	Environmental Management System

Acronym	Definition
F	
FAA	Federal Aviation Administration
FE	Finite Element
FIP	Forecast Icing Product
FCM	Flow Contingency Management
FMS	Flight Management System
G	
GA	General Aviation
GE	General Electric
GWU	The George Washington University
H	
HITL	Human In The Loop
I	
IFR	Instrument Flight Rules
J	
JAMS	Joint Advanced Materials and Structures
JPDO	Joint Planning and Development Office
L	
Li-ion	Lithium-ion
LSTC	Livermore Software Technology Corporation
M	
MMPDS	Metallic Materials Properties Development and Standardization
MEM	Memphis International Airport
N	
NARP	National Aviation Research Plan
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NDI	Nondestructive Inspections
NDIR	Non-Dispersive Infrared
NEPA	National Environmental Policy Act
NextGen	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
O	
OEE	Office of Environment and Energy
OEM	Original Equipment Manufacturer
OSU	The Ohio State University

Acronym	Definition
P	
PED	Portable Electronic Device
POD	Probability of Detection
R	
R&D	Research and Development
RAP	Rapid Update
RNAV	Area Navigation
RTA	Require Time of Arrival
S	
SAE	Society of Automotive Engineers
SDF	Louisville International Airport
SMS	Safety Management System
SRM	Safety Risk Management
T	
TRACON	Terminal Radar Approach Control
TFMS	Traffic Flow Management System
U	
UAS	Unmanned Aircraft Systems or Unmanned Aerial Systems?
UCSD	University of California, San Diego
U.S.	United States
W	
WSU	Wichita State University
WJHTC	William J. Hughes Technical Center