Federal Aviation Administration

Research and Development

ANNUAL REVIEW

FY 2017Accomplishments

FY 2017 Research and Development (R&D) *Annual Review* (AR) V3-MM
December 2017

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

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Executive Summary

The FAA uses R&D to support policy and planning, regulation, certification, standards development, and modernization of the National Airspace System (NAS). The AR is a companion document to the NARP. The AR highlights selected completed projects by various entities within the FAA research community. These projects benefit the American flying public by significantly contributing to aviation safety, efficiency, and environmental sustainability.

Section 44501(c) of Title 49 of the U.S. Code (49 U.S.C. § 44501(c)) requires the Administrator of the FAA to submit the NARP to Congress annually with the President's Budget. Section III of the statute specifically addresses the AR and outlines its requirements to report on the accomplishments of research completed during the prior Fiscal Year (FY). Additionally, the AR is responsible for describing research disseminated to the private sector and new technologies developed. The AR is organized to allow for comparison with, and traceability to research milestones outlined in the prior year NARP.

In the FY 2017 R&D AR, there are some updates compared to previous years. The narratives describing various significant accomplishments represent a fraction of completed research. The section, *Innovations in the National Air Space System* highlights some of the new technologies, patents and products that were directly developed during FY 2017 from various programs in Research, Engineering and Development (R, E&D), Airports Integrated Product Team, and Facilities and Engineering (F&E). The newly added section, *2017 NARP Milestones Summary*, provides status updates for each of the milestones from the 2017 NARP.

The AR is organized around the 2017 NARP research principles:

- Improve Aviation Safety
- Improve Efficiency
- Reduce Environmental Impacts

However, the 2018 NARP has been redesigned and updated with new goals that will be reflected in the FY 2018 R&D ARR along with other anticipated changes in scope and design.

<u>Objectives</u>

- Improve Aerospace Safety
- Improve Operational Effectiveness
- Reduce Environmental Impact

<u>New Goals</u>:

Goal 1: Improve airport operations, air traffic, and air space management capabilities.

Goal 2: Accelerate use of new technologies for aerospace vehicles, airports and spaceports.

Goal 3: Increase infrastructure durability and resiliency.

Goal 4: Improve the operation of the human component of the system.

Goal 5: Improve integrated modeling capabilities and system-wide analysis.

Introduction

The FAA uses R&D to support policy and planning, regulation, certification, standards development, and modernization of the NAS. The FAA R&D portfolio supports both the day-to-day operations of the 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. The R&D principles help the FAA align, plan, and evaluate its R&D portfolio. The R&D principles are:

- **Improve Aviation Safety –** systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve aviation 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 the 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.

The AR is a companion document to the NARP. This report highlights selected completed projects by various entities within the FAA research community. These projects are grouped by one of the three research principles, and more specifically, by the budget line items. The narrative write-ups throughout the AR result from a process in which the research contributors used a rubric to narrow down those completed milestones that are considered significant accomplishments. These projects benefit the American flying public by significantly contributing to aviation safety, efficiency, and environmental sustainability.

Innovations in the NAS

During the data collection phase of the FY 2017 AR, contributors were prompted to complete a *Significant Accomplishments Rubric* while providing status updates on 2017 NARP milestones. The rubric included questions on whether a completed milestone resulted in tangible research results such as, new technologies, patents and/or products. In addition to the detailed narrative write-ups, the AR aims to highlight these new innovations that will ultimately benefit the American flying public.

New technologies ranged from measuring heat release test apparatus in fire research and safety, to the completion of standard composite testing in aircraft catastrophic failure prevention, to new technologies in the area of reduced energy use, emissions and noise within environmental research of aircraft technologies, fuels and metrics.

New products resulted from 2017 completed milestones such as:

- Improved fleet risk analysis methods in propulsion and fuel systems;
- A published human factors compendium for flight deck displays and controls;
- Development of an information display for the controller decision support tool in the area of wake turbulence, and
- An airport emergency planning template, among many others.

These are just a few examples of the many new technologies and products that were developed by talented and dedicated teams conducting R&D on behalf of the FAA.

Improve Aviation Safety

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

Advanced Materials/Structural Safety

Commercial Aircraft Composite Repair Aircraft Composite Repair Committee (CACRC)

The CACRC, depot-bonded repair, round-robin testing research consists of two phases. Phase I evaluated the existing CACRC standards using approved materials, and assessed bonded repair process variabilities between repair depots and technicians with different experience and training levels. Phase II focused on conducting detailed post-test analysis of phase I repairs, to identify critical process parameters in the execution of bonded repairs, as well as create detailed documentation and video for educational and training purposes. This research was performed through the FAA's Joint Advanced Materials and Structures Center of Excellence, Wichita State University.

Over 100 composite sandwich coupons were repaired during the round-robin testing program in Phase I. Panel fabrication was conducted at the National Institute for Aviation Research /National Center for Aviation Training Facility at Wichita State University. Original equipment manufacturer-approved materials and processes were used to ensure that the resulting repair coupons were representative of production materials and procedures. Bonded repairs were conducted at the National Institute for Aviation Research original equipment manufacturer Research, and five operator depots/maintenance and Repair organization. The repair process used for the pre-preg system is shown in figure 1 below. Repair coupons were then subjected to static and fatigue testing to assess the performance of the repairs. The test set-up and representative failure modes are shown in figure 2 below. The results from phase I showed that the CACRC standards cannot be used as a sole document to repair a composite part and a partly specific document is required. The result also showed repairmen experience alone is not a predictor of repair performance and demonstrated the importance of workforce education and training for the proper execution of bonded repairs.

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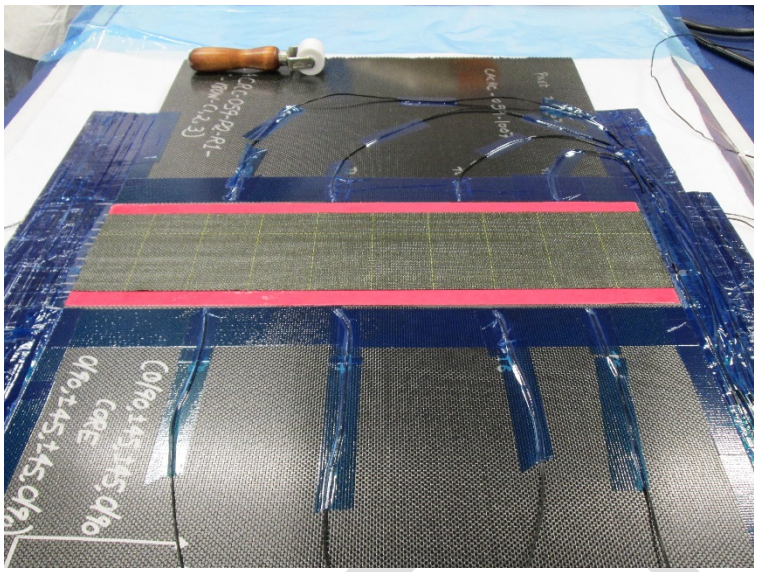

Figure 1: Pre-preg Repair Process

Phase II, a continuation of phase I, identifies critical process parameters in the execution of bonded repairs based on Phase I results and produces materials for educational and training courses. As part of this research, defective repairs were created. Critical process parameters such as material out-time, bagging scheme, incorrect resin ratios, pre-bond moisture resulting from minimal or no drying were used to create poor or weak bonds.

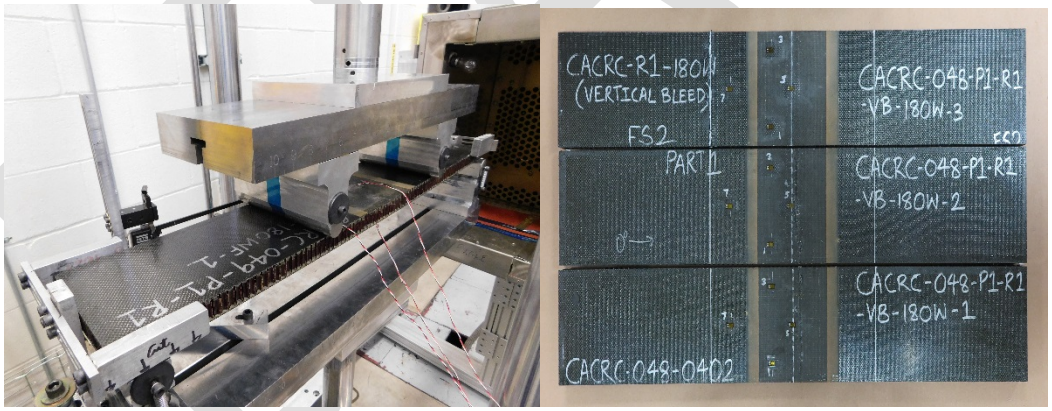

Figure 2: Coupon Test Set-Up and Representative Failure Modes

Structural Safety (Crashworthiness)

The FAA assigned the Aviation Rulemaking Advisory Committee to provide recommendations regarding the incorporation of airframe-level crashworthiness and ditching standards into Title 14, Code of Federal Regulations part 25 and development of associated advisory material. To support the development of FAA requirements and guidance material and the Advisory Committee and Transport Airplane Crashworthiness and Ditching Working Group, three principle areas for research were defined. Those areas included:

1. Transport airplane ditching;
2. Airframe structural crashworthiness response characterization,
3. Crashworthiness issues unique to composite structures.

Several projects were completed that quantified aircraft kinematics prior to impact. This effort included information from investigative reports (including black box data), as well as the use of accident reconstructive methods to supplement the existing data. The research included:

- Development of aircraft kinematics for transport aircraft crashes into water;
- Development of aircraft kinematics for regional jet crashes into terrain, and
- Development of aircraft kinematics for small (light, low pax count) jet transport crashes into terrain.

A study was also conducted and a report written on the study of structural factors influencing the survivability of occupants in airplane accidents, to understand and rate what structural factors played a significant role in occupant survivability in airplane crashes (non-fire). In order to study the influence aircraft kinematics, have on occupant survivability and aircraft structural damage, a full-scale finite element model of a narrow-body transport aircraft was developed. Future modeling work will use this model. The kinematic data obtained, as well as other recommended impact scenarios to help define future reference impact scenarios. The development of the full-scale model has been documented to provide guidelines and modeling best practices to similar modeling efforts.

To address the issue of identified data gaps concerning the fuselage response of various size aircraft and design, (i.e., material used) several aircraft drop tests were conducted. Two Fokker - 28 fuselage section drop tests were conducted to character the fuselage response of a metallic regional sized commuter aircraft (FAA/NASA Fokker-28 fuselage section drop tests). To obtain data on the fuselage response of a composite aircraft structure, a Hawker 4000 fuselage section was drop tested. This data will be used to compare the results with those of a future drop test of a comparable metallic aircraft.

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Figure 3: Flight 1549 Water Impact into the Hudson River, NYC

Figure 4: 1St FAA/NASA Fokker F-28 Fuselage Section Drop Test

Aeromedical Research Conducted

Airmen-Reported Beta-blockers versus those found by forensic analysis

Beta-blockers reported by pilots were assessed and compared to those found in the toxicology analysis of specimens received from fatal aviation accidents. Beta-blockers are a class of drugs that are used to manage cardiac arrhythmias and to treat hypertension. Several papers in literature have discussed drugs detected by toxicology analysis compared to those reported by pilots. However, no one has examined pilot-reported medications compared to those that were detected by toxicology analysis. Beta-blockers are disqualifying medications for flight and require a special issuance medical certificate. The majority of pilots (70%) reporting commonly used beta-blockers were found to be taking the beta-blocker by postmortem forensic toxicology analysis. In those cases where the medication was not found exists the possibility that the pilot missed taking the medication on the day of the accident. In some cases, pilots were found to be taking a different beta-blocker than was reported in their medical records. There are many other reasons why a postmortem forensic toxicology laboratory might not detect a beta-blocker in a postmortem specimen, such as elapsed time from taking the medication resulting in the concentration of the beta-blocker dropping below therapeutic concentrations and detectable limit. This study determined the capability of the Civil Aerospace Medical Institute laboratory in detecting reported drugs and identify pilots with medications below detectable limits. It also provides guidance in the clinical manifestations of beta-blocker use in the performance of aviation operations and evaluates medical certification processes regarding the reporting of these medications.

Figure 5: Forensic Toxicology Research Laboratory

Air Traffic Control (ATC)/Technical Operations Human Factors Research Conducted

Validate Terminal Radar Approach Control (TRACON) training standards

The goal of this effort was to develop new on-the-job training standards that would engage (ATC) training experts to qualitatively evaluate their suitability. The training would increase the certification rates and reduce time to certification for developmental controllers in TRACON facilities. The program is proposing a study on the longitudinal evaluation of the impact from the use of the standard. Research used an incremental approach to mastering the skills necessary for developmental controllers such as communication techniques, separation, and traffic flows and sequences. The training standards underwent iterative development and review with on-the-job instructors and other training experts. The new TRACON training standards were provided to the Air Traffic Organization's (ATO) Safety and Technical Training office for a trial implementation.

Figure 6: On the Job Training Standards Participants

Aircraft Catastrophic Failure Prevention Research Conducted

Complete standard composite testing for development of predictive modeling methodology, applicable to certification by analysis of aircraft engine fragment impact

Engine fragment impact into composite structure used for engine containment and fuselage structure is a vital aircraft safety consideration. Modeling and simulation of composites during an impact event is a huge challenge given the wide variety of composites and the associated complexity in characterizing the behavior. While composites have been in use for decades in a variety of industries such as civil structures, automotive and aerospace, building a predictive model is still daunting. In the U.S., several government agencies (including National Aeronautics and Space Administration (NASA) and the FAA) have recognized the importance of building a framework for composite systems by forming a public facing private consortium. FAA funded the first phase of the research effort to build a high-fidelity composites material model as an expansion of the tabulated modeling for metals, with the goal of implementing the model into the commercial finite element program, LS-DYNA, developed in 2012. Subsequently, in 2015, the NASA Advanced Composites Project provided further funding to go beyond the simple damage and failure models into the development of more complex ones suitable for modeling aerospace and other structures. Central to the development, verification and validation of this model are high-fidelity experimental data obtained by testing composite coupons and structural components under a variety of test conditions that is funded by FAA.

The laminated composite material, T800-F3900, was chosen as the material to study as it is close to the tape used in aircraft fuselage and the FAA has some of the material data associated with the composite. Toray Composite Materials, the manufacturer of the composite, describes the unidirectional composite as one with an intermediate modulus, high tensile strength fiber, developed as a cost effective alternative to T800H. The composite has excellent tensile properties and is specifically designed to meet the weight savings demand of aircraft and high performance recreational products.

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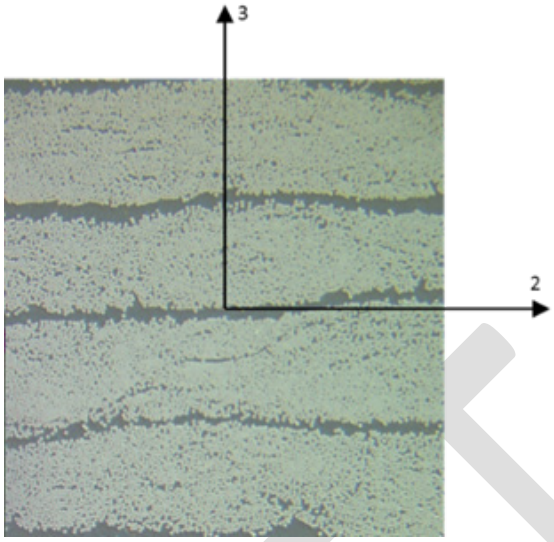

Figure 7: T800/F3900 Uniaxial Composite Micrograph

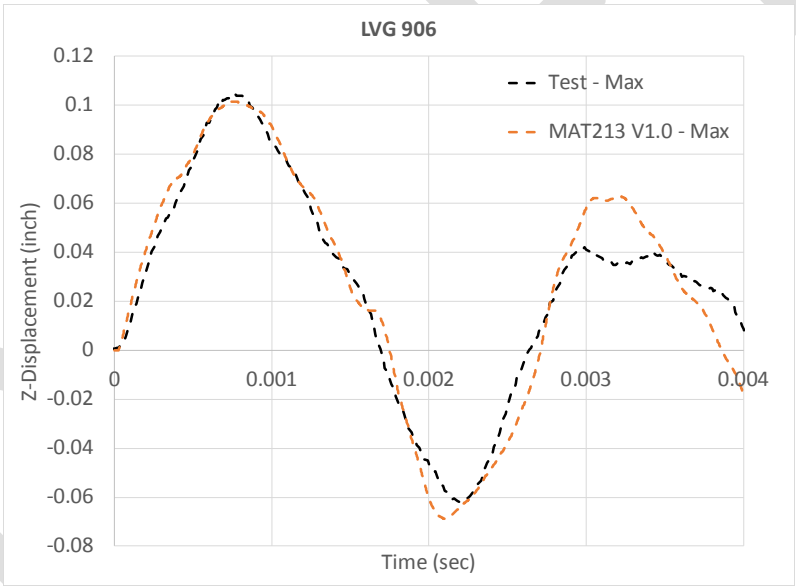

Figure 8: Comparison of out-of-plane displacement of impact test LVG906 and simulation results matches very well

Aircraft Icing Research Conducted

Complete sloped surface testing of fluid protection on extended flaps & slats on aircraft, airfoils & flat plates, at angles simulating aircraft surfaces

The FAA along with partner Transport Canada completed an investigation of the impact on holdover time when flaps and slats are deployed prior to anti-icing of the aircraft. The objective was to determine if the holdover time's tables used operationally need to be modified for those aircraft that follow the practice.

Figure 9: Testing Anti-Icing Fluid Performance on Full-Scale Aircraft and Flat Test Plates

Testing employed full-scale aircraft, flat plates, and airfoils. Analysis of test results showed that there was an appreciable reduction in holdover times for these aircraft. Flight Standards guidance for winter 2017-2018 calls for a 24% reduction in holdover time when flaps and slats are deployed prior to anti-icing of the aircraft.

Figure 10: Testing Anti-Icing Fluid Performance on Airfoils in Montreal, Canada

Conduct aerodynamic test of swept-wing, with ice shapes in ONERA F1 wind tunnel

The FAA along with partners (NASA and the French Aerospace Lab (ONERA)) completed aircraft swept-wing icing research at the ONERA F1 pressurized wind tunnel in Le Fauga-Mauzac, France from May 1-12, 2017. The objectives of this test campaign were to determine the changes in swept-wing aerodynamic performance for various configurations of artificial ice shapes along with the effect of Reynolds and Mach number.

