

2019 Research and Development Annual Review



October 2020

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2019 Annual Review
February 2020

The Research and Development Annual Review (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>).

Foreword

American aviation contributes to our nation's economy and quality of life. Aviation moves us safely and efficiently from place to place, promoting the interconnectedness of the American people. The aviation industry contributes 5% of the U.S. Gross Domestic Product, providing more than 10.6 million U.S. jobs and over \$446.8 billion in earnings* to the U.S. economy. American aviation facilitates business, tourism, and trade. On the average day, more than 27,000 flights carry 2.3 million passengers and 55,700 tons of cargo to more than 800 airports across the country**. The FAA strives to continue our leadership in global aviation, fueling a more connected society, and providing an important economic engine for the American economy.

The FAA actively partners with industry and academia to implement aviation solutions that lead to even higher levels of safety and efficiency in the most complex, efficient, and innovative air traffic system in the world. The FAA continues outreach efforts to nurture and strengthen relationships with our partners and stakeholders while managing the proper balance between government and private sector research and development investments.



The FAA's Research and Development (R&D) Management Division is charged with supporting the development of the agency's R&D portfolio, and tracking R&D program goals and activities to ensure their alignment with Department of Transportation (DOT) and FAA strategic goals for the National Airspace System (NAS). The R&D Management Division is responsible for producing the congressionally-mandated National Aviation Research Plan (NARP) and this R&D Annual Review on the behalf of the FAA Administrator.

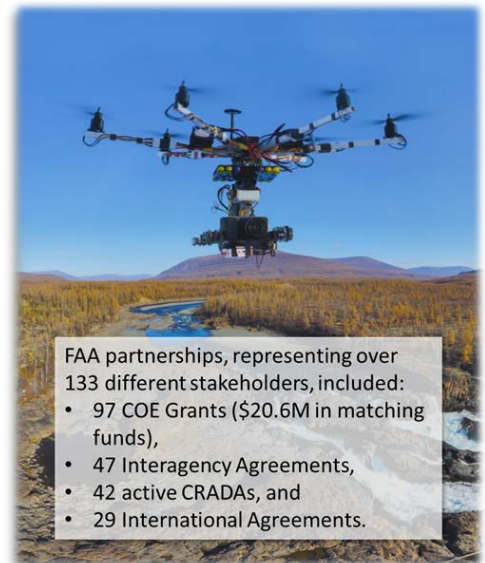
This R&D Annual Review is a companion document to the NARP. While the NARP is forward-looking and describes planned research activities during the next five years, the R&D Annual Review provides a snapshot of R&D work from the previous fiscal year, highlighting major accomplishments, R&D Goals, and current fiscal year performance information.

**The Economic Impact of Civil Aviation on the U.S. Economy* (Nov. 2016)

** [a4a-presentation-industry-review-and-outlook - link to airlines.org](#)

Partnerships

In pursuit of our mission, the FAA maintains partnerships with over 300 stakeholders representing federal agencies, academia, industry, international entities, and technical organizations. Our partners include aircraft and parts manufacturers, design and engineering companies, external testing facilities, domestic and international organizations, and representatives of large and small businesses. Together these relationships support the DOT strategic mission goals promoting safety, infrastructure, innovation, and accountability. Our partnerships include the following groups, associations, and agencies.



Category	Partnership Examples
Federal Agency / State / City	Department of Energy, Environmental Protection Agency, MIT Lincoln Labs, NASA Armstrong Flight Research Center, NASA Ames, NASA Glenn, NASA Johnson, NASA Langley, Port of Seattle, Smithsonian Institution, Transportation Security Administration Federal Air Marshal Service, U.S. Air Force Research Laboratory, U.S. Army, U.S. Marshals Service, U.S. Navy, U.S. Coast Guard, United States Department of Agriculture Forest Service, and Volpe.
Academia	Clarkson University, Rowan University, George Mason University, Rutgers University, Florida International University, University of California San Diego, University of Utah, University of Washington, Washington State University, Wichita State University, Massachusetts Institute of Technology, Stanford University, University of Colorado Boulder, University of Texas, Embry-Riddle Aeronautical University, Mississippi State University, Ohio State University, University of Alabama Huntsville, Purdue University, Pennsylvania State University, University of Dayton, and New Mexico State University.
Industry	Aircraft Owners and Pilots Association, Alaska Airlines, American Airlines, Boeing, Bombardier, Cirrus Aircraft, Delta Airlines, Embraer, FedEx, Garmin, General Electric, Harris, Honeywell, JetBlue, MOBIL, National Institute of Aerospace, NetJets, Raytheon, Rockwell, Society of Automotive Engineers, Southwest, Spirit, United, and UPS.
International	BlindSquare, CMC International, European Organization for the Safety of Air Navigation, International Civil Aviation Organization, Japan Civil Aviation Bureau, Single European Sky Air Traffic Management Research Joint Undertaking, Team Eagle, Thales, Transport Canada, and Warsaw Institute of Aviation.
Other	Aerospace Vehicle Systems Institute, American Helicopter Society, American Petroleum Institute, American Society of Mechanical Engineers, Battelle Memorial Institute, Flight Attendants Medical Research Institute, MITRE, National Air Transportation Association, National Business Aviation Association, National Fire Protection Association, National Institute for Aviation Research, National Institute of Aerospace, National Safety Council.

The FAA leverages agreements with federal, academic, industry, and international partners to promote technical innovation, technology transfer, and science, technology, engineering, and math (STEM) initiatives. Among the primary vehicles the FAA employs are Interagency Agreements (IAs), Memorandums of Agreement (MOA), Centers of Excellence (COE) grants, and other Cooperative Research and Development Agreements (CRADAs).

Several partnerships are cross cutting, representing a variety of stakeholders. One example is the FAA’s Aviation Environmental Design Tool (AEDT), which is used to model aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality impacts. Over 280 domestic and 300 international users employ the software suite to evaluate aviation environmental impacts.

Federal

The FAA leverages the research capabilities of several federal partners to advance national and aviation objectives primarily through Interagency Agreements (IA). We currently have five IAs with the Department of Defense

16 Federal Agreements in 2019

(DOD), four IAs with the National Aeronautics and Space Administration (NASA) and three with the National Oceanic and Atmospheric Administration (NOAA). Other IAs include the Department of Transportation (DOT) and Department of Energy (DOE). These represent a wide range of focus areas including:

- Modeling uncontained engine debris damage, development and testing of improved aircraft structures and materials
- Improved safety methodology for certifying general aviation aircraft
- Novel cockpit pilot interfaces
- Integration of unmanned aircraft systems into the National Airspace System (NAS).

In Fiscal Year (FY) 2019, the FAA entered into an agreement with the U.S. Air Force (USAF), NASA, and NOAA/NWS Space Weather Prediction Center (SWPC) to participate in the Aviation Weather Demonstration and Evaluation assessment for the Space Weather program. Members of the FAA Aircraft Catastrophic Failure Prevention Program collaborated with federal and academic researchers to develop new metal and composite finite element models and modeling guidelines. The research team included NASA Glenn Research Center (GRC), NASA Langley, Arizona State University, George Mason University, The Ohio State University, Livermore Software Technology Corporation (LSTC), Honda R&D Americas, and The Boeing Company. The high fidelity metal and composite models more accurately simulate characteristics of aircraft engines and structural materials during engine-related impact failures. The latest models utilize a generalized tabulated approach to accurately incorporate strain rate, temperature, and damage necessary to predict multiple observed failure modes with a single material model input. Accurate and predictive models are essential for advancing design and certification analysis tools, resulting in designs that are more robust to crash and engine blade loss and ultimately benefit aviation through improved safety.

Academia

The FAA collaborates with academic institutions through a variety of agreements including Cooperative Research and Development Agreements (CRADAs), the Joint University Program (JUP), and Centers of Excellence (COEs) and aviation research grants.

**6 CRADAs
97 COE Grants with
\$20.6M in Matching Funds
in 2019**

CRADAs provide a mechanism for Federal agencies to share facilities, equipment, services, intellectual property, personnel, and other resources, with industry, academia, and state and local government agencies. The FAA currently has CRADAs in place with Clarkson University, Fairfield University, George Mason University, and Rutgers University. The research focus includes enhancing algorithms for conflict detection, knowledge transfer of simulation tools and algorithms, and organizational change.

Under the FAA Joint University Program (JUP), faculty and students from leading aviation programs are investigating advanced technologies and research challenges. The JUP is a research partnership between the FAA and Massachusetts Institute of Technology, Ohio University, and Princeton University. This program researches promising technologies for development, conducts long-term research, and provides students valuable firsthand experience managing research. Current research activities include investigating the potential application of non-equilibrium nanosecond plasmas for aircraft in-flight icing mitigation, development of a distributed electric propulsion super-short takeoff and landing aircraft, integration of urban air mobility vehicles at major airports across the United States, and mapping airport surfaces using sensors on unmanned aerial vehicles to aid in the runway surface operation and maintenance.

COEs are a unique mechanism enabling the FAA to recruit the leading colleges and universities to advance aviation research objectives through matching contributions. COE participants are required to obtain additional funding to match the amount provided by the FAA. This effectively doubles the value and ensures the research aligns with industry priorities. The FAA has partnerships with more than 70 universities, colleges, and institutes through the COE program. COEs support technology transfers and research in the following core areas:

- Technology Training and Human Performance
- Unmanned Aircraft Systems
- Alternative Jet Fuels and Environment
- General Aviation Safety
- Commercial Space Transportation
- Joint COE Advanced Materials.

Under the COE for Advanced Materials, the FAA is collaborating with Washington State University, Florida International University, University of Washington, and the University of Utah to document structural integrity data for composite and metal bonded structures, evaluate industry process quality control procedures and test/analysis methods. Under this same COE, the FAA is collaborating with Wichita State University to evaluate industry repair design

characteristics and quality control procedures for aircraft composite structures, which will provide advanced training guidance and improved composite maintenance practices for industry.