Figure 11: Swept-Wing Model with Iced Leading Edge in the ONERA F1 Wind Tunnel

Testing was completed on a model aircraft wing (7.5' semi-span) designed with a removable leading edge, which allowed for artificial ice shape changes. Test runs were conducted at simulated flight conditions with sweeping angles of attack. The test matrix consists of nine different test conditions (varying Reynolds number and Mach number) for the clean leading edge and for each ice shape configuration. All 12 planned high priority configurations, two extra secondary configurations, and four repeat runs (checking repeatability) were completed, exceeding expectations. Data acquisition was complete and data will be analyzed during the next phase of the project. The model surface pressures, and force balance loads were recorded. The lift, drag and pitching moment coefficients are calculated from the force balance. The results will be used to develop a benchmark database for validation of ice accretion and flow field computer codes and computational simulations for possible use design and certification of aircraft for flight in icing.

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Airport Cooperative Research Program (ACRP) Research Conducted

Develop airport emergency operations center design guide

Emergency operations centers (EOCs) are involved in command and control, policymaking, coordination, and overall direction of responding forces in an emergency situation. Airports have begun to utilize EOCs to help manage planned and unplanned events and have benefited from managing all-hazards incidents and planned events in a strategic manner. Early incarnations of airport EOCs typically only included police and fire. However, as the benefits of an EOC have been realized in emergency management and shared with others, airports have begun adding other stakeholders. As those additional stakeholders are added, the design requirements of the EOC change. As airports begin to think about adding a new dimension to their emergency response management, they begin, typically, by utilizing or cross-utilizing existing space for their EOCs to allow them to have some functionality. There are FEMA (Federal Emergency Management Agency) documents and FAA Advisory Circulars (ACs) that provide a broad overview of the requirements, functionality, and general design of an airport EOC to help guide those airports.

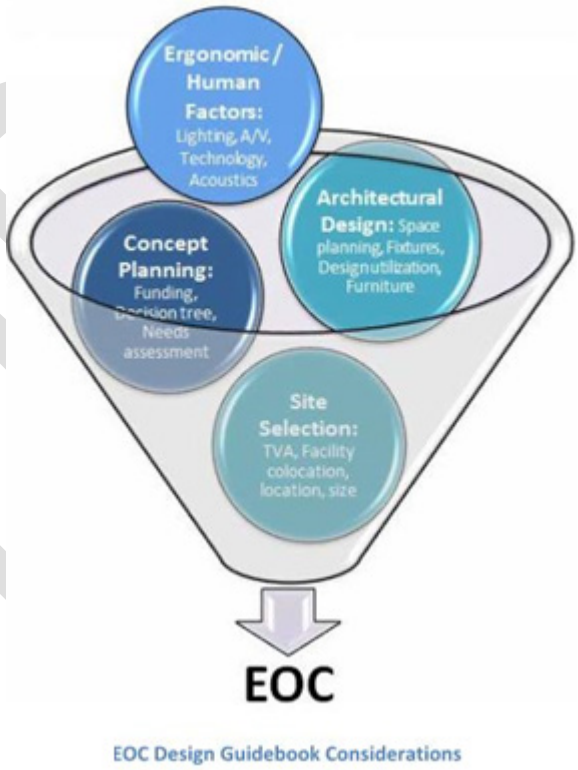

Figure 12: Emergency Operations Center

The objective of this research was to identify the detailed considerations necessary to design an effective airport EOC. The detailed considerations include, at a minimum, physical,

technological, functional, operational, and governance factors. The final report is scheduled to be printed (published) November 30, 2017.

Develop an airport management guide that provides aircraft fueling services

Publicly owned airports have an interest in providing aircraft fueling services, which may be due to market or other conditions that are not attractive to the private sector. Due to a variety of financial and economic barriers, some airports have lost full-service fixed base operators and must decide on whether to provide those services in full or in part. Some airports are assuming responsibility for fixed base operators facilities, fuel storage systems, and provisions for self-service fueling. Airport operators are unfamiliar with the requirements for selling fuel directly to aircraft owners and operators. Factors such as pricing strategies, inventory controls, customer expectations, staffing, regulatory requirements, capital investment, and operating and maintenance costs associated with the fueling services are some of the elements essential to the decision to engage in providing fueling services.

The objective of this research was to develop a guidebook for airports that are considering, or are currently providing, fueling services to their customers. The guidebook should serve as a manual that an airport can use as a reference to include a methodology to evaluate whether an airport should or should not provide fuel service; a checklist of action items required for providing fuel service; and a sample request for proposal, for the provision of aircraft fuel supply. The final report, titled 'Airport Management Guide for Providing Aircraft Fueling Services' was printed (published) September 2017.

Technology solutions that facilitate domestic travelers with disabilities

Airports strive to make their facilities more user-friendly by going beyond compliance to respond to the changing demographics and unique needs of the 21st century traveler. The airport industry has adopted specific design codes in response to state and federal regulatory requirements including The Americans with Disabilities Act to accommodate employees and travelers with disabilities. These design codes include general architectural guidelines and technology adapted for transportation facilities. Airports need guidance on current and potential innovations, technologies, business practices, and partnerships with stakeholders to better address the needs of passengers who have a variety of physical, sensory and/or cognitive challenges.

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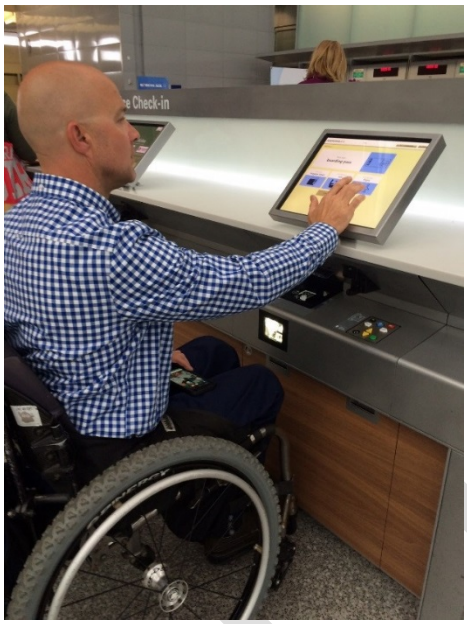

Figure 13: Accessible Check-in Kiosks at San Francisco International Airport

The objective of this research was to provide guidance and information to airports and their stakeholders on the availability of innovative solutions to facilitate accessibility for passengers who have a variety of physical, sensory and/or cognitive challenges. This guidance shall be applicable to a variety of types and sizes of airports and shall include at a minimum, the following considerations:

- Leveraging innovation (digital or physical) at passenger touchpoints and throughout the course of the journey, including at remote terminals;
- Issues related to physical facility layout (i.e., distance, time, physical and sensory obstacles, including access to and accommodations for service animals);
- Enhancements to existing airport physical and IT assets to improve accessibility and the passenger experience;
- Innovative resources and communication methods needed during irregular operations;
- Needs of the inexperienced passenger;
- Methods to allow continual process improvement among stakeholders, and
- Possible impediments to implementation (e.g., legal, regulatory and safety issues). The report is expected to be printed (published) at the end of 2017.

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Airport Technology Research Program (ATRP) Research Conducted

Complete in-service testing of new light emitting diode lighting circuits for use on airports

Testing of a new light emitting diode lighting fixture-centric circuit was completed at the Purdue University Airport in Lafayette, IN, in June 2017. The introduction of Energy Independence and Security Act of 2007 (which calls for the eventual phase out of all incandescent filament-based lighting technology), has required the FAA to develop new standards for light emitting diode lighting airport lighting circuit designs. Due to the higher efficiency and lower maintenance costs, researchers have found that the size of power supplies and cabling to construct an airport lighting circuit can be greatly reduced due to the lower power consumption. The end result is much cheaper, higher efficiency, long lasting lighting circuit design. A final report discussing these findings has been prepared and will be published in early FY 2018.

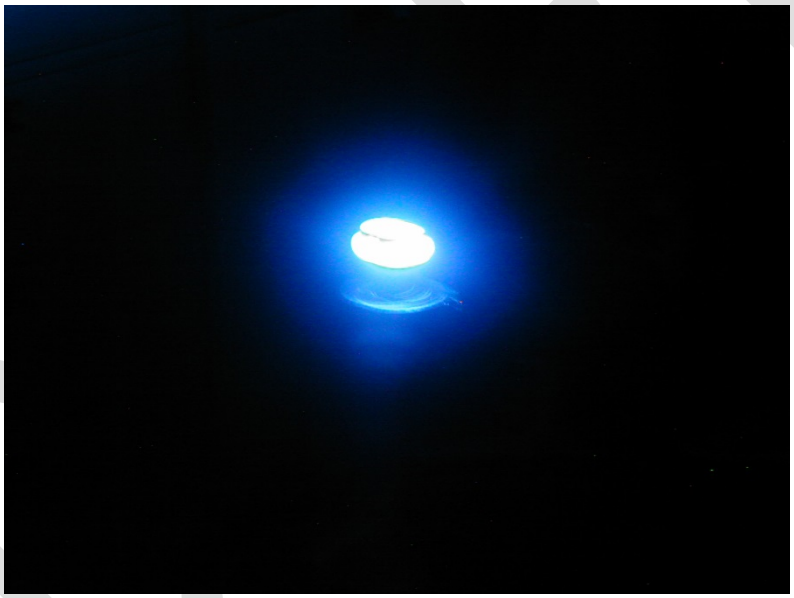

Figure 14: LED Lighting at Night

Figure 15: Airport Lighting Vault Being Used to Test New LED Circuit Designs

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Center for Advanced Aviation System Development (CAASD) Research Conducted

Developing a digital co-pilot concept to reduce single-pilot workload & increase general aviation (GA) safety

Single-pilot operations are riskier than two-pilot flights. This is in part due to the high workload associated with flying an airplane solo and the lack of a second pilot to crosscheck decisions. There is a lot of information competing for the pilot's attention and losing focus or situational awareness can be a precursor to an accident. Today, many GA pilots are shifting away from paper charts to using electronic versions of this information. Anything that causes the pilot to look down at a chart, or take their hands off the controls, creates a potentially unsafe situation.

The digital copilot acts as a cognitive assistant by reducing the solo pilot's workload. The digital co-pilot algorithms infer the pilot's intent (based on the flight context) and then automatically provide relevant information to the pilot at the appropriate time through a simple and intuitive speech-based interface. In FY 2017, CAASD conducted research to develop new digital copilot safety features, continued refining the research prototype, performed additional evaluation and testing, and continued outreach to industry. Some of the new features were aimed at increasing safety for single-pilot instrument flight rules operations. For example, during instrument approaches pilots must continually refer to the approach plate for information about the next fix. CAASD conducted a pilot workshop with 18 instrument rated pilots to evaluate the utility and usability of the new features. Pilot feedback from the workshop was used to refine and improve digital co-pilot. The new features have also been evaluated during several flight tests conducted in Cessna 172/182 aircraft. This provided a verification that the features would perform as expected in real-world operations.

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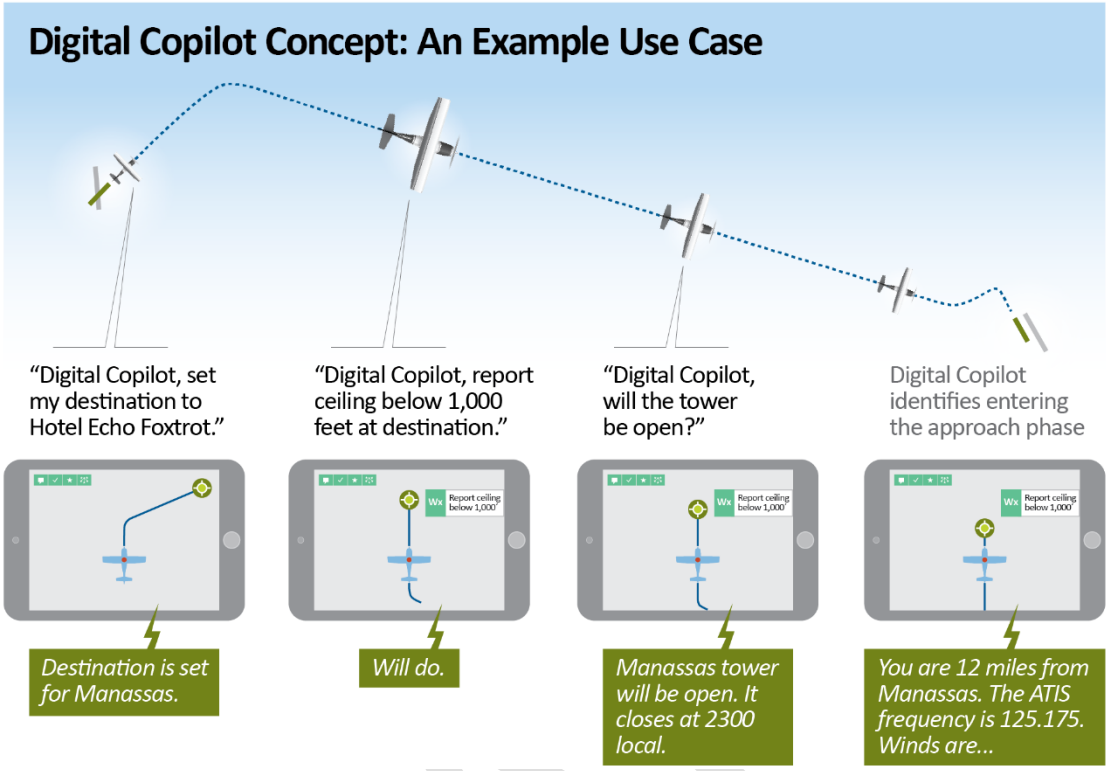

Figure 16: Example of Digital Copilot Usage

CAASD evaluated the digital co-pilot under the MITRE Corporation's Early Career Reach Program and the MITRE Innovation Program. The Early Career Reach Program project used human performance modeling to predict potential digital co-pilot benefits. The results showed that the digital co-pilot reduces heads down time and mental workload as compared to three commonly used Class 1 electronic flight bag software applications. Under a separate MITRE Innovation Program project, titled 'Evaluating Cognitive Assistance in Operational Safety,' a human reliability analysis and probability risk assessment were conducted. This analysis showed that, assuming 100% equipage, digital co-pilot has the potential to reduce the annual GA accident rate as much as 17%, and the fatal accident rate by up to 30%. Industry outreach completed this year involved manufacturers and developers who may have interest in commercializing the technology; interviews and articles in aviation news outlets; and academic publications. Four journal articles were published on digital co-pilot, and five articles have been published in Popular Aviation magazines. This capability is important and beneficial to FAA, the NAS, the aviation community and particularly the general aviation industry as this research is focused on safety.

Evaluating space traffic separation concepts

Since the 1960's, large amounts of airspace have been segregated for launch and re-entry vehicle operations, requiring other NAS operators to reroute traffic around the restricted airspace. The FAA is working to develop new and more efficient separation concepts and associated standards for a variety of launch and re-entry vehicle operations to minimize their effects on other NAS users. However, the safety of those concepts is unknown. Between 2015 and 2017, CAASD conducted research to develop a fast-time modeling and simulation capability to measure the safety for launch and re-entry vehicle operations with different separation concepts. This capability produces several metrics that the FAA can use to determine which separation concepts meet a target level of safety. It also examines operational risks of new separation concepts and provides insight into the required surveillance performance, ATC response times, and traffic limits to enable them. It supports the FAA's Safety Management System process by providing an analytic capability that can be used to examine the potential magnitude of risk for different operational conditions.

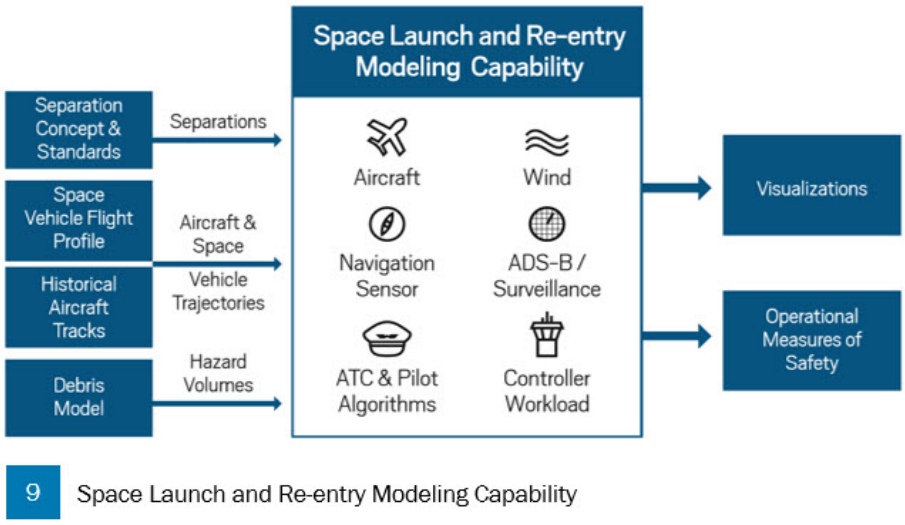

Figure 17: Space Launch and Re-Entry Modeling Capability Architecture

In FY 2017, CAASD finalized development and validation of its fast-time modeling and simulation capability for Space Launch and Re-entry Modeling (see figure above). CAASD also exercised the model to examine model findings candidate case studies. Specifically, CAASD applied this research capability to examine aircraft behavior in response to unplanned hazards in the airspace. The FAA provided CAASD with aircraft hazard areas from a prior launch, and the project team used the capability to assess how long it could take aircraft to evacuate each of the dynamic aircraft hazard areas. These findings were presented to the FAA during Safety Risk Management Panel discussions in December 2016. Under this project, CAASD also enhanced the FAA's debris modeling tool so that aircraft hazard areas can be quickly generated to impact a vehicle's trajectory at different time intervals (see figure below). This enhancement allows the

FAA to rapidly determine potential aircraft hazard areas from many what-if scenarios. These aircraft hazard areas can then be used to determine the number of impacted flights in a very rapid fashion. For example, the tool can be used to generate aircraft hazard areas for eight orbital reentry trajectories at different time intervals (e.g., every 30 seconds along a trajectory) within a few hours. This research provides the FAA's Safety and Technical Training Organization, Mission Support Organization, Office of Commercial Space Transportation, as well as the commercial space community, a fast-time capability to evaluate separation concepts and standards to determine if they meet a target level of safety. Additionally, it provides insight into the required performance of surveillance and ATC response times to enable future concepts and standards. Collectively, meeting these objectives ensures that all current and future users of the airspace can travel safely and efficiently.