Aviation research grants are another FAA mechanism to research areas necessary for the long-term growth of civil aviation. The grants were authorized by Congress in 1990 through the Federal Aviation Administration Research, Engineering and Development Authorization Act of 1990 (Public Law 101-508) and the Aviation Security Improvement Act of 1990, Federal Aviation Administration Authorization Act (Public Law 103-305). In 2019, the FAA awarded 11 grants for a total obligation of \$2.8M. Recipient institutions included Baylor University (TX), Broome County IDA (NY), MIT (MA), Rensselaer Polytechnic Institute (NY), Rutgers University (NJ), University of Central Florida (FL), University of Chicago (IL), University of Dayton (OH), University of Oklahoma (OK), and the University of Texas at El Paso (TX). Among the research topics are Modern Training Practices in the Air Carrier Industry, Microwave System for Surface Collection Efficiency Measurements, and Lighting and Visual Guidance Research for Airport Applications. A detailed list of FAA funded research is available at the following link:

https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/FAA_Active_FY2019_Agreements.pdf.

Industry

The FAA engages with industry partners through a variety of contract vehicles. One key tool is a Cooperative Research and Development Agreement (CRADA), which leverages federal laboratory resources in collaboration with industry to advance national and aviation objectives. Under a CRADA, other federal agencies, industry, and academic institutions can gain access to federally developed and funded laboratories, facilities, services, and intellectual property.

**42 Active Cooperative Research
and Development Agreements as
of 2019**

Through a CRADA, the FAA's Structures and Propulsion Branch and Engine & Propeller Standards Branch conduct research to inform standards issued by the Jet Engine Titanium Quality Committee (JETQC). This committee consists of commercial aircraft turbine engine manufacturers (General Electric, Pratt & Whitney, Rolls Royce, and Honeywell) and all of their titanium suppliers from North America, Europe, and Russia. The JETQC was formed at the request of the FAA in the wake of the Sioux City accident with the purpose of developing improved titanium melting and inspection practices to preclude the occurrence of defects in critical rotating engine components. That accident resulted from a catastrophic failure of the DC-10's tail-mounted engine causing 111 fatalities. Working with the committee, the FAA developed and provided to the JETQC members titanium metallurgical standards that will enable industry to accurately characterize detected hard alpha anomalies.

In support of the Continued Air Worthiness program, FAA researchers investigated the limit-load capability for center hole, and partial and full-depth scarf configurations for solid laminates. The FAA is collaborating with Boeing to assess bonded repair technology of composite panels

that are representative of transport airplane wing structure. The research promotes safety by developing and standardizing methods and tools to conduct, analyze, and predict structural performance of bonded repairs. This will enable users to monitor and evaluate repair quality over the life of a part.

The FAA has initiated CRADAs with airlines and manufacturers to promote the application of FAA research to increase aviation safety. For example, the FAA digital system safety program entered into collaboration with other federal agencies, equipment manufacturers, suppliers, and academia to complete the first phase of cooperative research on the Assurance of Adaptive Controls with Artificial Intelligence/Machine Learning (AI/ML) Implementation. This new technology represents a significant and growing research challenge to the aviation community. Members of the team will participate in the SAE International committee for Applied Artificial Intelligence in Aviation Systems to assist development of assurance standards for AI/ML applications.

Another noteworthy accomplishment is the FAA/Shell agreement, which resulted in significant progress toward the safe introduction of unleaded aviation gasoline (avgas) for the general aviation piston engine fleet. Under this agreement, a standardized series of test procedures were integrated into 49 test plans. Tests were completed for 10 aircraft and 15 engine models. The tests resulted in the identification of a range of safety and other issues. As a result, Shell invested substantially in R&D and has successfully resolved many of the concerns. The company continues to invest in research efforts to mitigate the remaining items. The goal of this effort is to replace the current leaded avgas supply chain with a safe unleaded alternative for the global market, ushering in newer technologies and practices in the petroleum refining industry, and reducing our overall environmental impact.

Memorandum of Agreements (MOAs) are another FAA mechanism used to leverage federal laboratory resources in collaboration with industry. MOA partners include the Delaware River and Bay Authority, Metropolitan Airports Commission, National Institute of Aerospace, Port of Seattle, and the University of Pennsylvania. These partnerships allow the FAA to develop research infrastructure at local airports. Work includes quantifying the safety benefits of Foreign Object Debris detection systems and an indoor navigation trial to help blind and visually impaired passengers navigate airports.

International

The FAA engages with international partners through international agreements and Cooperative Agreements to leverage research capacity to harmonize operations.

The knowledge capital obtained through FAA's R&D investments is necessary to inform the safe and efficient evolution of domestic and international air travel. Influencing global aviation standards is highly dependent on the knowledge base of FAA representatives and researchers who are on global harmonization and standards-setting

**29 International Agreements
5 Active Cooperative Research and
Development Agreements in 2019**

bodies, and who serve as world-renowned subject matter experts. This knowledge enables the United States to be a global leader in driving international standards that affect our aviation economic advantage.

Among the international partners that the FAA has teamed with are Transport Canada, EUROCONTROL, Civil Aviation Authority (CAA) – United Kingdom, CAA-Singapore, Brazil Air Navigation Service Provider, and the Technical University of Denmark. Areas of research include aircraft icing, wake turbulence, and air traffic management collaboration.

The FAA also leverages cooperative agreements with European, North American, and Asian aviation organizations to participate in aviation safety and air traffic modernization (ATM) programs, leverage research activities that harmonize operations, and promote a seamless and safe air transportation system worldwide. Examples of international partnerships include the European Organization for the Safety of Air Navigation, International Civil Aviation Organization, the Single European Sky Air Traffic Management Research Joint Undertaking, the Japan Civil Aviation Bureau, the Warsaw Institute of Aviation (Poland), and Transport Canada.

When international agencies are involved in the FAA's research, it is often because the results have a global reach, and benefit domestic and international partners. The FAA Fire Research and Safety Team initiated a Material Similarity Task Group within the International Aircraft Materials Fire Test Forum to develop methods and criteria for comparing the intrinsic flammability of component cabin materials. Due to the unavailability or environmental regulation of the original supplies, aircraft manufacturers and suppliers are often forced to change original materials, which results in costly recertification. The FAA is collaborating with industry to test samples of cabin interior materials to develop new procedures and pass/fail criterion for individual components. This research leverages the FAA's patented microscale combustion calorimeter for the small-scale fire performance testing of component materials. When testing is completed, the FAA will issue an advisory circular or policy letter to codify this cost effective FAA safety technology.

In June of 2019, members of the Aircraft Icing Research Program led meetings focused on aircraft icing with the National Research Council of Canada (NRC), Transport Canada, and National Center for Atmospheric Research. The researchers addressed ongoing and planned icing research, including efforts related to Unmanned Aerial Vehicles (UAV) icing. Among the projects the team is collaborating on are the In-Cloud ICing and Large-drop Experiment (ICICLE), the Terminal Area Icing Weather Information for NextGen (TAIWIN) project and the In-Flight Icing project.

Societal Participation

Professional societies play an important role in the world. They provide a mechanism to bring together people, knowledge, and technology for the purpose of sharing information, creating industry standards of conduct, and developing industry design standards for technology, processes, and systems.

As the world leader in aviation safety and air traffic control (ATC), the FAA is committed to active participation in pertinent professional societies. Our participation provides a forum for technology transfer of FAA research results, and collateral transfer of knowledge from other leading organizations back to the FAA. Collaboration with organizations such as RTCA, SAE ASTM, European Organization for Civil Aviation Equipment (EUROCAE) Institute of Electrical and Electronics Engineers, American Institute of Aeronautics and Astronautics (AIAA), Aerospace Human Factors Association (ASHFA), Royal Aeronautical Society, and the International Civil Aviation Organization (ICAO) leads to new global industry standards and information exchange. An example of the critical work accomplished by the FAA's participation in technical societies is the ongoing development of an international packaging standard for lithium batteries to be published by the SAE G27 committee.

FAA personnel hold key leadership and other supporting positions in many of these organizations helping influence the transfer of research knowledge. In 2019, FAA researchers served as executive officers, steering committee leads, and journal reviewers. Examples of these roles include ASHFA executive committee officer, president-elect for the Aerospace Medical Association, SAE International Cabin Safety Committee chair, chair of the government steering committee for Metallic Materials Properties Development and Standardization, Heavy Vehicle Simulator International Alliance executive committee member, and Aerospace Medicine and Human Performance journal reviewer. FAA experts also participated in outreach, and presented research papers at conferences, forums, and committee meetings.

The FAA Fuels and Energy group participated in SAE working groups researching unexpected lubricating oil impacts uncovered during engine testing. The team participated in the SAE International E-34 Turbine Propulsion Lubricants and E-38 Aviation Piston Engine Fuels and Lubricants working groups. These working groups are developing new standards for future aviation unleaded fuel chemistry candidates that will reduce environmental impacts.

FAA weather researchers participated on the RTCA committee responsible for DO-358A Minimum Operational Performance Standards for Flight Information Services. The publication provides minimum operations performance standards for incorporating six new weather products for uplink to the Universal Access Transceiver Automatic Dependent Surveillance–Broadcast for weather situational awareness.

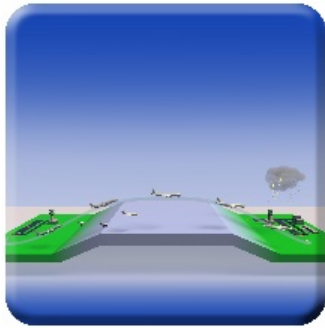
In support of the FAA’s mission, the FAA uses Research and Development (R&D) to support policymaking and planning, regulation, certification, standards development, and modernizing the national airspace system (NAS). The FAA R&D portfolio supports day-to-day operations in the NAS and balances near-term, mid-term, and long-term aviation needs.