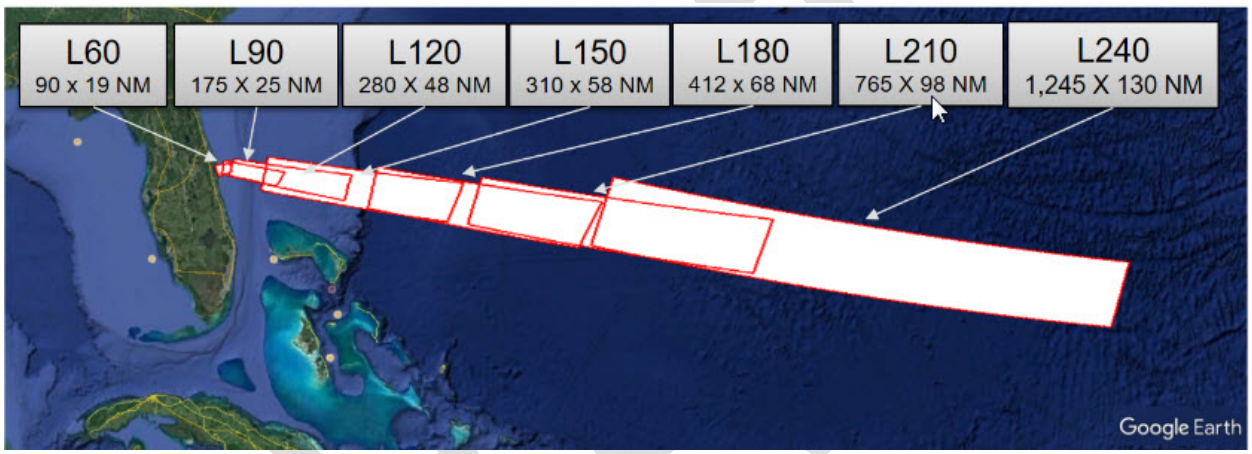

Figure 18: Conceptual depiction of aircraft hazard areas structured by time

To conclude research on this effort, CAASD prepared the capability for sustained use and technology transfer through documentation of the software code and algorithms.

Commercial Space Research Conducted

Comparison of debris predictions to empirical evidence from recent mishaps

Public safety and NAS efficiency during launch and reentry operations are tied to the efficacy of sophisticated computer models that predict where potential debris impacts could occur. A quantitative comparison was performed on pre-flight debris predictions to empirical evidence for several mishaps, including those for Virgin Galactic's SpaceShipTwo, Blue Origin's PM2, Orbital Science's Antares, and SpaceX's Falcon 9, and Falcon 9R. Figure 19 below shows that the actual impact locations from the SpaceShipTwo event were within the 95% probability of containment ellipses, including very light weight debris that landed for than 30 miles away from the main debris. In some cases, debris models were modified based on these evaluations. Approaches for further quantitative comparison, debris list development and post-breakup debris modeling are recommended. A design concept for a database of launch and reentry vehicle debris lists, and debris data from actual events, is recommended which can be queried to produce useful input to safety assessments by the FAA and other entities.

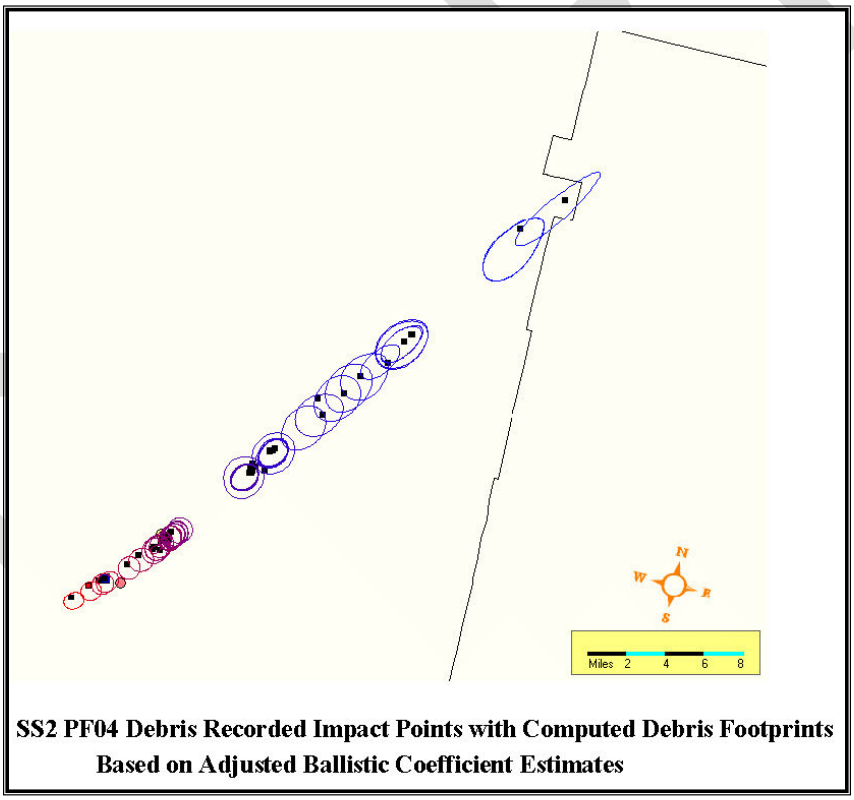

Figure 19: Comparison of actual debris impact points and predicted impact dispersion ellipses for SpaceShip Two accident (Lambert Nyman 2016)

Continued Airworthiness Research Conducted

Bonded repair technology

Under a cooperative R&D agreement, FAA and The Boeing Company are investigating the durability and damage tolerance aspects of adhesively bonded repairs through test and analysis. The primary initial focus has been metallic fuselage structure applications using panels harvested from retired B727 airplanes and tested using the FAA's Full-Scale Aircraft Structural Test Evaluations and Research facility. A phased approach was taken involving several panels containing boron-epoxy and aluminum bonded patches. Varieties of loading and environmental conditions, damage scenarios, and repair conditions have been considered. Altogether, four panels were tested.

In general, baseline results from Panel 1 demonstrated that properly designed and installed bonded repairs are durable under fatigue and capable of effectively containing significant damage under severe loading conditions. Repair patches were intentionally made deficient to permit damage growth in Panel 2 to demonstrate the effectiveness of several nondestructive inspection methods and a prototype piezoelectric-based structural health monitoring system. The effect of environmental conditions including ambient, hot-wet (165°F and 85% humidity), and cold (-25°F) on the mechanical and fatigue behavior of bonded repairs was studied in Panels 2, 3 and 4, respectively. High thermal residual strains developed within the footprint of the boron-epoxy patches and surrounding areas because of mismatches of the thermal coefficient of expansion in the composite patch and aluminum fuselage panel, and were much lower and often insignificant for the aluminum patches. The effect of applied environment on the notch-tip mechanical strains was determined where strains increased as temperature decreased for the boron-epoxy repairs, while not a factor for the aluminum repairs. Consequently, crack growth rates increased with decrease in temperature for boron/aluminum repairs with limited effect of environment to aluminum repairs. Data from this program has been used to assess tools and methods for evaluating and monitoring bonded repair integrity.

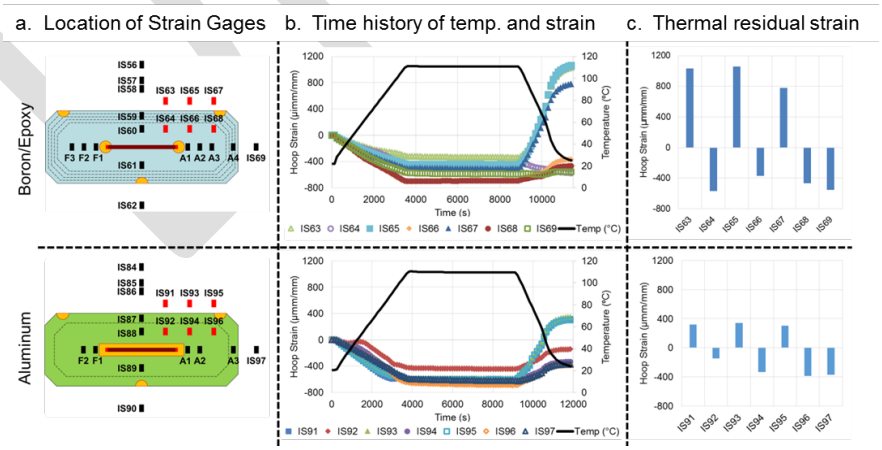

Figure 20: Strains monitored during cure process & resulting thermal residual strains

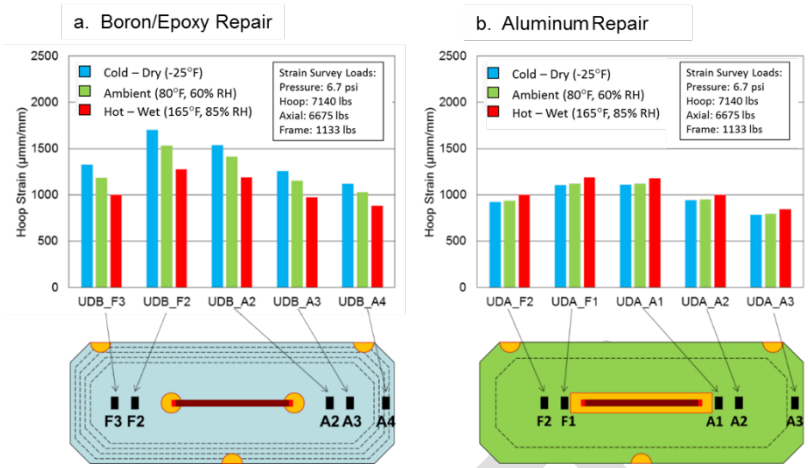

Figure 21: Effect of environment on notch-tip mechanical strain behavior

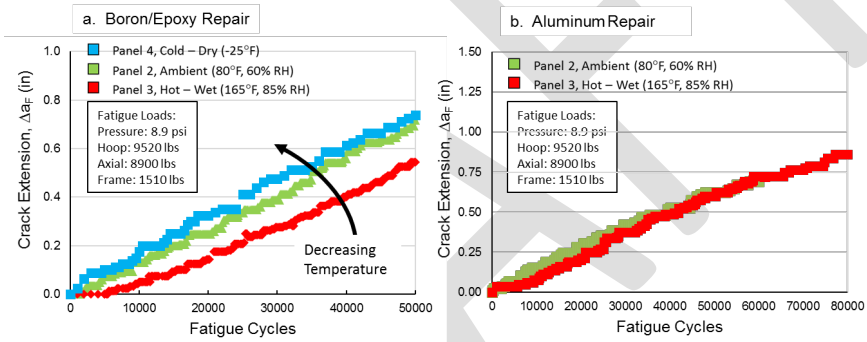

Figure 22: Effect of environment on fatigue behavior

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Digital System Safety Research Conducted

Assurance issues on use of virtual machines in avionics systems

Virtual machine technology uses a hypervisor that creates multiple virtual copies of a computer that is to be used by a single application as if it was the only one running. This virtual copy, known as a virtual machine must be isolated from other virtual machines. For the certification of avionics systems, this isolation is a valuable asset that potentially allows modularity of certification and re-certification. As a result, this study evaluates current virtual machine technology and related technology as it relates to the assurance of avionics systems.

During the first stage of the research, a detailed literature survey that tracks the historical origin of virtualization and explores related isolation and verification techniques was conducted. Several motivations and goals of the virtualization technologies were identified from the survey, in particular, how the initial virtualization techniques were more focused on simplicity of development and were used with a strong focus on throughput. Clearly, throughput has been a key driver of general purpose computing, but hinders the worst-case (timing) behavior needed to assure real-time systems. This research recommended alternative isolation mechanisms focused on real-time behavior. The research focus was on how the goals of assurance of avionics systems relate to different virtualization technologies, and how different innovations in the hardware layers interact with this virtualization. In this context, the research documented how recent innovations in real-time systems deal with hardware innovations in order to ensure a predictable timing behavior. The study was divided into timing verification and logical verification. From the timing perspective, multiple verification techniques were proposed which are generic enough to model virtualization, and the tradeoffs among them were documented. From the logical verification side, different techniques that require different degrees of human involvement, from fully automated, such as model checking, to more interactive, such as theorem provers were documented.

Following the verification techniques, the research progressed into the compositional techniques for verification. The enhancements on the discussion of the verification technologies with a strong focus on compositionality and modularity were reviewed. In particular, the brittleness of the modules and their interfaces that these techniques offer, and their effect on modular certification were documented. The research also highlighted the assurance data that can be affected by the porting of an application from single to multicore processors and the use of hardware emulation to try to preserve the behavior of the original hardware. Several recommendations and conclusions on the use of virtual machines in airborne systems were made. The research results will be used in developing guidance and training material for the certification engineers. The research also recommends additional research on isolation and verification techniques for improved modular re-certification and fostering the corresponding standards; on solutions for the impact of multicore on virtualization technology; and on verification schemes for virtualization implementations.

DRAFT

Fire Safety and Research Conducted

Develop new test apparatus & methodology to accurately measure heat release-rate of Honeycomb, Thermoplastic & other large surface-area cabin interior materials

The rate of heat release apparatus is a flammability test method required by the FAA to qualify large surface area interior materials such as ceilings, stow bins and sidewalls for use in commercial passenger aircraft. The current test apparatus is a modified version standardized by the American Society of Testing and Materials (ASTM), ASTM E-906. This test standard became an FAA flammability requirement in 1988 for large surface area cabin materials used in commercial aircraft. Test samples measuring six by six inches representing the completed interior component are injected into an environmental chamber through which a constant flow of air passes. The sample is exposed to a radiant heat source adjusted to produce a total heat flux of 3.5 Watt/cm^2 on the sample. The sample is tested with the exposed surface oriented vertically, with combustion on the lower face area initiated by piloted ignition. The products of combustion leaving the chamber are monitored by an array of thermocouples in order to calculate the release rate of heat. During the five-minute test, the peak heat release rate is calculated in kW/m^2, along with the total amount of heat released from the material during the first two minutes of exposure, expressed in kW-min/m^2. These two parameters are referred to as the peak and total, respectively.

Since 1988, these studies have indicated reproducibility of test results could be improved. There are many factors that can contribute to poor agreement between test laboratories. The FAA Fire Safety Branch, through the auspices of the International Aircraft Materials Fire Test Working Group, initiated a task to develop a new test apparatus with the goal of increasing inter-lab correlation. The new apparatus referred to as the HR2, focused on standardization of components, procedures and calibration to improve accuracy and repeatability. The primary change involved the airflow through the apparatus, which was switched from a dual flow bypass set-up to a single flow. Airflow is now controlled using a mass flow controller. The mass flow controller allows for constant monitoring and instantaneous adjustment of the incoming airflow, a marked improvement over the original method in which the flow of air was set using an orifice meter. In addition to the airflow improvements, a new ramping calibration procedure has been implemented, and the thermopile system used to measure the temperatures out the exhaust stack has been updated. Numerous other changes have also been adopted to improve the accuracy of the test. Two commercial fabricators have produced prototype apparatuses based on the new design.

One of the manufacturers also produced a transparent apparatus that was shipped to the FAA's Small Scale Flammability Laboratory located at the William J. Hughes Technical Center in July 2017. This apparatus is being used for flow visualization studies with Particle Image Velocimetry technology.

The development of the new test apparatus contributes to the FAA Objective of helping the aerospace community to effectively and efficiently certificate and license aerospace operators

and vehicles in different environmental conditions and envelopes. The initial correlation tests indicate a high level of agreement between the prototype apparatuses. This outcome provides further evidence that the improved methodology can be implemented with minimal disruption to aircraft interior component production. The new apparatus and test methodology were delivered to the Transport Airplane Directorate ANM-115 and presented publicly to the aerospace community at the International Aircraft Materials Fire Test Working Group meetings.

Determine mode of flame spread of structural composites in hidden & enclosed spaces

Experiments were conducted in the FAA's Full-Scale Fire Test Facility to determine the mode of flame spread on Carbon Fiber Reinforced Polymer (CFRP) fuselage structure in hidden areas and enclosed spaces in an airplane cabin. The test series was performed in response to an incident on a parked and unoccupied Boeing 787, in which the lithium batteries used in the Emergency Locator Transmitter (ELT) failed and went into thermal runaway. During thermal runaway, a lithium battery can inadvertently heat up, causing a buildup of internal pressure and subsequent release of the flammable electrolyte, which is ignited from the hot surface of the battery casing. During the 787 incident, high temperature flame jets from the ELT batteries impinged on the inboard surfaces of the CFRP fuselage skin and structure. The CFRP fuselage was found to support and propagate flames from the ELT over a large area above the cabin ceiling, in the narrow gap between the thermal acoustic insulation and the inboard surface of the fuselage skin. The extent of the flame propagation indicated that under certain conditions, the CFRP skin and structure were able to propagate flames, which is contrary to the testing and analysis originally conducted to certify the airplane. The recent experimentation was performed to determine what conditions must exist in order to observe significant flame propagation on the CFRP skin, and if similar flame propagation would also occur when simulating in-flight conditions by removing heat from the skin with enhanced external surface heat transfer.

Test results indicated that a self-propagating fire can develop on the composite panel with either ignition source, depending on the size of the gap between the thermal acoustic insulation and the inboard panel surface. The ELT ignition source was more intense and resulted in full-length propagation of flames in each test, while the foam block fire source did not consistently result in full-length flame propagation. Combustion product gas concentration measurements indicated that in some tests where the simulated hidden area was more confined, the amount of available oxygen to be drawn into the fire was limited, resulting in higher levels of carbon monoxide, and a smoldering, non-flaming combustion mode. For all tests where burning propagated the entire length of the panel sample, a similar test was conducted in which water was discharged on the external composite surface to simulate aerodynamic (in-flight) cooling. The increased rate of heat removal by water on the external surface was found to preclude any inboard flame propagation beyond the immediate area of fire source impingement. The test results contribute to the FAA objective of helping the aerospace community to effectively and efficiently certificate and license aerospace operators and vehicles in different environmental conditions and envelopes. The tests indicate that although composite skin can propagate flames during on-ground conditions, the aerodynamic cooling on the external skin surface experienced during in-flight conditions results in minimal flame propagation and no hazard to the occupants. This outcome provides further evidence that the level of safety of the current certification basis of

composite fuselage aircraft is equivalent to a traditional aluminum-skinned aircraft during an in-flight hidden area fire event. The test results were delivered to the Transport Airplane Directorate ANM-115 in February 2017, and presented publicly to the aerospace community at the International Aircraft Materials Fire Test Working Group meetings held in March and July of 2017.