1. Improving NAS Operations and Management Capabilities
2. Accelerating the Use of New Technologies in the NAS
3. Increasing NAS Infrastructure Durability and Resiliency
4. Improving Human Operations in the NAS
5. Improving NAS Integrated Modeling and System-Wide Analysis

The following sections contain a detailed description of these five FAA goals, followed by a status of the outputs planned in FY 2019, and success stories organized by goal. The output charts and success stories provide samples of the research being performed, as well as snapshots of NARP output performance results and key 2019 R&D results.



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



Efficient airport operations, together with enhanced air traffic and airspace management capabilities, are key to maintaining the world's most complex airspace system. Research under this goal supports airport operations, air traffic and traffic management research related to separation management, time-based management with respect to air and surface traffic management, integrated weather information, collaborative decision making, airport and spaceport systems, aerospace vehicle operations, and noise and emission management. As NextGen continues to evolve, additional research, concept development, and validation is needed to reduce risk and identify

technical and operational requirements that will deliver improved services in the effort to increase capacity, efficiency, system flexibility and safety. In addition, this work will result in the incorporation of new entrants into the NAS, including Unmanned Aerial Systems (UAS) and space vehicles.

Goal 1 Output Status

Output Description	Planned Completion Date	Status
Preliminary findings report of leveraging Electronic Flight Bag technologies to expand participation of airspace users, particularly the General Aviation and Business Jet communities, in integrated departure scheduling capabilities data sharing	9/30/2019	Completed
Concept of Operations (ConOps) for Class E Upper Airspace Traffic Management (ETM) to develop an airspace management concept that describes a vision for upper airspace operations, encompassing the range of operational mission characteristics in this airspace; including geostationary, extreme velocity and long duration operations	9/30/2019	Delayed

Weather – *Icing field program will enhance NAS safety.* Aircraft icing is a safety hazard especially to general aviation and Part 135 operations. To improve the diagnosis and forecasting of icing environments, the Weather Program led the In-Cloud ICing and Large-drop Experiment (ICICLE) field campaign. The purpose of ICICLE was to observe, document, and further characterize a variety of inflight and ground icing conditions, and test the ability of icing tools to detect, forecast, and differentiate between various icing conditions.

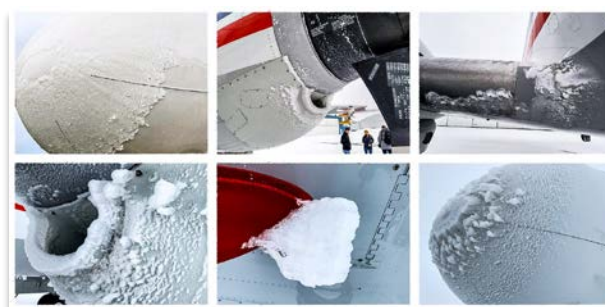
To meet ICICLE's objectives, the FAA Weather Program collaborated with the National Research Council Canada (NRC) and Environment and Climate Change Canada (ECCC) to fly the NRC Convair-580 research aircraft into icing conditions and collect extensive environmental measurements using multiple onboard instruments. The Convair was supplemented by ground-based instrumentation throughout the ICICLE environment.



Further collaboration involved the National Center for Atmospheric Research for forecasting, ground-based sensors, and data cataloging; the National Oceanic and Atmospheric Administration (NOAA) for high resolution weather

modeling; the National Aeronautics and Space Administration (NASA) for advanced weather satellite information; Leading Edge Atmospheric for campaign development and management of operations; the Desert Research Institute for weather forecasting; Meteo-France, United Kingdom Met Office, and Deutscher Wetterdienst (German Meteorological Office) for forecasting support; and several universities for supplemental atmospheric monitoring.

The ICICLE project began on January 27, 2019, and continued through March 8, 2019, with flights based out of Rockford, Illinois and samples made primarily over the western Great Lakes and bordering parts of the Midwest. The ICICLE field campaign was a major success with data collected from 26 research flights into a variety of icing conditions. After the valuable data collected is processed and quality checked it will be utilized to improve the analysis and forecasting of terminal and en route icing conditions that impact the safety and efficiency of the NAS. This data will also enhance icing detection and forecasting capabilities to meet FAA aircraft certification requirements and emerging microclimate requirements.



NextGen – Weather Technology in the Cockpit (WTIC) – Pilot Weather Knowledge Assessment – The FAA presented results from the WTIC program’s pilot weather knowledge assessment research at the Airline Pilots Association (ALPA) safety meeting. The team shared results from their pilot weather knowledge assessment research and their training materials that were developed to address areas where pilots did not score well. The information was so well received that ALPA has requested that the briefing be presented at their semi-annual Infoshare meeting to more widely address weaknesses in pilot weather knowledge revealed by the WTIC research.

Major Airspace Redesign – Separation Standards – Separation minima due to safety concerns is a major source of constraints on capacity at airports. The development and implementation of lower minima standards for runway 09/17 using Simultaneous Converging Instrument Approach procedures at Philadelphia International Airport (PHL) has resulted in measurable reductions in flight cancellations and delays during times of low ceilings when PHL is on an east flow configuration.

NextGen Wake Turbulence – New Data Screening Utility – The FAA developed new methods to measure wake turbulence impact on aircraft. The FAA NextGen – Wake Turbulence R,E&D program developed a data screening utility capable of processing large batches of Flight Operations Quality Assurance data post-flight to identify potential wake turbulence encounters. This will allow the FAA to gather quantitative statistics on wake encounters occurring in the NAS, instead of relying solely on reported incidents of wake encounters. The project also developed a wake turbulence modeling capability to explore wake encounter risks associated with proposed changes over a range of possible meteorological conditions. This wake modeling



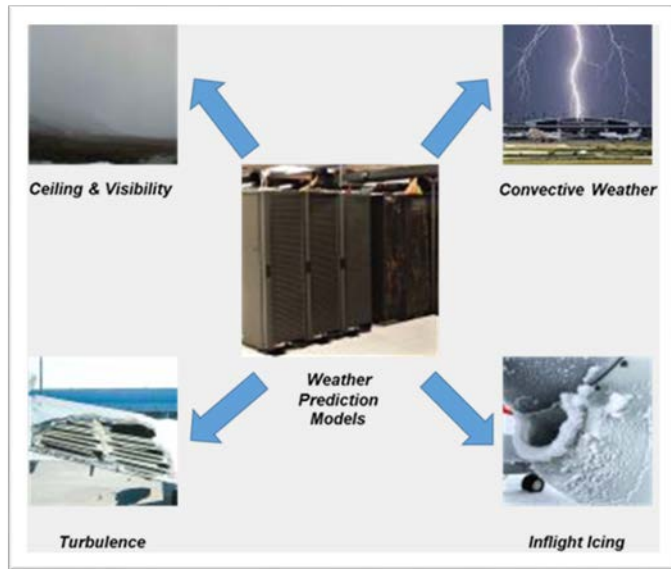
capability can be combined with quantitative statistics gathered from the screening of flight data during and after initial R,E&D phases to ensure wake encounter risks will not be adversely affected by proposed changes in separation minima and/or changes to ATC operating procedures.

Concept Development for Integrated NAS Design & Procedures Planning – Upper

Class E Traffic Management (ETM) Concept Development – There are expectations that aerospace operations in airspace above 60,000 feet (upper Class E) will increase exponentially over the next two decades. While current upper airspace regulations are predicated on traditional airspace usage, these increasing interests, along with the advent of new technologies and business markets, will present new challenges for the diversified operations within this airspace. The vision for upper airspace operations will encompass a range of operational mission characteristics to include balloons, glider, and supersonic aircraft. The FAA is collaborating with industry to perform research, analysis, and development activities to inform the infrastructure and regulatory framework needed to support the envisioned technologies and future operations. Engaging in stakeholder coordination activities, the ETM Concept Development project has identified the cross-dependencies of ETM, ATM, and UAS Traffic Management (UTM), and created the foundation to develop a concept of operations for ETM.

Surface Tactical Flow – Integrated Arrival, Departure and Surface Capability (IADS) – The FAA has traditionally collaborated with NASA and industry to mature concepts and develop technologies to improve the management of arrival, departure, and airport surface traffic. The research activities performed under the Surface Tactical Flow (STF) program is one such example. The goal of the STF program is to improve the efficiency of surface operations at the nation's busiest airports through time-based metering of departures and increased use and sharing of flight operations data among the various airport surface stakeholders. The FAA and NASA are executing a demonstration to validate an IADS at Charlotte Douglas International Airport (CLT). The research associated with the IADS demonstration and lessons learned from operations at CLT will inform future enhancements of the surface traffic flow automation system

(e.g., Terminal Flow Data Manager) that is scheduled for deployment at the largest airports starting in FY 2020.

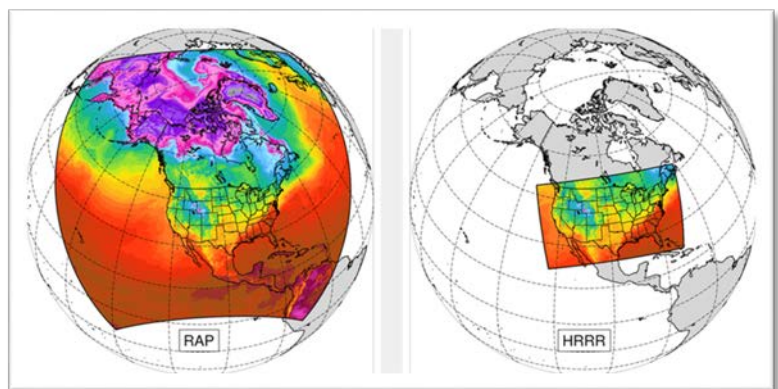


Weather – Numerical Weather Prediction Model enhancements increase NAS safety and efficiency – Weather prediction models are the basis for all aviation weather hazard forecasts beyond two hours either through the direct or indirect use of model output into relevant aviation parameters. Model development and enhancement research conducted under the FAA Weather program is designed to improve model predictions in order to enhance the safety and efficiency of the NAS. The Rapid Refresh (RAP) and the High Resolution Rapid Refresh (HRRR) weather prediction models are used

extensively for aviation weather hazard forecasting such as low ceiling and visibility, convective weather (e.g., thunderstorms), turbulence, and inflight icing. In FY 2019, Weather program-sponsored development resulted in the creation of RAP version 5 and enhancements to HRRR version 4, which were transferred to the National Weather Service (NWS) for operational implementation.