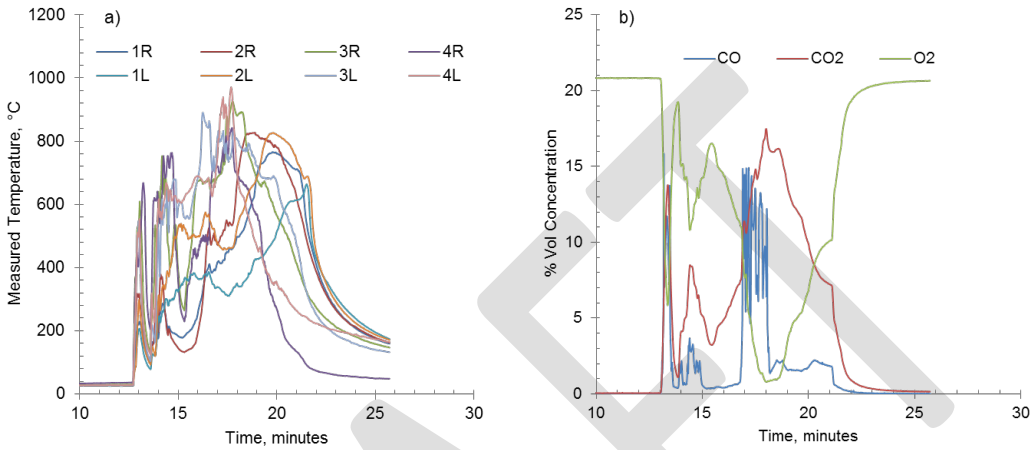

Figure 23: a) Measured inboard near-surface temperatures during ELT-induced flame propagation and b) measured combustion product gas concentration

Figure 24: Flames exiting the test fixture

Figure 25: Technician conducting test using new heat release apparatus

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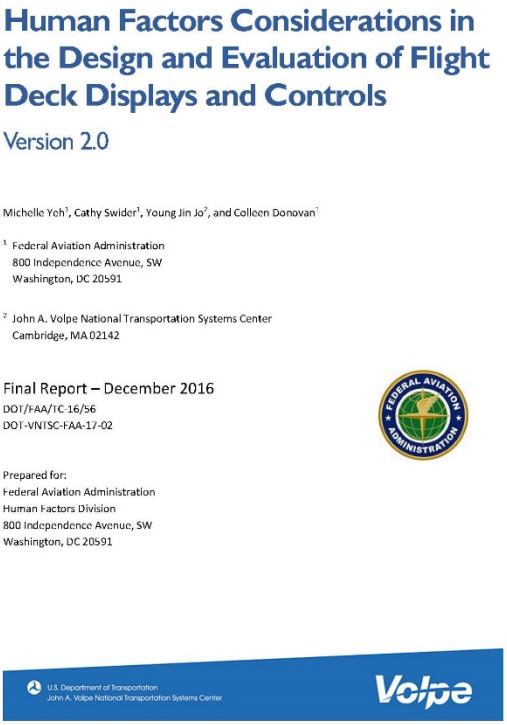
Flightdeck Maintenance System Integration/Human Factors Research Conducted

Update human factors guidance for design & certification of flight deck equipment

The single-source document for human factors issues for flight deck avionics is a resource that provides regulation, guidance, and best practices for the design and use of aircraft displays and controls. It is used by FAA certification and flight standards personnel to ensure pilots are able to operate their flight deck systems safely. In addition, it is a resource for industry to incorporate scientifically-proven human factors into flight deck displays and controls. This document pulls relevant data from over 200 sources, including 83 regulations, 18 ACs, 19 Technical Standards Order, and eight Policy Statements, three RTCA (International) documents, 15 Society of Automotive Engineers International documents, 68 Research Reports, and a sampling of European Aviation Safety Agency, military, and International Civil Aviation Organization (ICAO) documents.


Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls

Version 2.0

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Final Report – December 2016
DOT/FAA/TC-16/56
DOT-VNTSC-FAA-17-02

Prepared for:
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U.S. Department of Transportation
John A. Volpe National Transportation Systems Center

Volpe

Figure 26: Human Factors Report on Design and Evaluation of Flight Deck Displays and Controls

Propulsion and Fuel Systems Research Conducted

Develop & implement improved fleet risk analysis methods to address corrective actions

Recent developments in turbine engine component risk assessment software shows that high-energy rotating components in aircraft gas turbine engines may contain inherent or induced anomalies that can lead to rare but potentially catastrophic failures. FAA ACs address specific types of inherent and induced anomalies (AC 33.14-1 and AC 33.70-1) and establish a general framework for all life-limited engine parts (AC 33.70-1). The associated risk of fracture can be predicted using DARWIN®, the award-winning probabilistic fracture mechanics software developed by Southwest Research Institute® under FAA R&D funding.

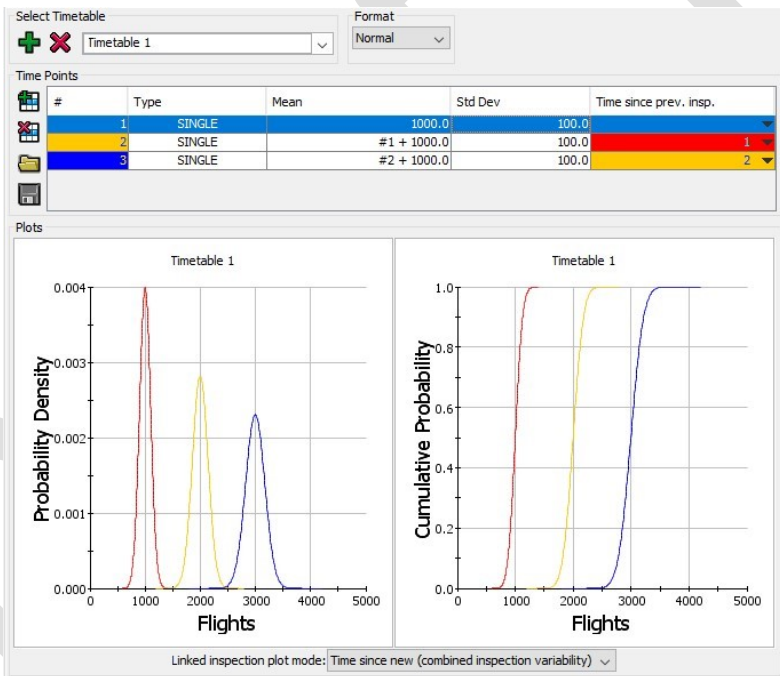

Figure 27: The DARWIN 9.2 Fleet Assessment Module includes a new inspection menu that enables users to specify multiple corrective action inspection times for application to fracture risk assessments.

The DARWIN® 9.2 Fleet Assessment Module introduces a new inspection-based corrective actions capability. FAA AC 39-8 addresses the risk associated with safety-related events in aircraft fleets. It enables users to assess the influence of inspection-based corrective actions on the fracture risk of aircraft fleets in accordance with AC 39-8. The module was enhanced to enable users to specify inspection times and to assign them to one or more sets of components in an aircraft fleet. The Fleet Assessment Module automatically exports the specified inspection times to DARWIN® mission-level project files, executes the risk analysis for each file, and retrieves the results for use in fleet risk assessments. This enables users to assess the influence of

inspection-based corrective actions on the fracture risk of an entire aircraft fleet. It provides a framework for defining groups of components based on mission profiles and the times at which component groups are placed into service. The module also has the capability to simulate the influence of component replacement corrective actions on the fracture risk of aircraft fleets. Previous versions did not provide effective treatment for inspection-based corrective actions.

DRAFT

System Safety Management Research Conducted

Integrated domain safety risk evaluation tool (ID-SRET)

An ID-SRET prototype supports the FAA Air Traffic Safety Oversight Service (AOV)'s decision-making process in the Safety Risk Management Document (SRMD) evaluation and NAS change impact analysis.

Whenever the ATO proposes a change to the NAS with potential safety implications, the ATO must develop an SRMD to identify the potential hazards associated with the proposed changes, and develop controls to mitigate the hazard risk to acceptable level. To mitigate high-risk hazards or hazards that require actions across the lines of business, the ATO must obtain approval or acceptance from the AOV prior to implement the proposed controls. To approve or accept the proposed controls for hazards associated with the NAS changes, AOV needs to evaluate the SRMD to assess the effectiveness of proposed controls and safety impact of proposed changes to the NAS.

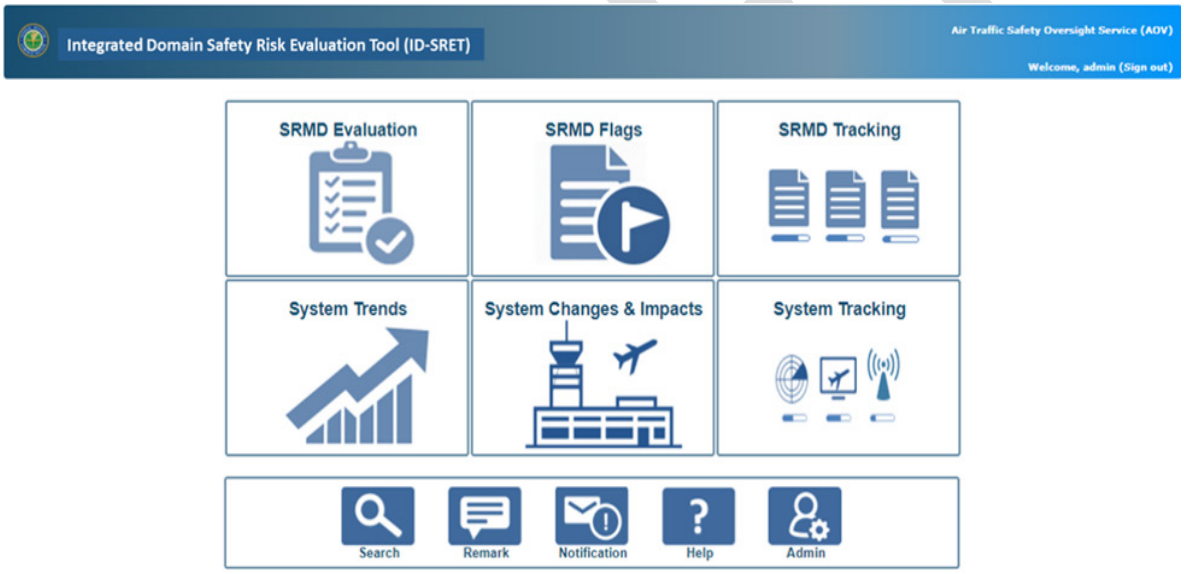

Figure 28: ID-SRET

The ID-SRET is designated to support AOV's decision-making in approving or rejecting the controls proposed for mitigating the high-risk hazards or hazards with controls across the lines of business. The ID-SRET prototype, which was built on a system model that integrates the NAS architecture and system safety data, is able to address the changes associated with 70 NAS critical systems which are classified as automation, navigation, surveillance, communication, and weather. It provides decision-making support in the process of SRMD evaluation by identifying similar NAS changes, similar SRMDs, similar hazards/causes/controls, single point of failure, potential missing hazards/causes/controls, and control dependencies; and assessing control effectiveness, system performance trend. To date, a functional ID-SRET prototype was delivered to AOV, including associated documentation, such as *A Study of Critical NAS Systems*

for Integrated Domain – Safety Risk Evaluation Tool (ID-SRET), published in December 2016, and *Concept of Operations, Model and Methodology for the ID-SRET*, published in May 2017.

DRAFT

Unmanned Aircraft System (UAS) Research Conducted

Develop prototype antenna & brass board electronics, lab-test & flight test antenna final designs for airborne collision avoidance system

The purpose for integrating the Airborne Collision Avoidance System into the sense and avoid for UAS is to incorporate both self-separation and collision avoidance functionality that provide maneuvering to remain well clear from and avoid collision with other conflicting air traffic. One of the projected benefits of this research is to examine active surveillance antenna requirements with UAS in mind, considering the size, weight, and power limitations of the particular UAS included in the SC-228 scope. The RTCA SC-228 scope set requirements found in the Traffic Alert and Collision Avoidance System. Developing a prototype antenna and brass board electronics, lab-test and flight test antenna final design for Airborne Collision Avoidance System antennas, along with hardware/software for test data collection, was an important step to complete integration in many ways. This helps to produce other products that directly affect this project such as Surveillance Sensor Models for Onboard radar, Automatic Dependent Surveillance Broadcast (ADS-B) and Active Surveillance Mode S and Mode C, and Reference Tracker of RTCA SC-228 Phase 1 Detect and Avoid Minimum Operational Performance Standards, which meets minimum surveillance performance requirements. Lastly, this project has an overall high relevance to the American public because it works toward the safety on the NAS in which they fly.

Figure 29: NASA IKHANA flight testing

Weather Program Research Conducted

Radar-like analysis of oceanic precipitation increases NAS safety & efficiency

Hazardous weather conditions can be undetectable to the controller in offshore sectors with diminished or no Next Generation Radar coverage. Controllers manage over 22 million square miles of airspace that have no weather radar coverage, which hinders their ability to issue precipitation information to airborne aircraft, assist them as needed in safe and efficient weather-related route deviations or reroutes, and issue pertinent information on observed/reported weather. The Weather Program sponsored an effort to develop the Offshore Precipitation Capability (OPC) to estimate radar-like precipitation intensity and echo top height of storms beyond radar range. This technology fuses global lightning data, satellite imagery and output from numerical weather prediction models. This database is used to construct an algorithm that is capable of estimating fields typically derived from radar in areas without coverage. The solution provides reliable detection of precipitation offshore to be merged with the Continental U.S. radar data and displayed on the controller's main display monitor. OPC was developed in response to an Air Traffic Safety Action Program Corrective Action Report 2011-023, submitted by the Miami Air Route Traffic Control Center regarding the unsafe conditions due to a lack of weather radar in offshore sectors that are beyond the range of reliable Next Generation Radar coverage.

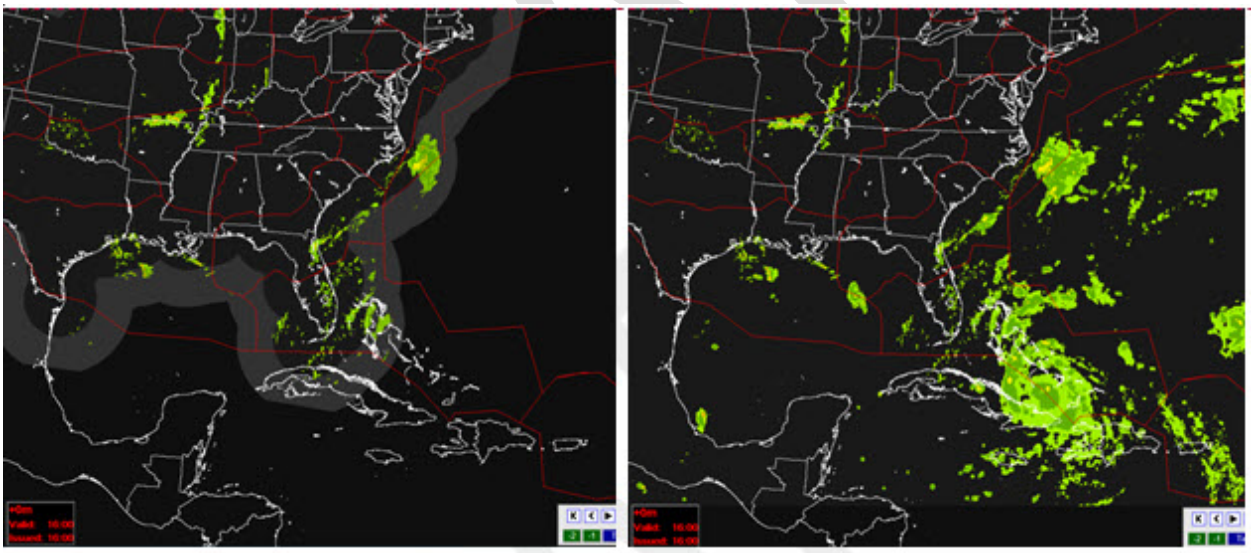

Figure 30:Left is the current radar mosaic used by the FAA. Image on the right is OPC, which clearly shows Hurricane Matthew as it crossed through the Caribbean

In FY 2017, after incorporating improvements recommended during previous user evaluations and conduct of validation testing to ensure accuracy and reliability, OPC met a significant milestone by achieving initial operating capability. ATC facilities in Houston, Miami, New York, San Juan and the FAA's Command Center in Warrenton, VA were given access to real time output from OPC via a restricted website. Controllers and planners at these sites view OPC on dedicated monitors and relay information from the displays to aircrews regarding general

location and strength of precipitation for situational awareness. OPC will also allow planners to anticipate the reopening of routes closed by weather without sending scout aircraft to determine conditions.

Automated visibility estimates from Alaska weather cameras enhance NAS safety

In Alaska, as in the Continental U.S., Aviation Routine Weather Reports (METARs) provide hourly observations of existing weather elements affecting a five statute mile radius around the station. Approximately 160 stations are available for Alaska, though many of these are physically located in Canada. In addition to METARs, the FAA owns and maintains hundreds of Alaska aviation weather cameras and provides access to the images on their website. Pilot weather reports are also a source for current ceiling and visibility information, but they are infrequent and prone to timing and location errors. The traditional METAR weather observations from Alaska's widely dispersed airfields inadequately forewarn of weather likely to be encountered along routes between stations or, in particular, through hazardous mountain passes with localized conditions. The addition of hundreds of weather cameras has helped tremendously. There is an incredible amount of information provided in the images, but pilots and meteorologists must manually assess each image in order to integrate the information into their flight planning decisions or weather products. This is a high cognitive workload task and becomes quite time consuming when multiplied by the number or camera sites in Alaska. For forecasters, it is impossible to consider each camera site in the preparation of their analysis and forecast products without resulting in high latency. Pilots are able to check the cameras as part of their flight planning, but they cannot review them continuously during flight due to bandwidth limitations and cognitive workload. Many of the cameras are located in remote areas, where no METARs are available, so the cameras are the only source of visibility information.

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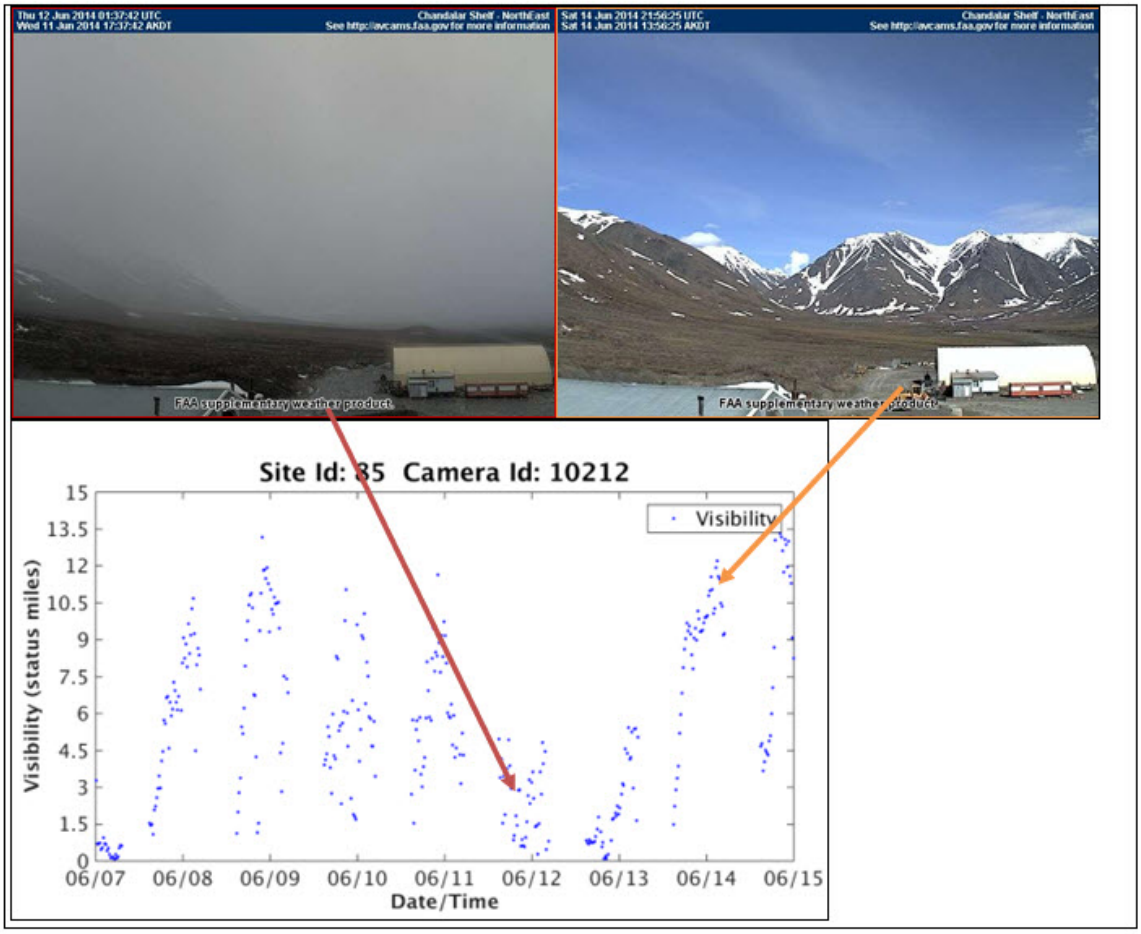

Figure 31: Current Visibility Estimate Capability – Correct Identification of a Clear Day and Low Visibility Day

The Weather Program is sponsoring research to develop and test technology that automatically creates visibility estimates from camera imagery, thus transforming weather cameras into weather sensors. This will enable the data to be incorporated into computer models or simply provided to pilots on a high glance value display. This effort to tailor existing visibility estimation software to the unique challenges in Alaska commenced in FY 2016 and in FY17 the initial testing of the software on subset of Alaskan cameras was completed and tuning the system to improve the performance commenced. The software now processes data for more than 200 Alaskan cameras and the visibility estimates are being evaluated and considered for inclusion on the FAA Aviation Weather Camera website (AvCams*Plus*.faa.gov). A proof-of-concept demonstration and evaluation on AvCams*Plus* is planned for the spring of 2018.

Improve Efficiency

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

ACRP Research Conducted

Integrate airport sustainability & the National Environmental Policy Act (NEPA) Process

Airports use sustainability initiatives to increase their economic and operational performance to reduce their environmental effects, and to enhance their social benefits. Separately, airports also undertake capital development projects, which may require NEPA review. However, sustainability and environmental review efforts have not been integrated. When an airport proposes an action, it can consider sustainability initiatives as part of the project to reduce the action's environmental impact. There are a number of strategies that airports can use as part of their sustainability planning that will assist with airport physical planning (master planning) as well as compliance with NEPA, for example incorporating sustainability goals into the process of evaluating development alternatives. The objective of this research was to prepare a guidebook with tools (checklists, matrices, and flowcharts) to help airport practitioners integrate sustainability with the environmental analyses required under NEPA. The guidebook addresses strategically considering the NEPA process in sustainability planning and leveraging sustainability plans and initiatives during the NEPA process. This guidebook identifying both the challenges and opportunities will be published (printed) in October 2017.

Figure 32: Kodiak Airport: Example of a successful integration of airport sustainability

CAASD Research Conducted

Predicting ATC student success & improving placement through skill aptitude testing

The FAA plans to hire more than 7,400 Air Traffic Controllers over the next five years. As part of the ongoing process to improve ATC training efficiency and reduce the risk of student failure, the FAA has a need for enhanced tools that can be used to predict student success in training and inform student placement in either an en route, terminal, or tower environment. By considering student aptitude early in the training process, the FAA could reduce training costs by reducing failure rates at facilities and reducing costly transfers between facilities. To explore the validity and benefits of early aptitude assessment, CAASD created a prototype Radar Vectoring Aptitude Test capability. The evaluation is designed to investigate the correlation between trainee performance on the vectoring aptitude test and trainee performance in the FAA's ATC training program. Trainees participating in the evaluation will be followed throughout the course of their training so that the relationship between aptitude test performance, training performance, and, their success in achieving certification as an Air Traffic Controller can be assessed. To develop the Radar Vectoring Aptitude Test prototype, CAASD leveraged past ATC training R&D. Radar vectoring is one of the critical tasks performed by terminal and en route controllers.

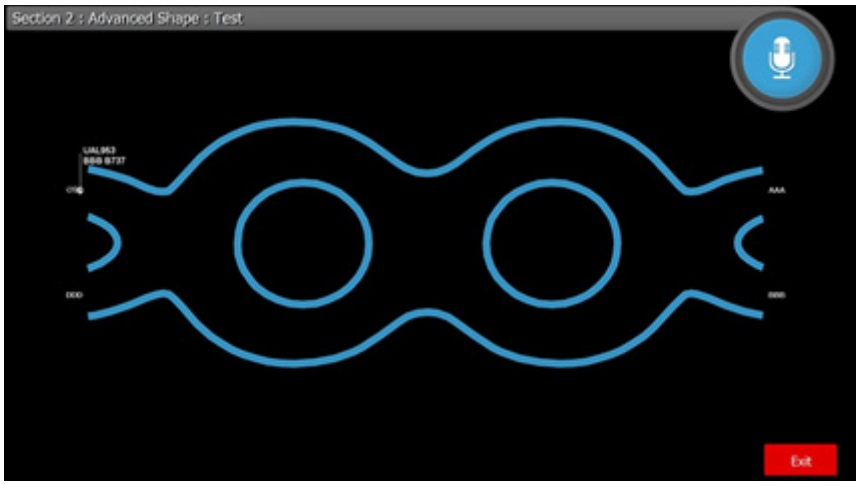

Figure 33: Radar Vectoring Test 1

The aptitude test supports objective and consistent performance, data collection, and analysis. It is designed to be administered to trainees at the start of or prior to their ATC training. The design includes features that test the fundamentals of understanding the compass rose and direction, interpreting information, and formulating and issuing vector clearances, and other fundamental ATC skills. The test uses technology such as speech recognition and synthesis, interactive simulation, and automated performance feedback and data collection. The prototype has been undergoing evaluation at the Civil Aerospace Medical Institute since June 2016. The initial phase of the evaluation that examined the prototype's validity for predicting student performance during the Academy phase of training was completed in 2017 and the results are summarized in the next section. To evaluate this capability a set of participants are being

followed throughout the course of their training so that the relationship between aptitude test performance, training performance, and, ultimately, their success in achieving certification as Air Traffic Controllers can be assessed. The initial phase of the evaluation focused on defining valid performance metrics and assessing correlation between trainee performance on the prototype and performance in training at the FAA Academy. The analysis of results from this initial evaluation phase indicates that the Radar Vectoring Aptitude test is a likely predictor of trainee success at the FAA Academy. Based on these results the evaluation of the prototype is continuing into 2018 to determine its ability to predict trainee performance throughout training to certification. This longitudinal study involves collecting and analyzing data from trainees as they progress through their facility training.

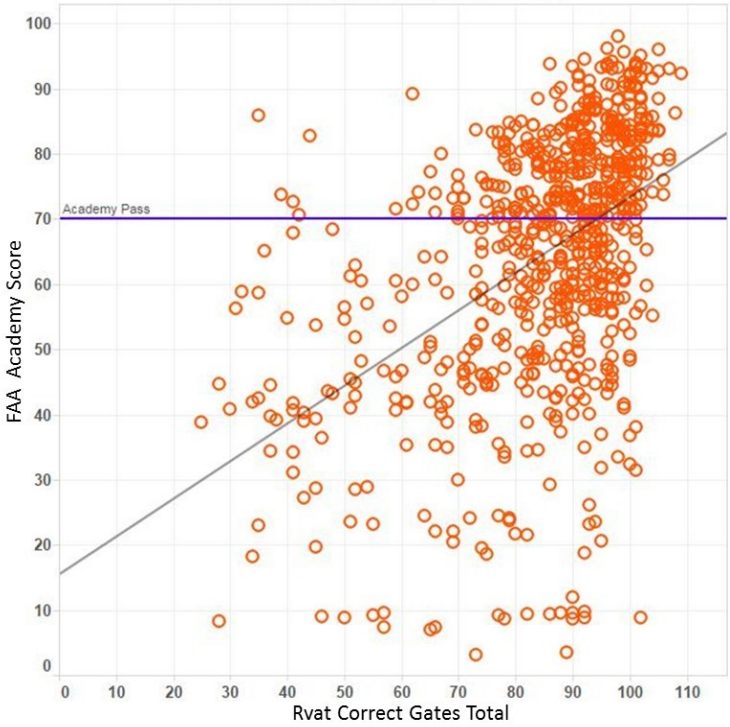

Figure 34: Aptitude Performance Assessment

The results demonstrated to date warrant consideration of this capability as part of initial qualification screening for ATC trainees. Included in this research is consideration of the cost savings associated with the reduction in the initial training failure rate, implementation costs, and other factors that relate to screening and hiring ATC trainee candidates. Additionally, the vector aptitude test provided a wealth of data about each trainee's basic vectoring strengths and weaknesses. This information could be used to develop individualized training. This research is important and beneficial to FAA, the aviation community, and traveling public through its focus on a process to improve ATC training efficiency, reducing the risk of student failure and associated costs, and to continue to proliferate safe and efficient ATC operations.

Speech recognition for pilot readback error detection

Controller-pilot voice communications contain a wealth of intent information and play a pivotal role in the daily operations of the NAS. In post-event analyses of loss-of-safety incidents, these communications are one of the main information sources used to reconstruct and identify the cause of the incident. One of the most asked-about speech recognition applications in the ATC domain is readback error detection. Technically, it is also one of the hardest speech recognition applications as it requires consistent and accurate recognition of both controller and pilot speech.

CAASD conducted research demonstrating the feasibility of a readback error detection application, and the viability of automatically recognized controller and pilot intent as an information source. To achieve this, CAASD examined and quantified how advanced techniques in speech recognition, such as Deep Neural Network (DNN)-based model training, improved on previously recorded accuracy benchmarks on ATC voice communications. CAASD also developed a prototype readback error detection application with configurable alert logic that clarified how alert logic and speech recognition accuracy combine to produce alerts, and highlighted the effect that differing levels of readback enforcement have on alert frequency and system acceptability.

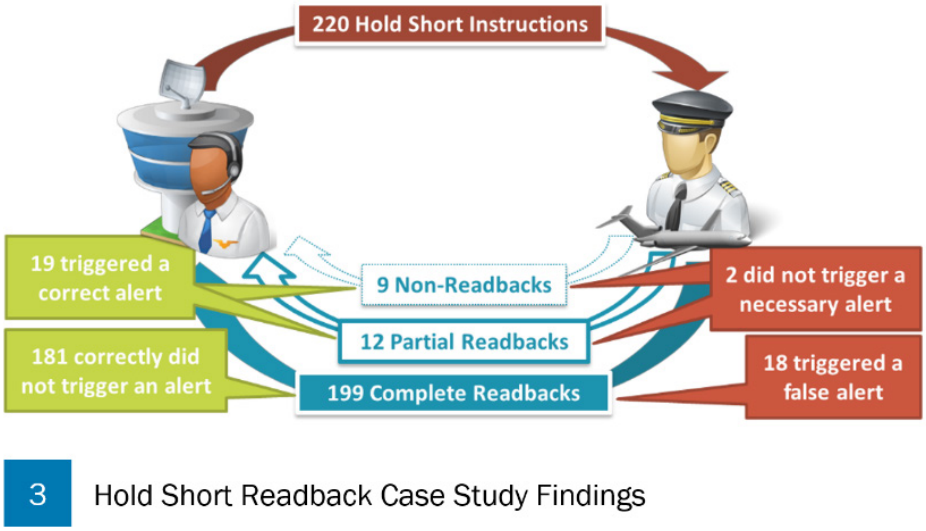

Figure 35: Readback Behavior for Hold Short Instructions

The CAASD team conducted research developing new recognition models to support readback error detection, explored concepts for alerting behavior, and developed a prototype to measure system performance. CAASD conducted an initial case study analysis to examine possible readback alert behaviors with initial speech recognition results for hold short instructions. The case study noted that nearly 10% of complete readback communications yielded a false alert, while only one percent of complete clearances failed to trigger an alert (see figure above). Using radio recordings and transcriptions, CAASD then developed DNN-based speech recognition models for John F. Kennedy International Airport and Reno-Tahoe International Airport, which

significantly improved on the initial speech recognition results. The new accuracy metrics collected benchmarked controller intent recognition accuracy between 99 and 100% and pilot intent recognition accuracy well above 90%. In researching operational needs for speech recognition alerting capabilities, CAASD surveyed 11 subject matter experts on acceptable readback error alert behavior for 30 different readback scenarios. This effort revealed a high level of variability in readback enforcement across experts, which will impact alert frequency and operational acceptance if a rigid set of alerting designs are applied across facilities and users. This research demonstrated that controller-pilot communications can be a reliable information source. Advancements in speech recognition technology have made a number of safety-enhancing speech-based capabilities feasible. The accuracy gain that is possible with DNN-based model training mitigates much of the risk associated with speech recognition-based concepts and demonstrates a path forward. The observed performance also indicates that speech recognition may not be the limiting factor in a readback error detection application, but rather the variability of readback acceptability may be the factor that impacts user acceptance.

The DNN-based model training process, the prototype models created, and the context-based aircraft identifier module are being transferred to the FAA's Safety and Technical Training Organization Work Program to improve the quality of systems engineering activities and safety analytics that depend on accurate controller and pilot speech recognition. Ultimately, speech recognition is envisioned as a way to improve the safety of air traffic operations for the flying public, through real-time safety alerting and improved analytics.

F&E Air Traffic Management (ATM) Requirements

Conduct engineering studies & analyses that evaluate translation of weather information into operational impacts

Current terminal area aviation weather forecasts do not adequately support future concepts for terminal airspace and airport ATM decision-making. Specifically, they lack sufficient accuracy and fidelity in time and space, do not properly measure, express or leverage uncertainty and lack a weather translation mechanism. In the context of strategic ATM decision-making driven by weather conditions in the airport environment, this program identified the characteristics of acceptable wind forecasts, including uncertainty, describing best ways to leverage uncertainty, and explore the translation of that information into expressions of configuration applicability.

F&E Major Airspace Redesign

Conduct engineering analysis for Caribbean airspace redesign implementation

The Caribbean Airspace Study was completed February 15, 2017. The study identifies and documents issues that may be mitigated through airspace and procedure changes. This study examined the growth in traffic transiting this airspace, issues and factors that contribute to sector complexity, and the resulting impacts due to the current airspace limitations. The output of this work will be used to inform decisions on solution development. A draft business case to evaluate cost and benefits has also been undertaken as part of a next steps initiative. Preliminary benefit estimate results are favorable but not conclusive.

Implement infrastructure changes resulting from airspace redesign

New York Air Route Traffic Control Center has been implemented to meet sectorization requirements for this initiative. In order to address coverage and interference issues for the air/ground frequency allocated to a New York Air Route Traffic Control Center offshore sector, two new remote communication air/ground sites will be established, one in Douglaston, NY and the other in Ocean City, MD FAA has validated the remedy and agreed to fund the identified work to address the frequency shortfall. Frequency installation work has been completed and final testing is underway. Implementation of the new frequency is expected in September 2017.

F&E NextGen Weather Observation Improvements

Complete 2015/2016 winter weather concept, maturity level 4 demonstration

The NextGen Portfolio Management and Technology Development Office has completed the Enhanced Present Weather Sensor Technology Package. This package results from a multi-year effort to evaluate industry's capabilities to produce a weather sensor capable of detecting ice pellets and drizzle. Automated reporting of these phenomena are system-level shortfalls of the Automated Surface Observing System (ASOS). The present weather sensor technology package includes a requirements specification that details desired sensor performance standards as well as several program artifacts that outline stakeholder positions, validation methodologies, and algorithmic logic for integrating the sensor into ASOS. The Development Office actively collaborated with flight standards service stakeholders throughout the validation effort to ensure the present weather sensor will meet the needs of their deicing and anti-icing initiatives. The present weather sensor specification supports incremental implementation respectful of both near-term sensor obsolescence and evolving user needs and is targeted to be implemented into ASOS via the Aviation Surface Weather Observation Network Technology Refresh program. Upon deployment, the present weather sensor will offer immediate, significant benefits to the de/anti-icing operational communities while also providing the opportunity for next-generation ASOS algorithms and reports tailored to the needs of the all aviation user.

F&E System Capacity, Planning and Improvements

Deliver performance modeling & economic analysis information to the ICAO

This program sponsors operational NAS performance capabilities that identify constraints in the system and assess capacity, the predictability of capacity and flight trajectory efficiency for operators. It fulfils FAA metrics reporting requirements, tasking under International Memorandums of Cooperation, Economic and Business Case Studies. The program delivered a capability for assessing the historical performance of Ground Delay Programs that is now in use at the ATC System Command Center and several field facilities. This capability provides performance information on delay, cancellations, and diversions for the historical capacity rates that called for specific operating conditions. The program developed a capability for examining decision windows for calling traffic management initiatives by calculating the percent of traffic that will become airborne as you get near to critical weather events.

The U.S. developed and presented the objectives, timeline and methodology for the Space Based Automatic Dependent Surveillance Broadcast (SB ADS-B) business case for the ICAO North Atlantic (NAT) Region. Deployment of SB ADS-B is expected in the latter half of 2018. The expected new technology, SB ADS-B, is being deployed in international waters and much collaboration between the U.S. and other members of the NAT Region was expected. The U.S. arranged for two dedicated workshops to share methodology, assumptions, data and preliminary results of the SB ADS-B business case analyses. Two workshops took place on November 29, 2016 in Washington D.C., and March 1-2, 2017 in Dublin, Ireland, and were instrumental in facilitating preparation for NAT SB ADS-B business case analysis. Phase I business case analysis was finalized at the Dublin workshop and delivered to the SB ADS-B planning telcons on March 6, 2017. During the NAT Region meetings, extensive discussions concerning NAT SB ADS-B business case analysis were conducted to review the benefits, costs, net present value, uncertainties, risks, and other developments. The participants concluded that as new technologies, such as SB ADS-B become available, it is important to assess the economic value of the investment for all stakeholders. Although, the current NAT concept of operations for SB ADS-B does not include user-preferred routes, simulation analysis for implementation of user-preferred routes in the NAT has potential, more than doubling fuel and time saving benefits. If user preferred routes are implemented in a cost-effective manner, operators could gain additional operational efficiency and cost savings.

NextGen – Wake Turbulence Research Conducted

Concept development for modifying current ATC terminal controller decision support tool (DST)

Based on the analyses of aircraft generated wake and associated airport weather data collected at NextGen Core airports, a determination was made that ATC applied wake risk mitigation separations could be reduced if certain weather conditions were present at and around an airport. This enables additional airport runway throughput capacity during periods of peak demand at the airport. A feasibility evaluation DST for use in reducing single runway wake risk mitigation separation standards was accomplished by adapting a DST that is in current use by controllers for monitoring RECAT (re-categorization) static separations during instrument flight rule approaches to a single runway. The feasibility evaluation DST can accommodate an increased number of wake separations categories and can provide a monitor display and alert warnings in terms of time interval separation minima between aircraft rather than distance-based minima.