The RAP is a Northern Hemispheric regional model and the HRRR is a Continental United States model that uses the RAP to provide finer resolution of weather features. The RAP provides direct input to Weather program-developed capabilities such as the Graphical Turbulence Guidance product, the Current Icing Product, and the Forecast Icing Product. HRRR output is used in the Traffic Flow Management (TFM) Convective Forecast, the Consolidated Storm Prediction Algorithm, TFM Gate Forecasts, as well other NWS weather tools.

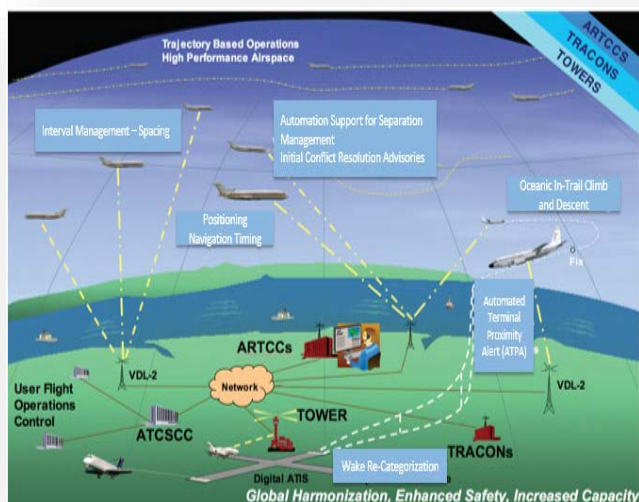
Assessments have demonstrated that RAP version 5 and HRRR version 4 improve the forecasts of winds, temperature, moisture, precipitation, and other variables crucial for the accurate forecasting of aviation weather hazards. The FAA transferred software code to the NOAA NWS Environmental Modeling Center in June 2019 to be ported to operational platforms for scientific evaluations and integration testing with an expected operational implementation in FY 2020.



NextGen – NAS Infrastructure Portfolio – Completion of the Trajectory Synchronization Prototype Development, Modeling and Simulation Plan – This plan represents the modeling and simulation body of work that will be performed in order to determine the best and most cost effective approaches for reconciling trajectory differences for a given flight. There are multiple Air Navigation Service Provider (ANSP) systems that compute trajectories for a given flight, known as trajectory modelers. Because the FAA and other ANSPs make use of automation systems that utilize different trajectory modelers, and aircraft systems also model the aircraft trajectory, often times the trajectory predictions are not synchronized due to computational differences, input errors (e.g. winds), and other phenomena. These trajectory errors can result in lost efficiencies. The over-arching objective of this plan is to provide methods for achieving air-ground trajectory synchronization (AGTS). The plan outlines 1) methods for evaluating AGTS business rules and implementing an AGTS Service prototype, 2) metrics for evaluating AGTS business rules, 3) and a viable approach to data collection and analysis.

NextGen – Traffic Flow Management Portfolio – Completion of the Technical Report and Research findings for Methods and Benefits of 2-way Data Exchange to support Integrated

Departure Scheduling – The FAA and NASA are executing a demonstration of a NASA-developed advanced Surface Management System (SMS) at Charlotte Douglas International Airport (CLT). The NASA SMS is designed to enhance the efficiency of aircraft surface movement at major airports. In addition to surface operations, the NASA SMS improves the efficiency of arrival and departure operations through the use of synchronized time schedules. The NASA SMS is being used to develop, test, and validate the use of such a systems at busy airports. The research associated with this demonstration and the lessons learned from operations at CLT

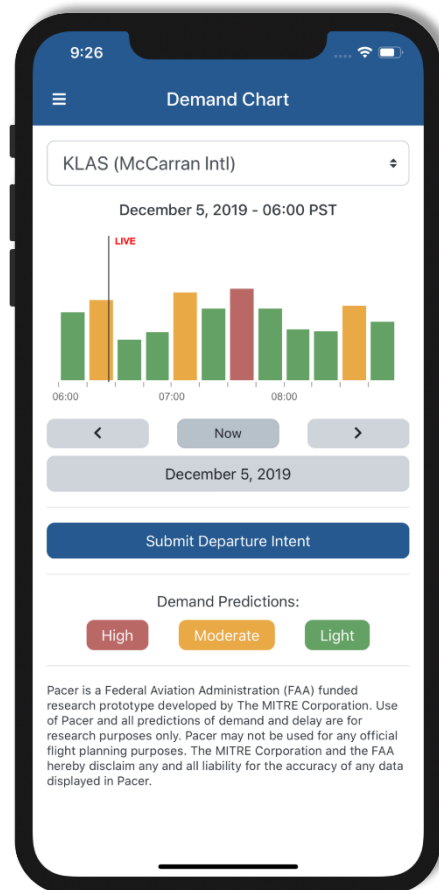


will inform future enhancements of the FAA's surface traffic flow automation system and the Terminal Flow Data Manager (TFDM) scheduled for deployment at the largest airports in the country starting in FY 2020. The technical report and its research findings are the start of the technical transfer in support of future TFDM enhancements.

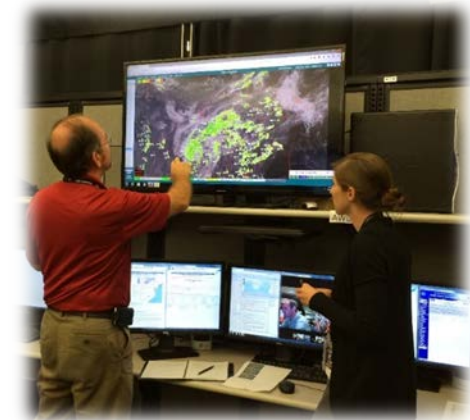
NextGen – WTIC – Tactical Turbulence Information in the Cockpit – The WTIC program completed and delivered a final report for research evaluating the use of the Terminal Flow Data Manager (TFDM) stream to replace the obsolete ASDI data stream and updating algorithms for predicting which aircraft are likely to encounter an area of identified turbulence. Researchers confirmed that updates to the tactical turbulence notification configuration is sufficiently accurate for notifying pilots of forecasted turbulence encounters even during widespread weather events.

NextGen – WTIC – Visual Flight Rules Not Recommended (VNR) – The FAA completed the final report for the VNR project. The results showed a large variance in assessing VNR conditions among flight service specialists (FSSs) due to the lack of an objective process. The pilots in the study were more conservative than the FSSs, but also had significant variations in their assessments and methods for making their decisions. Based on the results of this study, the WTIC program began the next phase of this research by developing objective processes for issuing VNRs. This research will enable automation compatibility and enhance its utility to pilots through consistent objective criteria.

Center for Advanced Aviation System Development (CAASD) – Electronic Flight Bag – CAASD commenced testing on a prototype Electronic Flight Bag (EFB) targeted for operators of unscheduled flights such as general aviation and business jets. CAASD worked with operators at CLT using data from NASA’s Airspace Technology Demonstration Phase 2 program to test an EFB that would provide users with a mechanism to view departure demand predictions and submit departure readiness information. The team issued a report in FY 2019 describing the effort. Testing on the prototype continues through FY 2020 at three additional locations: McCarran International Airport, Henderson Executive Airport and Dallas Love Field. Multiple reports describing the application, test efforts, and findings are scheduled for delivery in FY 2020.



Weather – Evaluation and user feedback are key to risk reduction and delivery of high-value aviation weather capabilities – Aviation Weather Demonstration and Evaluation (AWDE)



Services provides a process-orientated approach to integrate program management practices with demonstration and evaluation expertise. AWDE Services support many Weather projects including: Turbulence, Ceiling & Visibility, Convective Weather, and In-Flight Icing. AWDE Services not only collaborates with organizations within the FAA, but the National Weather Service (NWS), Airlines, and General Aviation as well. An example of this successful cross-agency coordination is AWDE’s yearly collaborative effort with the NWS Aviation Weather Center’s (AWC) Aviation Weather Testbed in Kansas City, MO to support their annual “Summer Experiment.” The “Summer Experiment”

provides a scientific environment for evaluations to facilitate the transfer of research

advancements toward improving NWS operations, products, and services intended to enhance National Airspace System (NAS) safety and efficiency.

For the 2019 Summer Experiment, AWDE services supported the evaluation and collection of user feedback for experimental 3D guidance and visualization techniques to determine if automated user-generated guidance improved the convective extended range (2–4 days) forecast for TFM planning. AWDE Services also evaluated and obtained user feedback for the experimental version of the Graphical Forecasts for Aviation and enhancements to the Helicopter Emergency Medical Services (HEMS) weather tool. AWDE Services not only provides critical feedback for improved aviation products, but also highlights cross-agency leveraging of testbed resources and expertise. This collaboration has led to low-cost, high-value efforts, benefiting both the FAA and the NWS, working in unison with various users to advance critical aviation weather capabilities.



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

The advancement and introduction of non-traditional aviation industries are pushing the boundaries of technology into all corners of the National Airspace System. Research under this goal supports: (i) applied innovation that identifies and demonstrates new aerospace vehicles and airport & spaceport technologies, (ii) certificating and licensing of aerospace operators and vehicles, (iii) the study of alternative fuels, and (iv) providing decision-makers essential data and analysis of that data to shape the future of the NAS. As the introduction of new technologies continues, this research will yield a safer, more efficient NAS with reduced environmental impact. Research will keep pace with continuously changing technology in order to properly certify operators and operations of the new industries, improve aircraft performance, and drive policy.