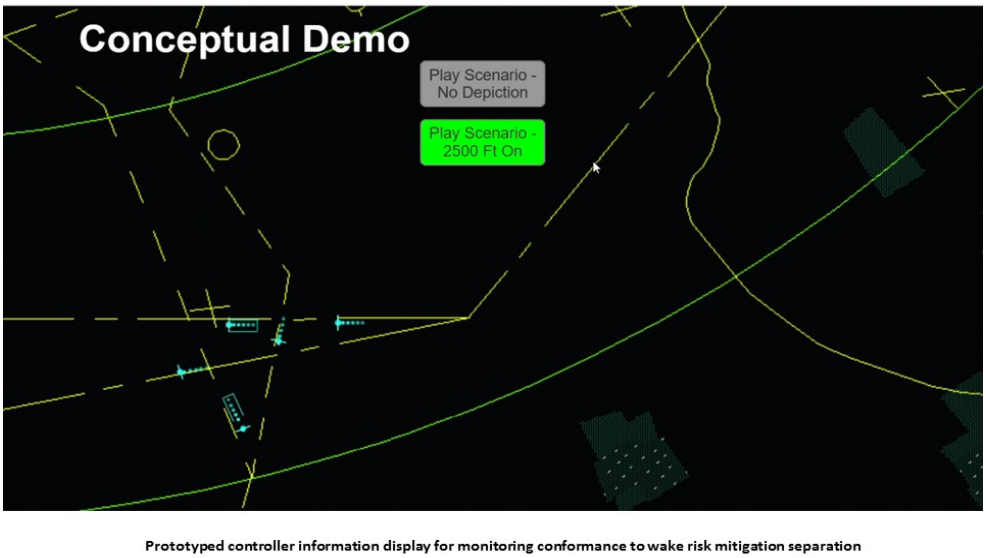

Figure 36: Prototype Controller Information Display for Monitoring Conformance to Wake Risk Mitigation Separation

NextGen – Wake Turbulence – Re-categorization Phase II Research Conducted

Deployment of RECAT Phase II wake separation standards to 4 metropolitan-area airports

The RECAT Phase II wake risk mitigation separation standards are now in use by controllers at the Philadelphia, Los Angeles, and Minneapolis and Miami airports. These wake risk mitigation standards are applied in a controller's setup of aircraft arrivals-to and departures-from an airport's runway, so the aircraft does not encounter the wake of the aircraft landing or departing in front of them. The RECAT Phase II project developed standards for wake safe minimum separation distances between 123 aircraft types. For a given airport, many of the aircraft types covered in the Phase II standards never or infrequently operate at that airport. The Phase II standards allows grouping of the most frequent aircraft types operating at that airport into six to seven categories that cover the separation minimums of the grouped aircraft types. This grouping into wake risk separation categories allows more departures per hour per runway under all weather conditions and more arrivals per hour when conditions (e.g. weather) at the airport requires the controllers to use instrument flight rule arrival operations. This RECAT Phase II deployment fulfilled the FAA's commitment to the FAA/RTCA NextGen Advisory Committee to implement RECAT Phase II at three major metropolitan airports.

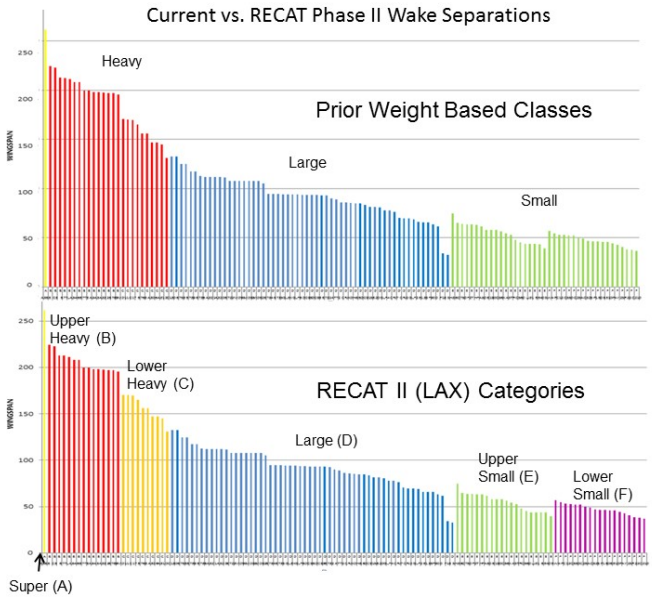

Figure 37: Using the RECAT II Wake Separation Categories at LAX has Provided the Airport More Runway Throughput Capacity

NextGen – Weather Technology in the Cockpit (WTIC) Research Conducted

Wind information recommendations for NextGen applications

Using the wind information analysis framework developed under the WTIC program, simulations and trade studies were performed to assess the impacts of wind information accuracy on the performance of various 4 Dimensional - Trajectory Based Operations (4D-TBO), such as interval management. The results of these trade studies support the development of realistic performance specifications for 4D-TBO, the development of minimum weather service recommendations for wind information accuracy necessary for 4D-TBO to achieve planned performance, and assessments on the impacts of realistic future Flight Management System (FMS) enhancements to support 4D-TBO. Research also assessed the accuracy of options for use as truth winds to support future analyses and simulations. Research results from this project are documented in the wind information requirements for NextGen Applications Phase 5 Report, dated May 31, 2017 and written by staff from Massachusetts Institute of Technology Lincoln Laboratory. Some of the specific research findings detailed in the report include identifying that speed constraints on procedural routes have a significant negative effect on Required Time of Arrival (RTA) performance.

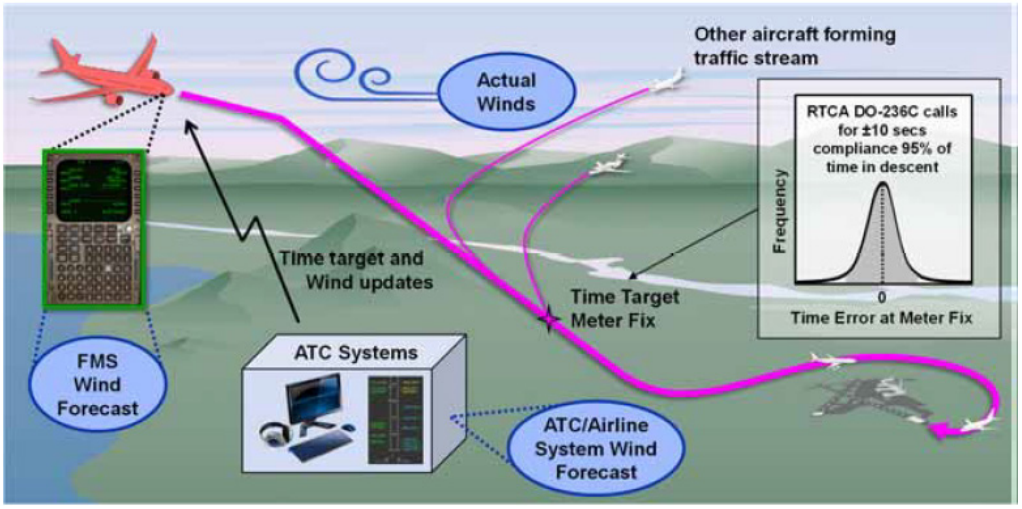

Figure 38: Focal Elements Relevant to 4D-TBO Operations

The results showed that it is nearly impossible for the current system to meet desired RTA performance goals given the current technology in FMS logic and atmospheric forecasting accuracy when speed constraints are present. The research also showed that flights on routes without speed constraints achieved nearly 100% desired performance with only a minimal amount of forecast information. Another key finding in this research project was that the global forecast system and high resolution rapid refresh were the most erroneous in the new metropolitan area of the four models evaluated. In using a modified FMS to enable RTA operations down to the initial approach fix, it was found that three descent forecast Levels l using global forecast system winds performed slightly better than nine descent forecast levels.

However, only a small sample size was modeled, therefore hard conclusions were not drawn. These and other research results from this and earlier wind-related WTIC projects were incorporated by RTCA into DO-369, a wind guidance document, which was released in July 2017. RTCA DO-369 provides guidance for ATM on the use of data linked forecast and current wind information with specific focus on wake mitigation, RTA, and interval management. The assessments of future FMS enhancements have been used by FMS manufacturers to align their product enhancements with the needs of NextGen and specifically 4D-TBO.

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

ACRP Research Conducted

Development of airport emergency planning template, National Incident Management System (NIMS) – Incident Command System (ICS) compliance

The FAA released AC 150/5200-31C titled Airport Emergency Plan (AEP). Under 31C (dated 6/19/2009), airports are required to have an AEP fully compliant with the NIMS/Incident Command System (ICS). Some airports have had difficulty getting FAA approval for their 31C compliant AEPs, as standardization is lacking because no two airports are alike. However, AEP standardization could be improved while making them NIMS/ICS-complaint in accordance with 31C. There are software packages in the emergency management field that are used to help stakeholders write NIMS/ICS-compliant emergency operations plan. Similar software is needed to assist airports with writing the AEP to be compliant with 31C. The objective of this research was to develop an electronic template that will extract airport-user input information and text through interactive sequential inquiries in order to prepare a draft airport-specific NIMS/ICS compliant AEP. It was also intended to develop a user-guide, training curriculum, and tools for learning, as well as how-to use the template and provide electronic interactive instructions and guidance embedded into the template. This was meant to help users understand the regulatory context of each element of the AEP with cross-references to Part 139, AC 150/5200-31C, and other relevant documents for guidance. The guidebook and templates are available beginning in October 2017.

CAASD Research Conducted

Concept exploration addressing aircraft noise from performance-based navigation (PBN) operations at low altitudes

PBN is one of the foundational improvements of FAA's NextGen program. PBN enables more predictable and direct routes unconstrained by the location of ground-based navigational aids, thereby reducing congestion, flight time, flight distance, fuel consumption, and carbon emissions. As illustrated below, PBN concentrates flight paths and reduces the size of the noise footprint for areas in the vicinity of airports; however, it can also increase exposure directly under PBN flight paths.

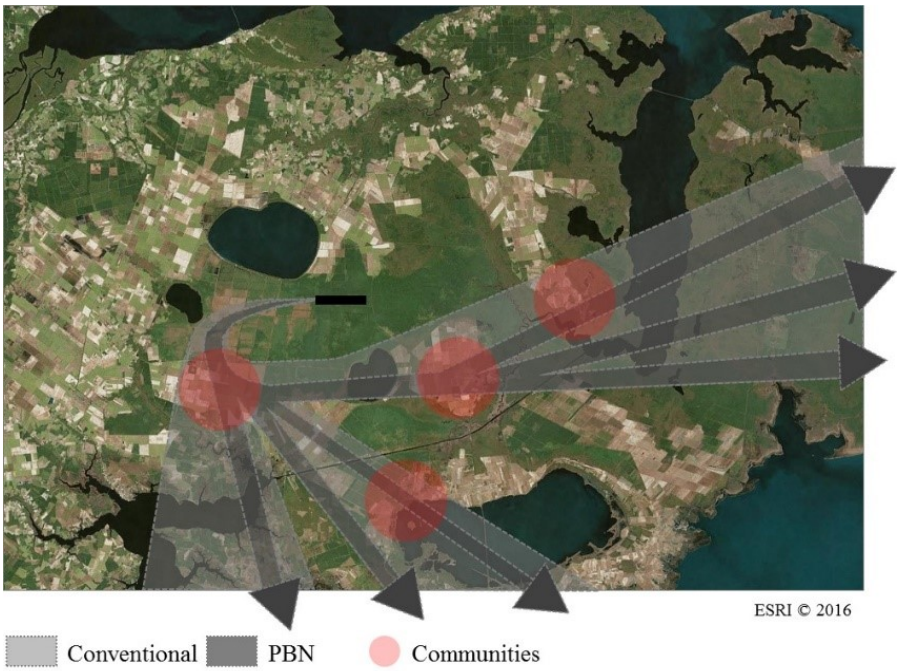

Figure 39:Flight Path Concetration

Adverse community reaction to the concentration of flight paths from PBN procedures presents a significant challenge to NextGen implementation. To inform potential solutions to the flight path concentration issue, FAA and MITRE's CAASD have been conducting research in several areas such as aircraft noise modeling tools and techniques, more effective and inclusive community outreach processes, and, in this case, potential operational mitigations. In FY 2016 and 2017, CAASD conducted research to inform FAA on PBN noise concentration issues, developed near, mid, and far-term concepts to manage noise concentration, created an analysis framework to understand the environmental and operational tradeoffs associated with such concepts and analyzed potential site-specific applications to understand how these concepts might be applied during the procedure design and implementation process. In FY 2016, CAASD developed a set of noise management concepts and analyzed associated operational and environmental tradeoffs; concluding that departure concepts showed more promise than arrivals due to departures being louder than arrivals, and because procedure designers can exercise more

flexibility in designing departures (given that arrivals must fly straight in). Furthermore, applications must be tailored to site-specific characteristics. In FY 2017, CAASD applied the near-term concepts at a specific site, demonstrating the noise implications of PBN, determining the noise management benefits of the concepts, and quantifying the operational costs (in this case, increased flight time and distance, as well as a slight potential increase in controller workload for certain operations). CAASD also continued to mature and analyze the operational and environmental tradeoffs associated with the mid- and long-term concepts.

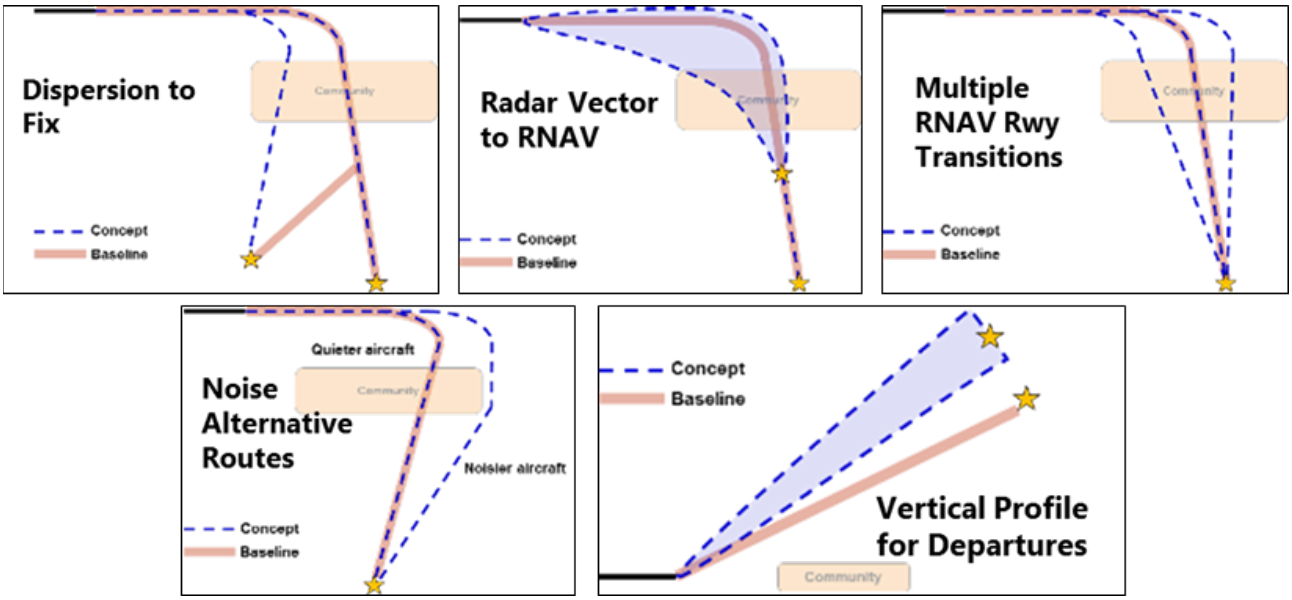

Figure 40: Near-Term Noise Management Concepts

This research has resulted in new FAA operational procedures for noise management, increasing the tools available to procedure designers and airport planners. This is essential given increasing opposition to airspace and procedure changes, PBN, Metroplex, and NextGen in general. In addition, the research has created an analytical framework that enables the FAA to make data-driven decisions when balancing traditional safety and efficiency goals against noise and environmental considerations. This work is a critical part of FAA's strategy and resolve to better address noise and other environmental issues earlier in the procedure design process, and to consider community input to ensure concerns are given due regard in FAA decision-making. This transformation is ongoing, and will require additional research and policy development to continue to evolve how FAA considers environmental impacts while implementing NextGen.

Environment and Energy Research Conducted

Advance understanding of noise impacts on social welfare & health

Through ongoing research efforts, the FAA continues to advance our understanding of how aviation noise impacts the health and welfare of those living in airport communities. Concerted efforts have been taking place on commercial aircraft, helicopters, and supersonic aircraft. Work has also been ongoing to understand the noise from UAS and commercial space vehicles. This year a comprehensive community noise survey of residents living around 20 airports in the U.S. was completed. The results provide updated scientific evidence of the relationship between aircraft noise exposure and its effects on communities around airports. The FAA is currently reviewing the results to determine any potential policy implications.

During the last year, the FAA continued research investigating the long-term cardiovascular health impacts of noise exposure. Additional U.S. longitudinal health cohorts were identified and work is currently being completed to link historic noise expose data with the health cohorts. FAA has also continued its work on sleep-disturbance due to aircraft noise. The original field test published a document on the findings in August 2016 (available at https://ascent.aero/project/noise-exposure-response-sleep-disturbance/). The study focused on testing a low-cost data collection methodology that would be appropriate for use in a national study. The primary outcome of the work will be an exposure-response relationship between acoustical properties of single aircraft noise events and physiological reactions during the sleep period.

Given the increased interest in the return of civil supersonic aircraft by U.S. manufacturers, FAA has expanded its work regarding the potential noise impacts of civil supersonic aircraft. FAA is working with NASA and internationally, through the ICAO, to determine appropriate ways to certify and measure the sonic boom from a civil supersonic aircraft. In addition, FAA, with its partners, are working to determine what level of sonic boom would be appropriate for flights across the U.S. FAA has narrowed the number of potential metrics being considered for the certification metric for sonic booms. In addition, we have expanded coordination with NASA regarding the potential noise impacts of civil supersonic aircraft and are working with NASA to develop conceptual modeled aircraft to provide data into understanding the potential noise impacts of civil supersonic aircraft.

Finally, FAA has expanded its research regarding helicopters. The work focused both on better understanding the community reaction to helicopters and reducing helicopter noise with noise abatement procedures. FAA and NASA will be conducting flight tests using potential noise abatement procedures in the August and September 2017 timeframe.