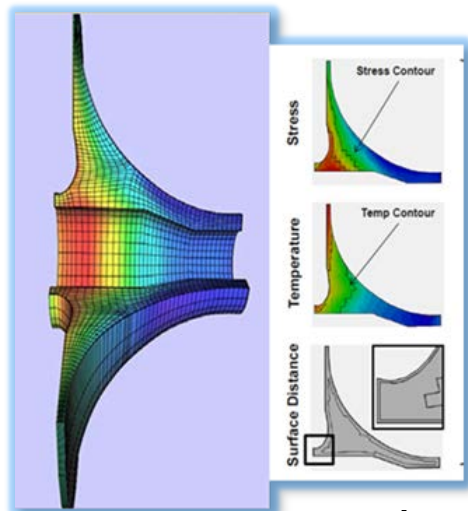
Goal 2 Output Status		
Output Description	Planned Completion Date	Status
DARWIN software version 9.4 having capabilities to analyze rotor blade slots using second-generation auto-modeling, improved user interfaces for 2D & 3D models, the ability to analyze shafts and casings, and advanced methods to account for residual stresses.	9/30/2020	Completed
Electroluminescent Lighting Technology (ELT) evaluation on Airport Vehicle Numbers, based on market survey and demonstration results	9/30/2020	Completed
Recommendations to industry to improve the safety of commercial space transportation operations by employing measures for protection of occupants across three perspectives (mission design, vehicle design, and human physiology) for commercial spaceflight in order to influence the technical standards.	9/30/2023	Completed
Documentation of the applied research effectiveness of implementing and providing bird concentration advisories to air traffic controllers, so that they can provide bird advisories to pilots.	9/30/2019	Completed

Fire Research and Safety – *Cost effective flammability testing of aircraft components* – The FAA initiated a Material Similarity Task Group within the International Aircraft Materials Fire Test Forum to develop methods and criteria for comparing the intrinsic flammability of component cabin materials.

Researchers are developing new procedures and pass/fail criterion for individual components found throughout cabin interiors. This process will help avoid costly recertification when aircraft manufacturers and suppliers are required to change materials due to the unavailability of parts or new environmental regulations.



Propulsion and Fuel Systems – Artificial Bird Substitute – The FAA participated on the SAE G-28 Simulants for Impact and Ingestion Testing committee. The committee aims to create an international standard for use of artificial substitutes in lieu of using real birds for aircraft certification testing. Industry representatives, including the Boeing Company, Fokker, General Electric, Honeywell, and Pratt & Whitney joined representatives from the FAA, European Aviation Safety Agency, and NASA, as well as academic and research institutions such as German Aerospace DLR, and the University of Dayton Research Institute participated in this effort.



The committee identified the need for testing standards and means of compliance to show that an artificial bird possesses equivalent mechanical characteristics to that of a real bird when tested against aircraft engines and structures. The committee determined that a building block approach, which uses layers of testing from simple to complex, shall be used to show equivalence between natural and artificial birds. Several key mechanical traits were identified and a test pyramid was defined, which will be documented in SAE aerospace standards and recommended practices.

The creation of an artificial bird substitute will help harmonize test standards between developmental and certification testing and reduce test variability. The development of an artificial simulant will also help create a better understanding of the mechanics of bird to aircraft impact thereby aiding in engineering more resilient designs and improving aviation safety.

NextGen New ATM Requirements – Trajectory Data Synchronization – The FAA initiated the Trajectory Data Synchronization project to align aircraft trajectory predictions across automation systems. The alignment of flight trajectories across automation environments is essential to achieving trajectory based operations in the NAS. To date, the project has successfully developed operational use cases to define the environments and situations that would require the flight data contained in the trajectory to be aligned, and identified the initial capability to synchronize the data elements across three automation systems: Time Based Flow Management, En Route Automation System, and Traffic Flow Management System. This initial capability will allow air traffic controllers across airspace domains to share an operationally consistent trajectory prediction for a given flight. Follow-on work will extend the synchronization capabilities across NAS automation systems.

Unmanned Aircraft Systems (UAS)

– *STEM Outreach* – The FAA has maintained ongoing multi-phase STEM outreach to students under-represented in STEM fields. The FAA shares real-world research results from UAS efforts at Centers of Excellence to effectively educate and disseminate the findings to a broader audience. The goal of the FAA’s research dissemination approach is to reach the future designers, operators, maintainers, and regulators of tomorrow’s UAS workforce using age-appropriate STEM events. Phases 1 and 2 of the STEM outreach program consisted of assessing existing materials, creating new materials, and designing programs such as student summer camps and roadshows, which have reached more than 1,000 students. Now entering Phase 3, the program is focusing on outreach to educators, rural communities, additional student summer camps, after school programs, and in-school immersion programs.



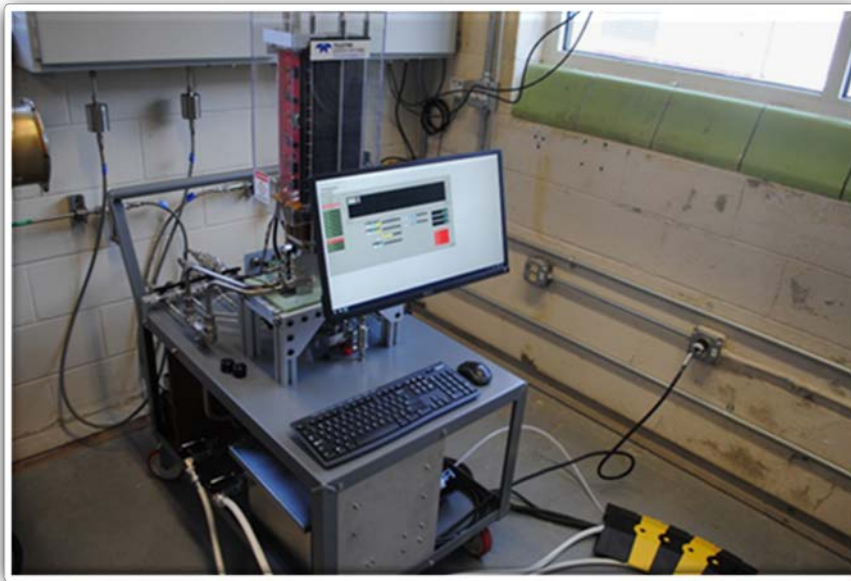
Propulsion and Fuel Systems Catastrophic

Failure Prevention – Predictive Modeling

Methodologies – The annual LS-DYNA Aerospace Working Group meeting for Engine Related Impact Failure was held on March 14, 2019 at Livermore Software Technology Corporation. The FAA presented to industry research progress on predictive modeling methodologies capable of simulating more than one failure mode with a single input deck. These

newly developed tabulated material models suitable for metal and composite impact applications were presented to industry along with updates to the aerospace quality assurance test problems and Modeling Guidelines documents. This suite of capabilities is the cornerstone of compliance for certification by analysis.

Continued Air Worthiness – Strain Measurement and Inspection System – In May 2019, a fully functioning strain measurement and inspection system was commissioned to support composite



wing panel testing using the FAA's Airframe Beam Structural Test (ABST) fixture located in the Structures and Materials lab. The new system features three translation stages mounted within an adaptable frame used to remotely position a high-resolution digital image correlation camera system within the test section of the ABST fixture. This enables the user to achieve quick and efficient digital

image correlation calibrations and complete monitoring of full-field strains and displacements within a panel during testing. The system is expandable to include additional translations stages for multiple digital image correlation systems. This unique system will be instrumental in improving efficiency and production in current and future test programs.

Goal 3: Capitalize use of NAS, airport, and spaceport infrastructure

A durable, long-life and resilient infrastructure forms the backbone of an efficient, safe, and secure NAS. Research in this goal applies to an infrastructure comprised of airport runways, taxiways, air traffic management, and aircraft systems and networks, as well as electrical airport sub-infrastructures and lighting. Goal 3 research focuses on (i) increasing the useful life of this infrastructure and decreasing maintenance and repair costs, (ii) NAS operations recovery from disruptive events, and (iii) cybersecurity that protects and defends FAA systems from both internal and external threats due to rapid advances and sophistication of cyber-attacks. Cyber work will include NextGen research that will leverage advanced big-data analytical approaches to our complex interdependent networks. Resulting research will lead to a longer lasting, lower cost, dependable infrastructure, defended against cyber events.



Goal 3 Output Status		
Output Description	Planned Completion Date	Status
N/A	N/A	N/A

Airport Technology Research Program – Unmanned Aircraft Systems, (UAS) Utilization – The FAA conducted an extensive outreach effort to investigate how airport stakeholders are utilizing UAS for various airport applications. Researchers interviewed a total of 23 stakeholders, including: 14 airport operators, six UAS solutions providers, and three federal and state government agencies. Researchers documented the findings from this outreach effort in a final report.



Figure 1 Runway incursion project. Image from <https://news.fit.edu/academics-research/runway-incursions/>

Based on this promising UAS activity, the FAA identified five applications for further development which include: obstruction analysis, pavement condition surveys, perimeter

security, wildlife hazard management, and aircraft rescue and firefighting. The FAA plans to develop technical guidance and standards, as well as develop a concepts of operations for these applications.



Airport Technology Research Program – Aqueous Film Forming Foam (AFFF) – The FAA conducted research on three different types of AFFF testing equipment that do not require foam to be dispensed on the ground during required operational testing of ARFF vehicles. Testing was completed in January 2019, and resulted in the issuance of FAA Cert Alert No. 19-10. This document provided information and guidance to airport operators regarding this portable equipment, and officially allows airports to

immediately use it to satisfy the Part 139 testing requirements. The results of the research effort were later published in a Technical Report titled “DOT/FAA/TC-19/26, Evaluation of Input-Based Foam Proportioner Testing Systems”. While not a complete and final solution, this important research led to an immediate reduction in the amount of AFFF being dispersed onto the ground as part of an operational test requirement.

Digital System Safety – The FAA along with other agencies, original equipment manufacturers, suppliers, and academia have successfully completed the first phase of cooperative research on the Assurance of Adaptive Controls with Artificial Intelligence/Machine Learning (AI/ML) implementations. The research has identified some major concerns and safety implications of the



2019 Annual Review – Performance Results: Goal 3

AI/ML implementations in airborne systems. Some of the team members have been invited to participate in the SAE G-34 committee to assist development of the assurance standards.

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



Humans, serving as aircrew (including UAS remote pilots), cabin crew, maintenance personnel, air traffic controllers, and in other NAS roles, are inevitably at risk of psychophysiological breakdown, and therefore less than optimal performance, during both normal and emergency events. Research in this Goal looks first to optimize human performance in these various roles through capability assessments, training, and operation evaluations. Secondly, research addresses aeromedical factors related to an individual's inability to meet flight demands. Optimized human performance in the NAS is fundamental to

the safe operation of the NAS and inherent to the safety of the airspace community, especially the flying customer, who relies on the FAA to provide the safest transportation system in the world.

Goal 4 Output Status		
Output Description	Planned Completion Date	Status
Technical Report on the role of the microbiome on human safety in civilian air operations	9/30/2024	Complete

Flightdeck/Maintenance/System Integration Human Factors – Stabilized Approach and Go-Around Guidance – A human-in-the-loop simulation experiment with 24 commercial airline pilot participants was completed to gather data to develop updated stabilized approach and go-around guidance. The experiment produced data for over 1900 approaches that will be analyzed to determine what factors (speed, rate of descent, weather, etc.) have the strongest influence on approach and landing safety. The results will be documented in publically available reports for industry use.



Aeromedical Research – Publication of Advisory Circular (AC) 121-24D, in March 2019.



Research leading to the production of Advisory Circular (AC) 121-24D was a multi-year effort by CAMI's Biodynamics, Cabin Safety, and Izone Teams, along with FAA's Air Carrier Operations. This official FAA guidance provides information on new brace positions. Over the course of the next few years, the airlines will be revising their passenger safety briefing cards to

reflect the new brace recommendations to raise public awareness. Included in the guidance is a reference to Serious Games that are used for education purposes. Both of these changes should result in passengers who are better prepared for an emergency and in turn, a reduction in injuries and fatalities in aircraft accidents and incidents.

Aeromedical Research – The Detection and Quantitation of 12 Cannabinoids in Postmortem Blood and Tissues Using Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) Following Solid Phase Extraction – This research provides the capability to reliably test for the presence of marijuana in postmortem blood and tissue samples in determining accident causation and cause of death for fatalities. If approved, this will assist us in determining possible pathways to mitigate the risk associated with accidents in which marijuana consumption is determined to be the whole or partial cause of a fatal accident.



NextGen – Enterprise, Concept Development, Human Factors, & Demonstrations Portfolio – Upper E Traffic Management (ETM) – In April 2019, the FAA and NASA hosted the ETM Tabletop session. The purpose of the event, comprised of industry and government stakeholders, was to gain an understanding of planned operations above Flight Level 600 and begin discussions related to the development of a concept of operations for ETM.

Discussions included identifying common principles and assumptions about the operating environment with emphasis on cooperative traffic management. Upper Class E stakeholders from AeroVironment, Liberty Works, Loon, Boon, Aurora, Alta Devices, Lockheed Martin, and Leidos, participated along with the Department of Defense and the International Civil Aviation Organization. This meeting is significant in that it marks the start of a government / industry partnership that ensures that stakeholder interests are considered as the concept is matured.

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

Research associated with this goal includes developing a scientific understanding of aerospace systems used to develop NAS improvements; developing analytical and predictive capabilities used in the capture, parsing, analysis, and sharing of data; and developing a toolset to evaluate NAS system wide performance, especially in view of the introduction of new and emerging technologies. Integrated modeling capabilities and system-wide analyses will facilitate the FAA's ability to produce state-of-the-art quantitative and qualitative analyses of complex systems of systems. This work will also improve the robustness, adaptability, flexibility, and accuracy of these integrated analytical and computational modeling tools. This will enable NAS effectiveness in the delivery of the highest quality service to the greatest number of stakeholders in a timely, safe, and practical manner.



Goal 5 Output Status

Output Description	Planned Completion Date	Status
Documentation of UAS Contingency Procedures Human-in-the-Loop (HITL) Simulations.	9/30/2020	Completed
Documentation of the validation of the extensibility of the CAASD IDEA Lab's simulation modeling framework to support fast-time continuous simulation in the IDEA Lab. This is based on a growing need to have regional and NAS-wide continuous simulation capabilities that can support human-in-the-loop simulation, agent-based modeling, and combinations thereof.	9/30/2019	Completed
Documentation of the characterization of arrival and departure procedure usage by incorporating analysis of voice clearances issued by air traffic controllers, including improvements in unique use cases, output quality, and scalability of the data processing algorithms.	9/30/2019	Completed
Enhanced simulation modeling framework that can be deployed across an enterprise cloud infrastructure so that fast and real-time simulations can scale to meet increasing computation demands of sophisticated new entrant modeling.	9/30/2019	Completed

Environment and Energy – Aviation Environmental Design Tool (AEDT) – AEDT is a FAA software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences. Current figures indicate that AEDT version 2 counts 284 users domestically and 323 abroad, spanning the entire range of the aviation sector constituents. The tool is used by major manufacturers including Boeing, Airbus, Bombardier, and Gulfstream; and airlines such as Delta, Ryanair, United, and Virgin America. The tool is also widely used in worldwide academia such as the Massachusetts Institute of

Technology (MIT), Georgia Institute of Technology, and Stanford domestically; and Delft, University of Florence, University of Canterbury, and Sejong University internationally, just to name a few. Although the majority of users are consulting firms supporting airports in assessing their environmental footprints, some airports have acquired the tool to perform such work internally. Additionally, the tool is used by U.S. government agencies including NASA, EPA, and DoD, and many organizations outside the United States such as the British, French, Brazilian, and South Korean Civil Aviation authorities. AEDT is the primary modeling tool used by the International Civil Aviation Organization's Committee on Aviation Environmental Protection to create new international policies and Standards and Recommended Practices related to aircraft noise and emissions.

NextGen – Wake Turbulence – Boeing Wake Risk Mitigation

– In December 2019, the NextGen Wake Turbulence research team recommended wake risk mitigation separations for the Boeing 777X series aircraft, which is to enter operational service in the NAS beginning in early 2020. The FAA has been working with Boeing over the last two years to obtain, review, and analyze the company's engineering design, and use wind tunnel and computational fluid dynamic results to determine the recommended wake risk mitigation separations for the new aircraft design series.



NextGen – Wake Turbulence – Aviation Safety Information Analysis and Sharing (ASIAS) – FAA-sponsored research by the National Institute of Aerospace resulted in a successful extraction/translation of ASIAS flight data recorder data sets for use with ATR's flight data recorder screening utility. The flight data recorder screening utility is to be used for estimating the occurrence of low impact (not major enough to report) wake encounters during flight and post implementation estimation of the impact of wake encounter risk resulting from a change to ATC procedures and/or air routes.

NextGen – Separation Management – The Multiple Airport Route Separation (MARS) Concept of Operations (ConOps) Completed in FY19. MARS is a concept that leverages the Established on Required Navigation Performance (EoR) concept of procedural separation to deconflict arrivals and departures to and from multiple airports in close proximity. EoR is approved to separate aircraft on adjacent instrument approach flight procedure paths to parallel runways at one airport for simultaneous independent operations. Pending favorable safety analyses, once MARS is implemented, controllers will be able to use procedural separation between suitably equipped and capable aircraft on parallel Area Navigation/Required Navigation Performance routes to multiple airports without requiring 1,000 feet of vertical or three nautical mile lateral separation. This will eliminate conflicts between adjacent airport routes and, in some cases, provide shorter routes. The MARS Concept of Operations represents the culmination of the FAA's collaboration with industry that may yield throughput improvements for the NAS.

NextGen – Unmanned Aircraft Systems (UAS) – Completion of Version 2.0 of the Unmanned Aircraft System (UAS) Traffic Management (UTM) Concept of Operations (ConOps) – The UTM ConOps is essential for defining and expanding future industry and FAA capabilities required to

support UTM operations in the National Airspace System (NAS). This includes development and validation of scenarios and use cases for conceptual elements to include remote identification and tracking, performance authorizations, small cargo, and controlled airspace operations. The completed document will serve to provide guidance to the stakeholder community for the continued development of system requirements and procedures for the operation of air and ground systems to enable the safe integration of UASs in the NAS. The UTM ConOps is a living document and will be updated to reflect lessons learned as further live demonstrations are executed and results documented.



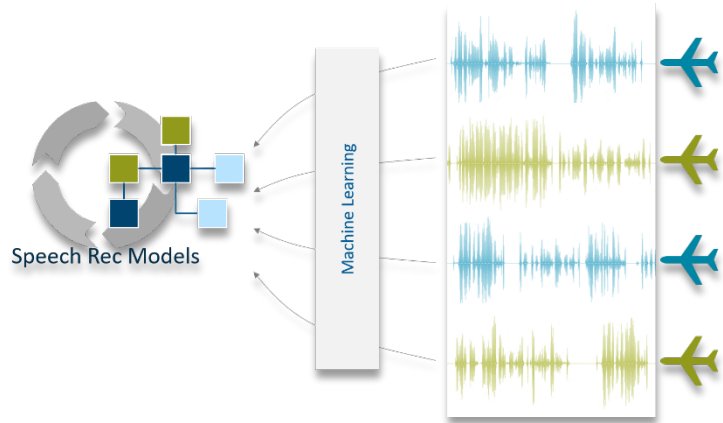
System Capacity, Planning, and Improvements – Hurricane Reporting – The FAA developed and implemented standardized reporting on the impact of hurricanes on NAS operations. The reporting is designed to inform air traffic managers of operational impacts experienced during these events in order to enable operational decisions. This reporting is now integrated into Joint Air Traffic Operations Command reporting. There will be a focus on fully automating the report in FY 2020.