Refine methods for estimating aircraft contribution to climate change & to implement in analytical tools

A reduced-order climate modeling tool has been developed to quantify the historic, current and future climate impacts of aviation to inform decision making at FAA. In the past year, the tool has been improved to include the latest scientific understanding. Beyond revising underlying

data and projections, three major modules of the tool have been updated to improve the quantification of Carbon Dioxide emissions to account for the latest scientific studies; refine the overall modeling of the impacts caused by short-lived aviation emissions based on the latest scientific studies; and include a new model for considering the climate sensitivity and its uncertainty distribution. These updates have been completed at the end of FY 2017, and validation and verification is underway. A major use for this improved tool will be the evaluation of the costs and benefits of a particulate matter standard being developed in ICAO.

Aircraft engines burning hydrocarbon-based fuels emit gaseous and particulate matter emissions as by-products of combustion. At the engine exhaust, particulate emissions mainly consist of ultrafine soot or black carbon emissions. Such particles are called non-volatile particulate matter (nvPM). A standardized measurement methodology has been developed and specified in the ICAO Annex 16 Vol. II as part of the new nvPM mass concentration based visibility standard. The North American reference system was built to these specifications to acquire nvPM data and was deployed in multiple engine tests in order to acquire such. These datasets not only demonstrated the robustness of the standardized measurement approach, but also characterized the nvPM emissions profile from the different engines. The tested engines ranged from smaller mixed turbofans for use in regional jets to larger engines rated for use in Boeing 737 and Airbus 320 aircraft (Figure 42). During FY17, measurement campaigns were conducted at General Electric Aviation, OH and Pratt and Whitney, CT to characterize engine nvPM emissions and to perform inter-comparison of measurement systems. In addition, the standardized system was also used to measure nvPM emissions to develop corrections for fuel sensitivity and ambient conditions.

In FY18, North American Reference System will be used to perform comparisons with a research system that is employed to characterize altitude nvPM emissions. Comparisons will be performed on the ground with regular and alternative jet fuels. Data acquired will be used to provide the needed input into cruise emissions modeling; advance our understanding of contrail formation; and quantify changes in particulate matter emissions from alternative fuels. Contrails are line-shaped clouds sometimes produced by aircraft engine exhaust, typically at aircraft cruise altitudes several miles above the Earth's surface. This will also help facilitate the promulgation of a health impacts based international engine nvPM emissions standard by February 2019.

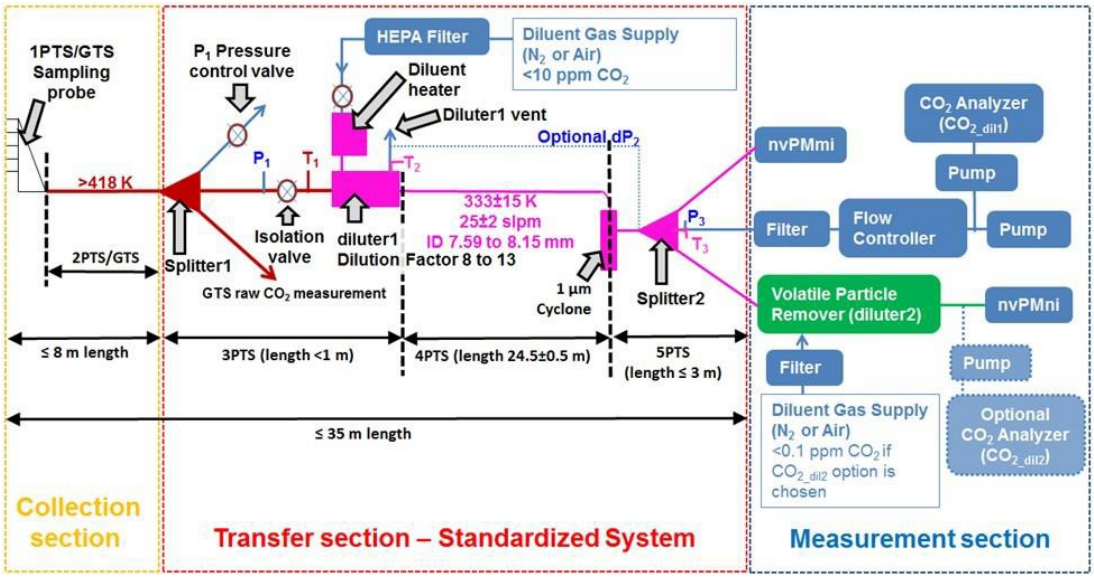

Figure 41: Componenets of the North American Reference System Compliant with ICAO Annex 16 Vol. II Appendix 7 Specifications

NextGen Environmental Research – Aircraft Technology, Fuels and Metrics Research Conducted

Demonstrate CLEEN I advanced turbine components

During the final work performed under the Phase I CLEEN I Program, Pratt & Whitney has developed and demonstrated an ultra-high bypass ratio geared turbofan engine and associated advanced technologies. Pratt & Whitney conducted their final full-scale engine test of their CLEEN I ultra-high bypass geared turbofan technologies at their engine test facility in West Palm Beach, Florida. Acoustic testing was also conducted and the performance was deemed consistent with simulation models and scaled fan rig results. In summary, geared turbofan engine technologies will contribute to reduced aircraft noise and fuel consumption because of increased engine efficiency.

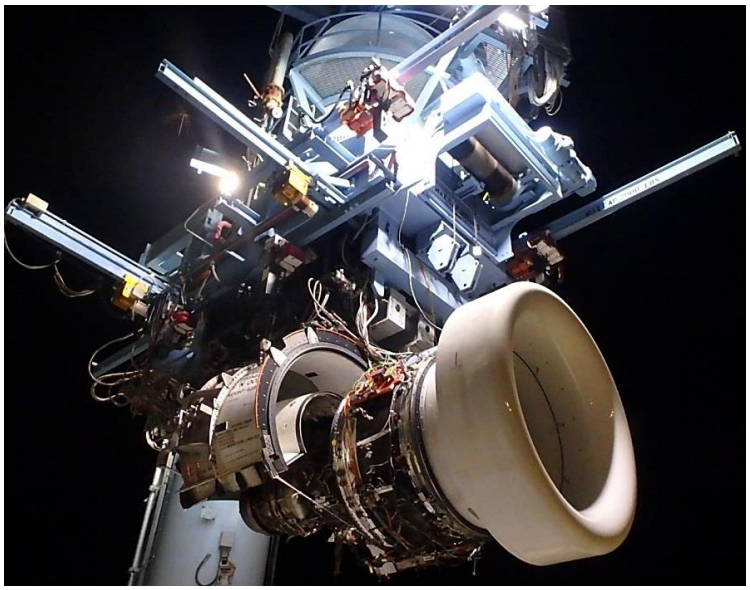

Figure 42: Pratt and Whitney Engine

Demonstrate technologies that reduce energy use, emissions & noise through the CLEEN II Program

Work performed in FY 2017 under the CLEEN II involved a conceptualized design phase of Aurora's double-lobe fuselage concept, a technology that enables noise and fuel burn reduction. Aurora is conducting analysis and investigations into crack formation at the base of their 'y-clip' during load testing.

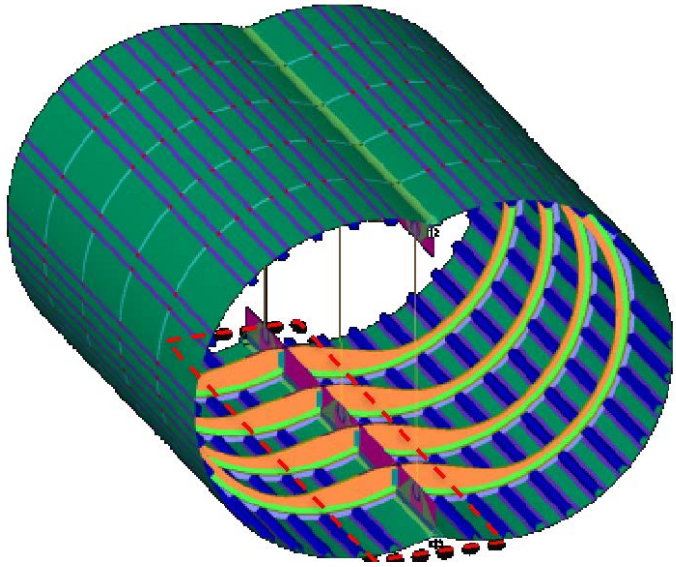

Figure 43: Conceptual Design of the Aurora Fuselage

Boeing completed the detailed design review for the structurally efficient wing in July 2017. Tooling design and fabrication is ongoing. The kickoff meeting for the Compact Nacelle project took place on July 11-13, 2017 at Stennis Space Center. General Electric's More Electric Systems and Technologies for Aircraft in the NextGen team, is working on the Starter Generator Motor Controller prototype. Completion of the prototype is expected in July/August 2017. General Electric's CLEEN II FMS project is continuing its work towards optimal cruise/climb algorithms. General Electric FMS is making progress on their simulation work and with their collaborations with both Georgia Tech and FAA for modeling. For the TAPS III project, General Electric is in the process of manufacturing prototypes for their Twin Radial Splitter Chevron -Slots as well as a prototype of their Dual Main Mixer.

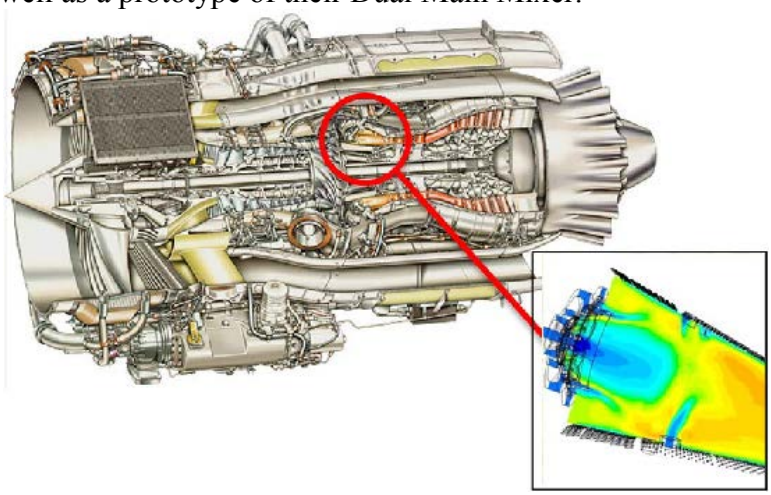

Figure 44: Honeywell Combustor Rig

Honeywell is fabricating the test hardware for the compact combustor rig. They have also completed the fabrication of three out of the four required ceramic matrix composite components; the 'T' type attachments for the Turbine Blade Outer Air Seal System. Design of

experiments for the thermal barrier coating is in progress. Rolls Royce is continuing to build their combustor rig and plan to have it completed and running by late August, early September 2017.

Advance development of alternative jet fuels

FAA funded efforts on testing, analysis, and coordination continue to advance the availability of alternative jet fuels. In FY 2017 through Center of Excellence for Alternative Jet Fuels and Environment (ASCENT) Project 31, FAA began funding an alternative jet fuel-testing clearinghouse at the University of Dayton Research Institute to provide a one-stop shop to coordinate alternative jet fuel candidate fuel testing, to support ASTM evaluation and approval. This new clearinghouse should streamline the approval process of fuels through the ASTM process. Under the CLEEN II program, General Electric has selected the alternative fuels to be tested in the full annular rig testing in 2017 and the core engine test in 2020. They will test the developer, GEVO's alcohol to jet fuel, to examine if there are ways to reduce the testing requirements within the ASTM international fuel certification and qualification process. General Electric will also test a blend of the Virent Synthesized Aromatic Kerosene and hydro processed esters and fatty acids to support ASTM international approval of Virent's Synthetic Aromatics Kerosene. Under the CLEEN II program, Rolls-Royce is planning to start testing LanzaTech alcohol to jet fuel as early as August 2017. Rolls-Royce is planning on blending 90% LanzaTech alcohol to jet with 10% aromatics to support the ASTM International approval of the LanzaTech fuel.

The ASCENT Project 1 team continues to be instrumental to the development of information to ensure that alternative jet fuels are included within the ICAO Committee on Aviation Environmental Protection carbon offsetting and reduction scheme for international aviation, and the corresponding ICAO standards and recommended practices. ASCENT Project 1 team's efforts domestically produced alternative jet fuels that will be included within the carbon offsetting and reduction scheme for international aviation. The team also continues to work with the Volpe Center to develop scenarios of alternative jet fuel production with the goal of identifying barriers to entry for alternative jet fuels and means to overcome these barriers. One of the reports published by the team shows the potential means of reducing the costs of alternative jet fuels such that they could reach cost-parity with conventional jet fuel. FAA also worked with the Department of Energy's National Renewable Energy Laboratory to conduct jet fuel scenario analysis using their Biomass Scenario Model, to assess availability of alternative jet fuels under different policy scenarios. This was accomplished with funding from Department of Energy and data from FAA ASCENT Project 1.

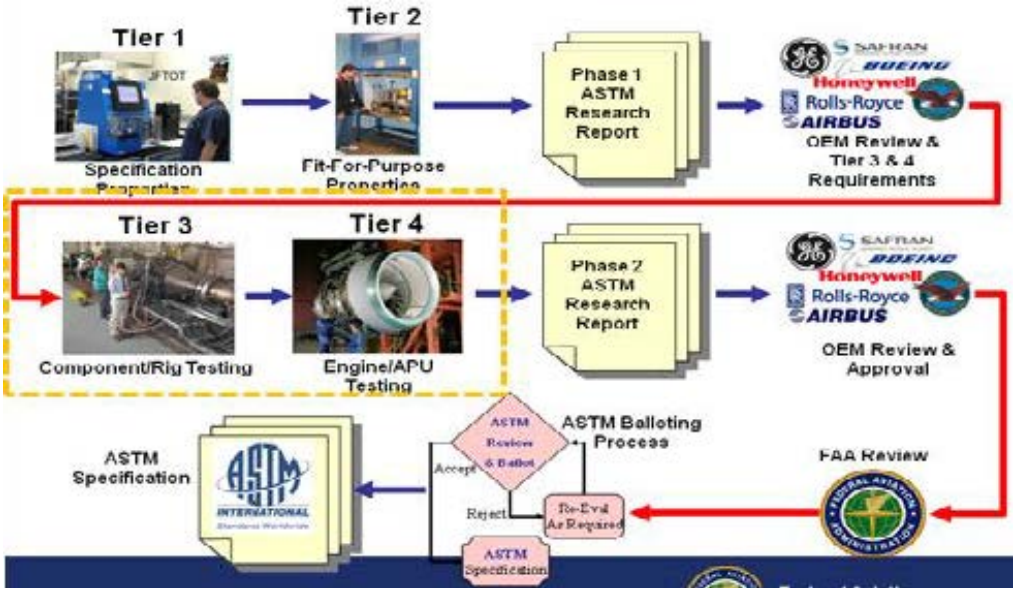

Figure 45: ASTM Process for Alterative Jet Fuels

Coordination between the public and private sectors continues via the Commercial Aviation Alternative Fuels Initiative (CAAFI). In FY 2017, CAAFI was successful in supporting early commercialization of alternative jet fuels. CAAFI is a coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants and U.S. government agencies. Together these stakeholders are leading the development and deployment of alternative jet fuels for commercial aviation. In 2016, United Airlines became the first U.S. airline to use a commercial-scale, sustainable aviation biofuel for regularly scheduled flights. United Airlines has committed to purchase at least 15 million gallons of alternative fuels from a single facility in Los Angeles over a three-year period with the option to purchase more. The alternative jet fuel producer purchased an unused petroleum refinery and converted it to the production of alternative fuels bringing economic benefits as well as a source of aviation fuels to Los Angeles. Investments from the FAA, and the efforts by CAAFI, were instrumental in making this investment possible. CAAFI is continuing to bring the alternative fuel community together. With CAAFI support, two U.S. Department of Agriculture funded Community Agricultural Project awards were made in Florida and Arizona to develop biofuel supply chains that include jet fuel as a targeted product.

2017 NARP Milestone Summary

This section provides a detailed view of all 2017 research milestones statused in the 2017 NARP. Selected milestones are used to provide significant accomplishments listed herein.

The research community has been developing techniques not only to show on time and on-cost performance of research efforts, but also to show the quality of the work being conducted. In conjunction with the NARP redesign effort, the FAA envisions redesigning the AR (starting with the FY 2018 R&D AR, which will accompany the 2019 NARP) to include qualitative highlights of the Agency's R&D work during the year along with a more quantitative or substantive view of the research.

A11.a Fire Research and Safety

Year	Milestone	Status
2017	Develop a new test apparatus and methodology for accurately measuring the heat release rate of honeycomb, thermoplastic, and other large surface-area cabin interior materials	Completed
2017	Determine mode of flame spread of structural composites in hidden areas and enclosed spaces	Completed
2017	Examine alternative smoke sources and/or procedures for smoke penetration and cargo compartment smoke detection certification testing	Completed

A11.b Propulsion and Fuel Systems

Year	Milestone	Status
2017	Develop and implement improved fleet risk analysis methods to address corrective actions	Completed

A11.c Advanced Materials Structural Safety

Year	Milestone	Status
2017	Evaluate new material forms (e.g., discontinuous fiber composites) that have found application in primary aircraft structures	Completed
2017	Address specific Aviation Rulemaking Advisory Committee inputs and certification needs for certification of composite aircraft	Completed
2017	Build specimens and conduct test to study defective repairs	Completed

2017	Conduct composite damage growth studies of composite-metal hybrid bolted joint study	Completed
2017	Experimentally determine the matrix compression response of carbon fiber composite panels using typical aerospace materials	Completed
2017	Build full-scale test composite fuselage-type panels for investigating frame-to-floor beam joint stiffness effects under blunt impact conditions	Completed

A11.d Aircraft Icing Digital System Safety

Year	Milestone	Status
2017	Complete sloped surface testing of fluid protection on slats and flaps and main elements of aircraft and airfoils and flat plates at angles simulating angles of aircraft surfaces	Completed
2017	Conduct aerodynamic test of swept wing with ice shapes in ONERA F1 wind tunnel	Completed
2017	Identify the assurance issues related to the applications running on virtual machines in airborne systems	Completed

A11.e Continued Airworthiness

Year	Milestone	Status	Notes
2017	Develop technical data to assess the fatigue and environmental durability of bonded repairs to metallic structure	Completed	
2017	Conduct mechanical testing on procured aged-in service bonded repairs (M&I)	Revised Research Plan	The original test plan has been revised based on the distribution of the types of repairs that are present on the procured aircraft structural components. The structural tests identified in the revised plan will be continue in FY18. (Projected Completion Date: FY 2018)
2017	Conduct round-robin repairs to evaluate technicians ability to successfully perform Structural Repair Manual (SRM) repairs	Revised Research Plan	Voluntary nature of the airline depots' involvement in this round-robin exercise impacts the original schedule outlined for this research project. Projected new completion date is 12/31/2017. (Projected Completion Date: FY 2018)

2017	Collect reference model of a fixed wing aircraft to be used for the evaluation of active flutter suppression systems	Completed	
2017	Provide technical data for use by the FAA for approving angle of attack systems installation on general aviation airplanes	Completed	

A11.f Aircraft Catastrophic Failure Prevention Research

Year	Milestone	Status	Notes
2017	Complete standard composite testing for certification by analysis	Completed	

A11.g Flightdeck Maintenance System Integration Human Factors

Year	Milestone	Status	Notes
2017	Publish revision to human factors compendium for flight deck displays and controls	Completed	

A11.h System Safety Management-Terminal Area Safety

Year	Milestone	Status	Notes
2017	Develop concept of operations and a model to establish safety oversight profiles for Air Traffic Organization facilities, systems, procedures, and safety standards	Completed	
2017	Develop an integrated domain safety risk evaluation model of NAS critical systems to support the assessment and approval of NAS critical system changes and controls for high risk hazards	Completed	
2017	Develop criteria for determining when a missed approach should be performed	Revised Research Plan	Original completion date for research was September 2017. The revised anticipated date is now September 2018 due to prolonged procurement process. Recent research findings revealed that additional experiments are necessary. (Projected Completion Date: FY 2018)

A11.i Air Traffic Control-Technical Operations Human Factors

Year	Milestone	Status	Notes
2017	Validate the Terminal Radar Approach Control training standards and engage ATC training experts to qualitatively evaluate their suitability	Completed	

A11.j Aeromedical Research

Year	Milestone	Status	Notes
2017	Analyze medical certification and accident data to derive methods or tools to enhance aircrew health, education programs, and medical certification decision-making processes	Completed	

A11.k Weather Program

Year	Milestone	Status	Notes
2017	Transition ceiling and visibility Alaska analysis capability for implementation (as part of the NAS Infrastructure Portfolio section of the NextGen Implementation Plan)	Completed	
2017	Develop preliminary roadmap for weather product development to support safe and efficient UAS operations	Completed	
2017	Transfer in-flight icing Alaska analysis and forecast capability to NWS for operational implementation	Completed	
2017	Complete development of software to ingest and process more than 200 Alaskan weather cameras to provide enhanced visibility conditions data	Completed	
2017	Transition Offshore Precipitation Capability (radar-like analysis) for operational implementation	Completed	

A11.l Unmanned Aircraft Systems

Year	Milestone	Status	Notes
2017	Develop prototype antenna and brass board electronics, lab-test and flight test antenna final designs for Airborne Collision Avoidance System antennas along with hardware/software for test data collection	Completed	

2017	Document the most optimal sensor fusion strategy and the sensitivity of each data fusion performance parameter in transitioning from sense and avoid Function one (remain well clear) to Function two (avoid collisions)	Revised Research Plan	Rescoped from "most optimal sensor fusion strategy" to "one that meets the minimum surveillance requirements". The phases of the project were modified to include the new milestone. (Projected Completion Date: FY 2018)
2017	Collect and analyze UAS Safety Data from Congressionally mandated test sites	Completed	

A11.m NextGen-Alternative Fuels for General Aviation

Year	Milestone	Status	Notes
2017	Perform initial engine and aircraft testing	Completed	

A11.n Commercial Space Transportation Safety

Year	Milestone	Status	Notes
2017	Compare debris predictions to empirical evidence from recent mishaps to identify potential areas for improvement in public safety assessments (Supports advanced safety assessment methods)	Completed	
2017	Review available data and analyses to identify priority areas of concern for repetitive use considerations of high utilization reusable spaceflight vehicles (Supports advanced vehicle safety technologies and methodologies)	Revised Research Plan	The overall research activity is being formulated. (Projected Completion Date: FY 2018)

A12.a NextGen-Wake Turbulence

Year	Milestone	Status	Notes
2017	Develop prototype information display for the controller decision support tool used to allow reduced wake separations for instrument approaches to a single runway	Completed	

A12.b NextGen-Air Ground Integration Human Factors

Year	Milestone	Status	Notes
2017	Create a report presenting human factors considerations for the evaluation and integration of electronic flight bag/portable electronic device/tablet technologies with NextGen applications/operations	Revised Research Plan	A change in requirements (Projected Completion Date: FY 2018)

A12.c NextGen Weather Technology in the Cockpit

Year	Milestone	Status	Notes
2017	Perform simulations and/or demonstration of providing initial minimum weather service enhanced wind information (accuracy, timeliness, etc.) recommendations to the Flight Management System and Air Traffic Control Systems to verify realization of predicted benefits of associated NextGen application program(s)	Completed	
2017	Develop recommendations for standards on time stamping of cockpit composite weather presentations	Completed	
2017	Develop recommendations for standards / guidance to resolve/reduce meteorological information shortfalls that were identified as causal factors in selected weather-related safety incidents/accidents	Completed	
2017	Provide recommendations for rendering standards for inclusion in the Weather Technology in the Cockpit minimum weather service recommendations for general aviation	Completed	

2017	Demonstrate examples of the integration of weather information, along with selected navigation and other flight information into cockpit decision-making and shared situational awareness among pilots, dispatchers, and Air Traffic Controllers supported by NextGen air and ground capabilities	Revised Research Plan	A change in technical complexity of the flight demonstration (Projected Completion Date: FY 2018)

A12.d NextGen Information Security

Year	Milestone	Status	Notes
2017	Develop program plan and research initiatives to support the FAA Cybersecurity Strategic Plan	Completed	
2017	Formulate research activities to support national aviation system priority needs set forth by the FAA Cybersecurity Steering Committee	Completed	

A13.a Environment and Energy

Year	Milestone	Status	Notes
2017	Refine methods for estimation of aircraft contribution to climate change and implement them in analytical tools	Completed	
2017	Advance the understanding of noise impacts on social welfare and health	Completed	

A13.b NextGen Environmental Research-Aircraft Technologies, Fuels and Metrics

Year	Milestone	Status	Notes
2017	Demonstrate Continuous Lower Energy, Emissions and Noise Advanced Turbine Components	Completed	
2017	Demonstrate technologies that can reduce energy use, emissions, and noise in year three of the second phase of the Continuous Lower Energy, Emissions and Noise Program	Completed	

Airport Cooperative Research Program

Year	Milestone	Status	Notes
2017	Develop a renewable resource strategy at airports	Revised Research Plan	Plan was changed to 3 phases for the 3 topic areas covered separately: finance, planning, engineering, and environmental, and strategy. It is estimated to be completed March 28, 2018. (Projected Completion Date: FY 2018)
2017	Integrate airport sustainability and the NEPA process	Completed	
2017	Develop an airport emergency planning template: NIMS – Incident Command System Compliance	Completed	
2017	Prepare for the connected airport and internet of things	Completed	
2017	Develop an airport emergency operations center design guide	Completed	
2017	Develop an Airport Management Guide for providing aircraft fueling services	Completed	
2017	Technology solutions to facilitate Americans with disabilities travelers	Completed	
2017	Airport metrics and impacts of Air Traffic Control restrictions	Revised Research Plan	Plan was changed to multiple phases for the topic areas covered separately. It is estimated to be completed March 28, 2018. (Projected Completion Date: FY 2018)

Airport Technology Research Program

Year	Milestone	Status	Notes
2017	Complete in-service testing of new light emitting diode lighting circuits for use on airports	Completed	
2017	Complete Mu-Slip testing with nose gear brake testing and main gear brake testing, both on contaminated runway surfaces	Completed	
2017	Publish guidebook on dynamic test performance requirements for frangible connections/structures utilized in runway and terminal safety areas	Completed	

2017	Complete of engineered material arresting system signs for airports	Complete	
2017	Publish a report on the taxiway centerline deviation data collection effort at airplane design group -II airports	Completed	
2017	Complete a one year cost-benefit study of utilizing foreign object debris detection systems on airports, which will be based on available foreign object debris systems currently in operation at civil airports as of October 2014	Completed	
2017	Complete testing of input-based foam proportioned testing as a viable alternative to the output-based method requiring foam discharged to the ground	Completed	
2017	Pavement roughness index for airports	Revised Research Plan	Delayed due to unanticipated complexity for project completion. For example, milestone progress in FY2017 included a statistical correlation of acceleration values using simulator values and existing pavement roughness indexes. After this statistical correlation, we are now researching the correlation of the acceleration values using frequency and wavelength data. Completing the analysis of the frequency and wavelength is expected to be complete in January 2018; testing and validation is expected to be complete by September 2018. (Projected Completion Date: FY 2018)
2017	Complete data collection for the Aircraft Noise and Annoyance study	Completed	
2017	Complete updates to the dose-response curves for U.S. airports using data collected from the Aircraft Noise and Annoyance study	Completed	

2017	Publish a report on the findings of the artificial turf installation and its effectiveness in mitigating the burrowing of the protected gopher tortoise	Completed	

F&E Major Airspace Redesign

Year	Milestone	Status	Notes
2017	Conduct engineering analysis as needed for Caribbean airspace redesign implementation	Completed	Recurring Annual Milestone
2017	Implement infrastructure changes resulting from airspace redesign	Completed	Recurring Annual Milestone

F&E New Air Traffic Management Requirements

Year	Milestone	Status	Notes
2017	Establish, standardize, and document the baseline versions of exchange models	Completed	
2017	Develop enterprise solution documentation to mediate across NAS system	Completed	
2017	Develop initial document for two-way communications procedures between Flight Management Systems and Ground Systems	Completed	
2017	Finalize Multifunctional Phased Array Radar performance requirements	Change in Research Priority	FAA has prioritized work on the Spectrum Efficient National Surveillance Radar (SENSR) program, amongst radar research efforts. No additional work on MPAR is planned.
2017	Develop detailed Multifunctional Phased Array Radar advanced technology demonstrator test and evaluation plan	Completed	
2017	Assess Flight Information Exchange Model compliance with the International Civil Aviation Organization Reference model	Completed	
2017	Develop transition plan for Flight Information Exchange Model	Completed	
2017	Conduct quality assurance /quality control validation for Weather Information Exchange Model	Revised Research Plan	This milestone is delayed until 2018.

2017	Review the Airborne Collision Avoidance System Xu System Requirements and Specification V1.0 document to inform RTCA SC-147 and SC-228 with standards development activities	Completed	
2017	Conduct engineering studies and analyses which evaluate the translation of weather information into operational impacts	Completed	
2017	Develop and validate weather requirements for NWS to improve forecasts in support of FAA operational decision making	Completed	
2017	Develop validation plan for air/ground procedure synchronization	Change in Research Priority	This milestone is redundant with one currently planned for 2018 to develop a simulation plan for validation activities.
2017	Develop documentation of air/ground procedures standards with user community	Change in Research Priority	This milestone is redundant with one already present in 2020 for publishing final air/ground trajectory synchronization implementation recommendations.
2017	Conduct trials and develop a validation report for air/ground procedure synchronization	Change in Research Priority	This milestone is redundant with one already present in 2019 that covers completion of air/ground trajectory synchronization validation.
2017	Develop Minimum Operational Performance Standards for Iridium-Next which will enable the SatCom system to support data communications in domestic airspace	Change in Research Priority	Delays to the Iridium Next satellite system put focus on MOPS development for Swift Broadband satellite systems. While FAA did develop draft input to the Iridium Next MOPS, no further effort is currently planned toward this.
2017	Conduct prototype testing to support the development of Internet Protocol Standards to support the FAA's Data-Comm Segment 2 and Future Communication Systems including NextSat, L-band Digital Aeronautical Communications System and Aeronautical Mobile Airport Communications System	Change in Research Priority	Deletion of this milestone reflects a decision to move the prototype validation effort to industry

F&E Operations Concept Validation and Infrastructure Evolution

Year	Milestone	Status	Notes
2017	Develop annual updates to the NAS Enterprise Level Operational Requirements based on prior year research and development	Completed	
2017	Develop annual updates to the NAS Enterprise Architecture for NAS level operational improvements and operational sustainment activities based on prior year research and acquisition decisions	Completed	
2017	Conduct concept engineering activities and develop concept engineering/requirements validation artifacts, such as shortfall analyses, concept of operations, requirements, technical assessments, and evaluation documents	Completed	
2017	Develop technical papers and reports in support of RTCA, the premier public-private partnership forum to develop consensus among aviation stakeholders across the globe. These artifacts include safety and performance requirements, operational services and environment definitions, minimum aviation system performance standards, minimum operational performance standards, and other reports as necessary	Completed	
2017	Conduct an ATM operational integration analysis designed to identify potential operational issues associated with the simultaneous use of multiple new capabilities within the same operational space	Completed	

F&E Runway Incursion Reduction Program

Year	Milestone	Status	Notes
2017	Publish the Project Plan and Resource Management Plan for the utilization of a small airport surveillance sensor as a sensor to drive the activation of direct to pilot alerting safety logic	Revised Research Plan	The Small Airport Surveillance Sensor (SASS) system is still under development at MIT Lincoln Lab. Development of the Project Plan and Resource Management Plan will be initiated in FY18 to align with ongoing engineering development of the sensor, which is expected to be ready for shadow testing in FY19. (Projected Completion Date: FY 2019)

2017	Complete annual technical and operational evaluation report of existing Runway Incursion Reduction Program prototype systems	Completed	
2017	Complete annual report on testing of safety logic enhancements to runway incursion detection and prevention products	Revised Research Plan	The Runway Incursion Prevention Shortfall Analysis (RIPSA) project assessed several technologies in FY17 meant to enhance runway safety at small-to-medium airports. This assessment will culminate in an FY18 solicitation and acquisition of one or more technologies for a test operational evaluation at candidate sites identified in FY16, with testing scheduled to commence in FY19. (Projected Completion Date: FY 2019)
2017	Provide site selection criteria for first location to test the utilization of a small airport surveillance sensor to drive direct to pilot alerting safety logic	Change in Research Priority	SASS will continue to undergo engineering development at the current test bed at Hanscom Air Force Base (HAFB). Any additional test sites, if any, would be determined upon the successful completion of testing of all surveillance capabilities identified for the SASS system.
2017	Complete integration report on initial testing of the utilization of a small airport surveillance sensor to drive direct to pilot alert safety logic	Revised Research Plan	The Small Airport Surveillance Sensor (SASS) system is expected to be ready for shadow testing in FY19. (Projected Completion Date: FY 2019)

F&E System Capacity, Planning and Improvements

Year	Milestone	Status	Notes
2017	Produce Annual Joint Performance Benchmark Report with EUROCONTROL/European Commission	Completed	
2017	Deliver performance modeling and economic analysis information to support the development of a business case with International Civil Aviation Organization member states in the North Atlantic region for reduced oceanic separation using Automatic Dependent Surveillance Broadcast (Out)	Completed	

F&E Wake Turbulence-Re-categorization

Year	Milestone	Status	Notes
2017	Complete concept feasibility description of dynamic wake separation standards	Completed	
2017	Complete initial deployment of the RECAT Phase II wake separation standards to three metropolitan area airports – for evaluation of the standards use and modification (if required) for ease of application by controllers	Completed	
2017	Develop detail descriptions of ATC dynamic wake separation standards alternatives and how they would be applied in the NAS	Completed	
2017	Deliver briefings to and conduct data gathering with the aviation community concerning alternative ATC dynamic wake separation processes and procedures	Completed	

F&E Surface Tactical Flow

Year	Milestone	Status	Notes
2017	Deliver a Departure Metering Demonstration Test Readiness Report documenting readiness for Surface Collaborative Decision Making metering concept at Charlotte Douglas International Airport	Completed	
2017	Deliver a report that will identify and describe the less-equipped airports within a metroplex that impact operations at the primary airport	Completed	
2017	Conduct ATD-2 Phase 1 Safety Assessment	Completed	

F&E NextGen Weather Observation Improvements

Year	Milestone	Status	Notes
2017	Complete 2015/16 Winter Weather Concept Maturity Level 4 Demonstration	Completed	

F&E Oceanic Tactical Trajectory

Year	Milestone	Status	Notes
2017	Complete benefits analysis and validation and report results	Completed	

2017	Complete shortfall analysis and validation and report results	Completed	

F&E Advanced Methods

Year	Milestone	Status	Notes
2017	Conduct concept-engineering activities to develop the following products for individual capabilities under Constraint Prediction, Monitoring and Alerting, Operational Response Development, and TFM System Performance Analysis Capability	Change in Research Priority	The work supporting this milestone was tech transferred to the AFST Capability
2017	Conduct concept validation activities – prototyping/evaluations/human in the loop (HITLs)/reports for individual capabilities under Monitoring and alerting; and TFM System Performance Analysis Capability	Change in Research Priority	Work supporting this milestone was tech transferred to the AFST Capability

F&E Closely Spaced Runway Operations

Year	Milestone	Status	Notes
2017	Perform analysis of RNAV SID procedure path conformance on departure and provide technical report	Revised Research Plan	The analysis is on-track, the scope of work of this project was increased. The timeframe because of this scope of work increase was extended to Dec. 2017. (Projected Completion Date: FY 2018)

Acronym List

Acronym	Definition
0-9	
4D-TBO	4 Dimensional - Trajectory Based Operations
A	
AC	Advisory Circular
ACRP	Airport Cooperative Research Program
ADS-B	Automatic Dependent Surveillance Broadcast
AEP	Airport Emergency Plan
AOV	Air Traffic Safety Oversight Service
AR	Annual Review
ASCENT	Center of Excellence for Alternative Jet Fuels and Environment
ASOS	Automated Surface Observing System
ASTM	American Society of Testing and Materials
ATC	Air Traffic Control
ATM	Air Traffic Management
ATO	Air Traffic Organization
ATRP	Airport Technology Research Program
C	
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAASD	Center for Advanced Aviation System Development
CACRC	Commercial Aircraft Composite Repair Committee
CFRP	Carbon Fiber Reinforced Polymer
CLEEN	Continuous Lower Energy, Emissions, and Noise
D	
DNN	Deep Neural Network
DST	Decision Support Tool
E	
ELT	Emergency Locator Transmitter
EOC	Emergency Operations Center
F	
F&E	Facilities and Equipment
FAA	Federal Aviation Administration
FMS	Flight Management System
FY	Fiscal Year
G	
GA	General Aviation

I	
ICAO	International Civil Aviation Organization
ICS	Incident Command System
ID-SRET	Integrated Domain Safety Risk Evaluation Tool
M	
METAR	Aviation Routine Weather Reports
N	
NARP	National Aviation Research Plan
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAT	North Atlantic
NEPA	National Environmental Policy Act
NextGen	Next Generation Air Transportation System
NVPM	Non-Volatile Particulate Matter
NWS	National Weather Service
O	
ONERA	French Aerospace Lab
OPC	Offshore Precipitation Capability
P	
PBN	Performance Based Navigation
R	
R&D	Research and Development
R, E &D	Research, Engineering and Development
RECAT	Wake Re-Categorization
RTA	Required Time of Arrival
S	
SB ADS-B	Space Based Automatic Dependent Surveillance Broadcast
SRMD	Safety Risk Management Document
T	
TRACON	Terminal Radar Approach Control
U	
UAS	Unmanned Aircraft Systems
U.S.	United States
W	
WTIC	Weather Technology in the Cockpit