Closely Spaced Parallel Operations (CSPO) – EoR – In partnership with industry stakeholders through the NextGen Advisory Committee (NAC), several capabilities have been developed and implemented at several major airports around the country in order to make arrival and departure operations at busy airports more efficient, saving the public and NAS operators' time and money. This includes the introduction of Wake Recategorization operations allowing aircraft to safely fly at decreased separation distances based on extensive research performed on wake dissipation between aircraft types. In addition, EoR has been introduced at a number of airports. EoR enables aircraft with advanced navigation capabilities to fly extremely efficient arrival procedures at busy airports, cutting as much as 10 to 30 miles off of the traditional approach to landing route. EoR can be utilized at airports having two and three parallel runways.

Human factors research helped to enable the use of EoR by providing guidance as to how to perform the operations safely by introducing procedural recommendations and, when appropriate, the use of automation tools. Integrated National Airspace Design and Procedure Planning's (INDP) MARS ConOps analysis has shown that MARS is a viable option for improving arrival and departure operations in metroplexes — metropolitan areas with multiple airports and complex air traffic flows — by creating more efficient routes for properly equipped aircraft. The MARS concept leverages EoR and closely spaced parallel operations research findings. The current plan to mature the concept includes conducting MARS data collection activities that support concept validation and safety collision risk analyses. MARS is currently being implemented in the Northeast Corridor of the United States, with expansion planned for other sites.

Center for Advanced Aviation System Development (CAASD) – Sim-Pilot Agent – CAASD completed validation testing of CAASD IDEA Lab's fast-time continuous simulation using a

Sim-Pilot Agent to alleviate the need for live/human sim pilots. The research was driven by the growing need for regional and NAS-wide capabilities that can support continuous human-in-the-loop simulations and agent-based modeling. The Sim-Pilot Agent was designed as a two-part application enabling advanced Text-to-Speech (TTS) and Automated Speech Recognition. The TTS capability was implemented using Polly, the Amazon Web Services TTS service. In March 2019, researchers demonstrated the new capability in a full simulation providing voice feedback over the laboratory audio system for commands entered by the Sim-Pilot.



As a result of the testing, researchers developed a technical proposal to further explore the effects of traffic management decisions in a strategic timeframe. The task included a design exercise to determine if current laboratory components could support a new type of exploratory simulation that runs in real-time to a strategic decision point and then "jumps" ahead in time to when the decision will have an impact on the participants.

Researchers determined that a seamless way for simulations to go from real-time to continuous fast-time and then back to real-time is still needed. Although the team identified possible low-risk modifications to infrastructure, agents, and model components that could improve the simulations, researchers determined major high-risk modifications would be necessary in order for the system components to incorporate large NAS automation systems such as Time Based Flow Management and the Traffic Flow Management System.

The research resulted in expanded fast-time simulations using the CAASD IDEA Laboratory ground and air traffic modeling components to create the continuous fast-time mode for the flight modeling capabilities in the IDEA Laboratory. Specifically, the research confirmed that model behaviors, and the agents that control them, are operationally sound. The fast-time simulation incorporated commercial airplane flight models into the framework, and implemented the necessary logic to respond to airport surface constraints and conflict avoidance. The team held a concept demonstration of the capability at Hartsfield-Jackson Atlanta International Airport.

CAASD – Voice Data Analysis – CAASD completed analysis and classification of air traffic controller voice clearances. Controller-pilot voice communications contain valuable information about operations and events in the NAS, and in many cases voice data is the only source for important contextual information about an event or operation. CAASD has developed capabilities for analyzing recorded controller-pilot voice data to take advantage of operational insights not previously possible. These capabilities, which include automatic speech recognition and natural language processing technologies, link voice communications to flight tracks, allowing the information to be analyzed NAS wide.

CAASD researchers used these voice data analysis capabilities to identify approach procedures cleared by controllers for each flight. Building on these research efforts, CAASD in FY2019, completed an analysis and characterization of arrival and departure procedure utilization. For example, the analysis measured the effects of Cleveland and Detroit Metroplex implementations on altitude, heading, and speed instructions issued by controllers. Through updated IDEA Lab modeling and refined algorithms, CAASD research has improved the accuracy, robustness, and flexibility of the analysis capabilities. These improvements enable new use cases to be developed for voice data to support operational analysis.

CAASD – Data Distribution – CAASD completed development of an enhanced simulation capability for NAS new entrant modeling. Research included the development of new laboratory interfaces to make flight data available to simulated air traffic management systems submitted to the lab by external research participants. Specifically, the work extended the simulation data distribution framework, leveraging Representational State Transfer, WebSocket technologies and Active MQ to demonstrate how applications not directly connected to the lab can participate in laboratory simulations.



Researchers also created a platform to integrate new entrant flight models, surveillance systems, monitors, and system behaviors associated with new entrant operations into the lab. The platform addresses the complexities of UAS traffic management and subsequent counter-UAS operations in cases of unexpected or hostile behaviors. As a result, UAS flight modeling and Flight Management System models were integrated into the

application. Researchers demonstrated the new capability in March 2019, which included detect-and-avoid and swarming algorithms.

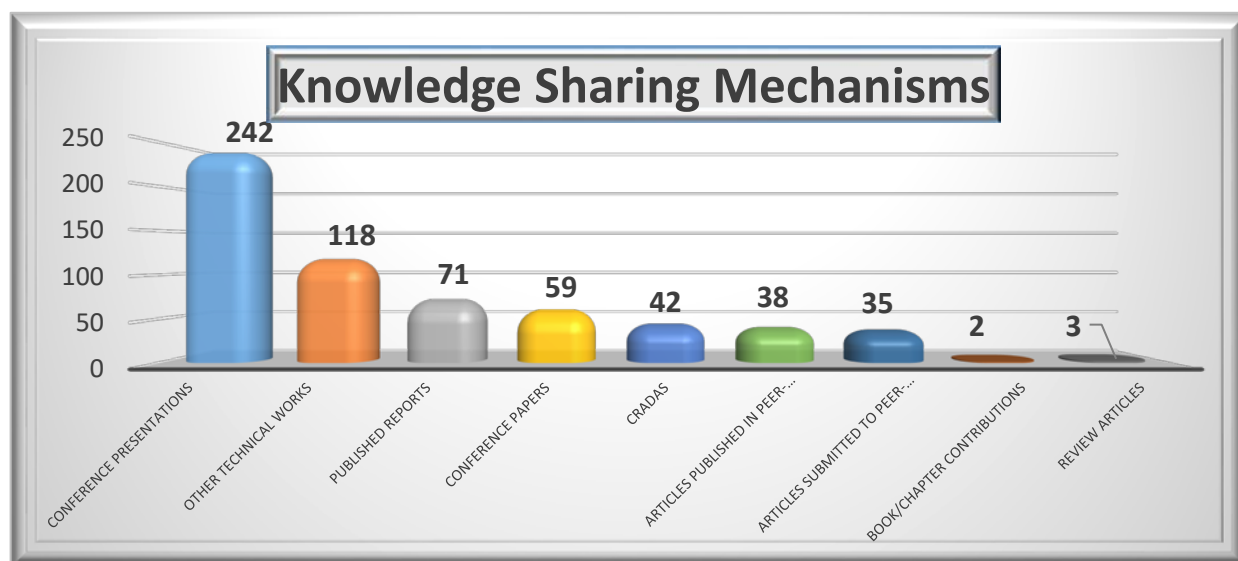
UAS Concept Validation & Requirements Development – Integration of UAS – UAS efforts included integrating UAS under Air Traffic Management (ATM) and the development of UAS Traffic Management (UTM). These efforts will inform changes to FAA automation needs, impact rulemaking and operations, and ultimately support the air traffic workforce in managing integrated UAS operations. The alternatives will favor approaches, such as procedural mitigations, as to not result in changes to NAS automation, thereby reducing the possibility of high implementation costs. The development of a UTM ConOps is essential for defining and expanding future industry and FAA capabilities required to support UTM operations. This includes development and validation of scenarios and use cases for conceptual elements to include: remote identification and tracking, performance authorizations, small cargo, and controlled airspace operations.

Research Deployed

The FAA Research and Development (R&D) portfolio is a robust, productive portfolio of 25 research programs spanning core R&D domain areas of airport technology, aircraft safety assurance, digital systems and technologies, environment and weather impact mitigation, human and aeromedical factors, and aviation performance and planning. The objective of FAA research is to enhance aviation safety, promote NAS efficiency, and foster global harmonization. Our agency benefits the American public and the nation's economy by leveraging agency knowledge, facilities, and capabilities to fulfill public and private sector needs. We broadly disseminate our findings and advances to other agencies, industry, and professional organizations through a variety of mechanisms.

Technology Transfer

The figure below illustrates knowledge transfer captured through data calls conducted by the Research, Engineering and Development (RE&D) research portfolio group. The FAA technical transfer program is in the process of framing an over-arching plan to effectively capture the broad range and number of products produced across the agency.



FAA knowledge-sharing mechanisms include tangible products, such as those reflected in the figure above, as well as other equally important collaborations and partnerships. In FY 2019, the FAA produced advisory circulars, engineering briefs, orders, statutes and regulations, and over 500 tangible research products including and more than 200 conference presentations. In addition to these formal products, the FAA collaborated with other federal agencies, universities, industry, and standards organizations to share expertise and resources to promote federal, Department of Transportation, and agency objectives.

A few examples of the products and collaborations performed in support of the technology transfer directive are provided below. The examples range from tangible products including formal reports and standards to collaboration with external partners.

CRADA

A CRADA is an agreement that enables the FAA to collaborate with non-Federal partners. FAA laboratories contribute personnel, services, facilities, equipment, or other resources (but not funding) toward the conduct of a specified research or development effort. In 2019, the FAA entered into 19 new CRADAs. These included collaborating with Mistras to test new technologies in the FAA's Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) laboratory. In another example, the FAA and Rockwell Collins will collaborate on research to characterize human factors pilot performance considerations using Advanced Vision Systems and Sensor-based technologies for existing and new low visibility capabilities.

Formal Reports

- In support of the aviation performance and planning initiative, the FAA prepared a technical report identifying standard procedures and potential technological mitigations for workload and safety impacts during en route UAS contingency operations.
- The Civil Aerospace Medical Institute (CAMI) issued over 30 publications including: A report entitled *Occupant Oxygen Mask Design* in response to a Congressional request, *Ionizing Radiation and Radiation Safety in Aerospace Environments*, *A Medical Review of Fatal High-G U.S. Aerobatic Accidents*, *Aircraft Seat Dimensions: Evaluation of the Effects of Seat Pitch and Width on Transport Category Airplane Egress*, and *An Evaluation of Egress from Side-Facing Seating with Deployed Inflatable Safety Equipment*.
- The FAA report titled DOT/FAA/TC-19/10 Large Engine Uncontained Debris Analysis – High-Bypass Ratio Engine Update was published in April 2019. The Naval Air Warfare Center, under contract to the FAA, has conducted an analysis to update the characteristics of large commercial transport turbine engine uncontained debris. This work was initiated in response to NTSB recommendations after the 2010 uncontained disk failure of a third generation, high-bypass engine on an A380 aircraft. The analysis highlights the fact that during an uncontained event the aircraft may experience multiple “small” fragment impacts, which can threaten redundant critical systems. This work will enhance aviation safety by providing an improved debris model to be used in an eventual update to Advisory Circular (AC) 20-128A so that the risk to transport aircraft from uncontained engine failures can be reduced.
- The FAA and the Aerospace Industries Association Rotor Manufacturing (RoMan) Team published report DOT/FAA/TC-19/14 entitled *Guidelines to Minimize Manufacturing Induced Anomalies in Critical Rotating Parts- 2019 Revision*. This is an update to the 2006 RoMan report of the same title (DOT/FAA/AR-06/3). The revised report is the result of over fifteen years of manufacturing “lessons learned” captured by the RoMan industry team during its annual meetings, and FAA-funded research on best practices for advanced manufacturing process control and monitoring. The report will be referenced in future Part 33 advisory circulars and is poised to further reduce the kind of engine events that have historically caused the most severe engine failures and unsafe conditions due to manufacturing induced anomalies. Some of the topics in the revised report include: design credits for manufacturing best practices, process improvements for disk slot manufacture, edge break methods, titanium spark impingement, process monitoring, and automated blending.

Standards

- The Biodynamics, Cabin Safety and Izone teams at CAMI provided substantive updates to the advisory circular on Passenger Safety Information Briefing and Briefing Cards (AC 121-24D). The new publication updates the instructions with new brace positions for passenger Safety Cards.
- The Airports Technology Research program developed new airport firefighting testing equipment and procedures. The team tested new firefighting equipment that would eliminate the need for the discharge of aqueous film forming foams into the environment. These aqueous film forming foams are bio-accumulative and toxic, raising health and environmental concerns. The team issued new guidance to airports through CertAlert No. 19-01.
- As a result of Weather in the Cockpit (WITC) research and Minimum Weather Service recommendations, RTCA SC-206 completed and delivered the RTCA Standard, DO-358A Minimum Operational Performance Standards for Flight Information Services. This technical transfer to a standards document incorporated the result of multiple WTIC research projects and WTIC technical support on RTCA SC 206, as well as being the government lead of the special committee.

Books/Chapters

- The Fire Research and Safety team published the *Aircraft Material Flammability Handbook* (Revision 3).
- Another example of knowledge transfer is the draft of a chapter in the book titled “Next Generation of Aviation Professionals”, which will be published by Taylor and Francis in early 2020. The chapter describes the WITC WeatherXplore application and its use in virtual reality for training.

Academic Collaboration

- Under a recent Cooperative Research and Development Agreement (CRADA) with Clarkson University in New York, the FAA is collaborating on testing aircraft aluminum panels to help develop a reliability methodology for Structural Health Monitoring (SHM) systems.

Other Federal Agency and Industry Collaboration

- The FAA Aircraft Catastrophic Failure Prevention Program (ACFPP) team collaborated with NASA Glenn Research Center, NASA Langley, Livermore Software Technology Corporation, Arizona State University, George Mason University, Ohio State University, Honda R&D Americas, and the Boeing Company to develop high fidelity metal and composite models. Accurate and predictive models will result in design and certification analysis tools leading to designs that are more robust to crash and engine blade loss thereby improving safety.
- The team researching alternative fuels for general aviation aircraft collaborated through a CRADA with Shell to develop a standardized series of test procedures and completed tests for 10 aircraft and 15 engine models. The goal is to replace the current leaded aviation gas supply chain with a safe unleaded alternative for the global market.

- CAMI, in collaboration with NASA, completed essential crashworthiness testing to quantify and codify generic crashworthiness requirements for commuter class aircraft. The FAA/NASA team conducted drop tests including a vertical drop of a forward section, a vertical drop of a wingbox section, and a swing of the entire Fokker 28 aircraft. For the full aircraft test, the aircraft was outfitted with roughly 24 fully instrumented anthropomorphic test devices. The research enhances safety by providing a baseline response of a metallic aircraft for comparison with aircraft using newer materials, such as composites. In addition, the results are being used to investigate if a predictive computer model is sufficient to guide certification decisions, thereby significantly reducing certification costs to the aviation industry.

Subcommittee and Standards Organization Participation

- Members of the Fire Research Safety team participated in the SAE G27 committee to develop a packaging standard for lithium batteries. The FAA provided test support for the development of the standard, and continued support to refine the test method, including inter-laboratory comparative testing of various lithium cells to verify the reproducibility of the proposed test method. In collaboration with airline industry representatives, the FAA developed scripts for informational videos to present the fire hazards of portable electronic devices in airplane flight decks and cabins. Filming of these videos will take place at Alaska Airlines training facility.
- The FAA System Safety Section provided technical presentations at the 2019 AIAA AVIATION Forum. The annual event focuses on recent progress in aircraft design, air traffic management and operations, and aviation technologies, as well as policy, planning, and market issues impacting the future direction of the global aviation industry. Nearly 2,500 aerospace professionals from government, industry, and academia attended this year's forum, which had a theme of "Shaping the Future of Flight." The team coauthored two papers, providing detailed results of a human-in-the-loop study investigating the effects of environmental parameters on touchdown performance and examined go-around decision-making. Dr. Angela Campbell and Mr. Somil Shah presented the paper "Pilot Evaluation of Proposed Go-Around Criteria for Transport Aircraft" during the Pilot Ops and Decision Support session, which Shah also co-chaired. While at the conference, Campbell and Shah also attended the Excellence in Aerospace Awards Luncheon, where they received the 2018 AIAA Modeling and Simulation Best Paper award for a study they coauthored titled "Human-in-the-Loop Study on Angle-of-Attack Indicator Effectiveness for Transport Category Airplanes".

Technology Utilization

- The CAMI developed CARI-7A software for calculating the effective dose of galactic cosmic radiation received by an individual on an aircraft. The results are being used by the NOAA- Space Weather Prediction Center for space weather requirements, USAF Research Laboratory high altitude researchers, and Boeing/Old Dominion researchers for rocket flight dosimetry estimation.
- The National Transportation Safety Board (NTSB) announced the closure of their safety recommendation to permit Helicopter Emergency Medical Services (HEMS) operators to use the HEMS weather tool as an official weather product. This NTSB recommendation was made in September 2009 after a dozen HEMS accidents including eight fatal

accidents and 29 fatalities occurred in a single year (2008). The HEMS weather tool was developed by the FAA weather program as an intuitive web platform to display low-altitude weather information quickly and effectively for non-weather experts. At the time of the NTSB recommendation, the tool was still in experimental status. The weather program responded by transitioning the HEMS tool onto an operational website and providing revisions for Advisory Circular 00-45H to include a detailed description of the tool. The NTSB marked their recommendation, “CLOSED--ACCEPTABLE ACTION” and stated, “Thank you for taking these actions to improve HEMS safety.”

- The WITC team developed the Weather Information Latency Demonstrator (WILD) and completed a technical transfer to Mindstar Aviation. The Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) universities and Mindstar signed an agreement to incorporate the WILD capabilities into Mindstar’s software, which is used in numerous commercial trainers and in professional gaming software. With this technology transfer, users of Mindstar’s software will accurately see the latency in cockpit weather information thereby improving pilot weather training.



Acronyms

Acronym	Definition
A	
ACFPP	Aircraft Catastrophic Failure Prevention Program
AEDT	Aviation Environmental Design Tool
AIAA	American Institute of Aeronautics and Astronautics
AR	Annual Review
ASHFA	Aerospace Human Factors Association
ASIAS	Aviation Safety Information Analysis and Sharing
ATC	Air Traffic Control
B	
C	
CAASD	Center for Advanced Aviation System Development
COE	Center of Excellence
ConOps	Concept of Operations
CRADA	Cooperative Research and Development Agreement
D	
E	
EFB	Electronic Flight Bag
EUROCAE	European Organization for Civil Aviation Equipment
F	
FAA	Federal Aviation Administration
FY	Fiscal Year
G	
H	
HRRR	High Resolution Rapid Refresh
I	
IA	Interagency Agreements
ICAO	International Civil Aviation Organization
M	
MOA	Memorandum/a of Agreement
N	
NARP	National Aviation Research Plan
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NOAA	National Oceanographic and Atmospheric Administration
NWS	National Weather Service

Acronym	Definition
O	
R	
RAP	Rapid Refresh
R&D	Research and Development
R,E&D	Research, Engineering and Development Appropriation
RNP	Required Navigation Performance
ROMIO	Remote Oceanic Meteorology Information Operational (demonstration)
S	
STEM	Science Technology Engineering and Math
U	
UAS	Unmanned Aircraft System
USAF	U.S. Air Force
V	
W	
WILD	Weather Information Latency Demonstrator
WTIC	Weather Technology in the Cockpit