U.S. Department
of Transportation
**Federal Aviation
Administration**

Office of the Administrator

800 Independence Ave., S.W.
Washington, DC 20591

October 16, 2020

The Honorable Roger F. Wicker
Chairman, Committee on Commerce,
Science, and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

I am pleased to transmit the Federal Aviation Administration (FAA) FY 2020-2025 National Aviation Research Plan (NARP), as required by 49 U.S.C. § 44501(c). The plan is organized to conform to the Government Performance and Results Act.

The NARP highlights and reports annually on FAA's applied Research and Development (R&D) as defined by the Office of Management and Budget (OMB) Circular A-11. It aligns with the U.S. Department of Transportation's Strategic Goals, and supports guidance issued by OMB and the Office of Science and Technology.

The NARP describes research deemed necessary to ensure the continued capacity, safety, and efficiency of aviation in the United States. As required by code, the NARP identifies goals, objective priorities, funding estimates, research governance practices, and technology transfer activities. The FAA R&D strategy includes funding programs in either of three appropriation accounts: Research, Engineering and Development; Facilities & Equipment; and Airport Improvement Program.

I am also pleased to transmit the FAA's FY 2019 R&D Annual Review and Active Agreements, which are companion documents to the NARP.

Identical letters have been sent to Chairwoman Johnson, Senator Cantwell, and Congressman Lucas.

Sincerely,

Steve Dickson
Administrator

Enclosures

U.S. Department
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**Federal Aviation
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Office of the Administrator

800 Independence Ave., S.W.
Washington, DC 20591

October 16, 2020

The Honorable Maria Cantwell
Ranking Member, Committee on Commerce,
Science, and Transportation
United States Senate
Washington, DC 20510

Dear Senator Cantwell:

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800 Independence Ave., S.W.
Washington, DC 20591

October 16, 2020

The Honorable Eddie Bernice Johnson
Chairwoman, Committee on Science,
Space, and Technology
House of Representatives
Washington, DC 20515

Dear Madam Chairwoman:

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Office of the Administrator

800 Independence Ave., S.W.
Washington, DC 20591

October 16, 2020

The Honorable Frank D. Lucas
Ranking Minority Member, Committee on Science,
Space, and Technology
House of Representatives
Washington, DC 20515

Dear Congressman Lucas:

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National Aviation Research Plan (NARP)

FY 2020 - 2025

September 2020

Report of the Federal Aviation Administration to the United States Congress pursuant to Section 44501(c) of Title 49, United States Code

This plan of the NARP fulfills the U.S. Code requirements for FY 2019 and FY 2020

NARP (FY 2020 – 2025) DRAFT V4
September 2020

The *National Aviation Research Plan* (NARP) is a report of the Federal Aviation Administration (FAA) to the United States Congress pursuant to § 44501(c) of Title 49, U.S. Code. The NARP is available on the Internet at http://www.faa.gov/go/narp. This volume of the NARP fulfills the U.S. Code requirements for FY 2019 and FY 2020

Message from Administrator Steve Dickson

The FAA is pleased to present the National Aviation Research Plan (NARP) FY 2020–2025.

Aviation is transforming at a rapid pace. To be successful in an industry where safety is the ultimate arbitrator, innovators must do the right thing when it comes to safety. The FAA is here to help. We make sure safety propels innovation. Targeted research and development is critical to safely integrate advances in aerospace technology. Research focused on air traffic system modernization, drones, commercial space vehicles, and emerging aircraft types will ensure the safe integration of new capabilities into the National Airspace System. This will ensure the continued safe and efficient movement of passengers and cargo across the country and internationally.

The NARP FY 2020-2025 describes the research, engineering, and development necessary over the next five years to investigate improvements for the safe integration of commercial space operations into the national airspace, and safety research related to Unmanned Aircraft Systems (UAS). The UAS research includes safety implications of new UAS operational concepts and technologies to support the development of new regulatory standards. The UAS research will focus on areas such as detect and avoid, datalink aircraft control and communications with air traffic control, and emergency response requirements. Other safety-related research areas include advanced materials, aircraft icing, continued airworthiness, and information security.

The NARP demonstrates alignment to the strategic vision of the U.S. Department of Transportation. It illustrates how the Agency is committed to engaging with aviation partners to deliver research solutions that maximize taxpayer contributions. The plan also describes how the FAA considers the needs of the airlines, airports and concerns of the public. Finally, the NARP describes how research results enable the FAA to develop certification requirements that promote safety without burdening the aviation industry.

Our world-class scientists and engineers are conducting exciting and cutting-edge research in the FAA’s state-of-the-art facilities. I invite you to read on, to learn more about the role FAA research plays in American prosperity and in American aviation leadership globally.

Executive Summary

The National Aviation Research Plan (NARP) is the FAA's performance-based plan to ensure that Research and Development (R&D) investments, as defined by the Office of Management and Budget (OMB) Circular A-11, are well managed, deliver results, and sufficiently address national aviation priorities. The NARP is a statutorily required document according to Section 44501(c) of Title 49, U.S. Code (49 U.S.C. §44501(c)). This requires the Administrator of the FAA to submit the NARP to Congress annually with the President's Budget. The NARP presents FAA R&D activities funded in three budgetary accounts: Research, Engineering and Development (RE&D), Facilities and Equipment (F&E), and the Airport Improvement Program (AIP).

The plan describes the research, engineering, and development activities across each of these accounts to ensure the continued capacity, safety, and efficiency of aviation in the United States over the next five years. The NARP features a framework of R&D goals, objectives, and outputs that support the strategic visions laid out by the President, Secretary of Transportation, and FAA Administrator concerning safety, innovation, infrastructure, and accountability. This approach enables the FAA to address the current challenges of operating the safest, most efficient aerospace transportation system in the world, while building a foundation for the future system in an environmentally sound manner. The NARP also describes how the FAA's world-class scientists, researchers, and engineers partner with industry to take on the challenges of the current and future National Airspace System (NAS).

In FY 2020, the FAA plans to invest a total of $515.921 million in the Research and Development portfolio, distributed across the three accounts. $192.665 million is assigned to R,E&D; $275.100 million to F&E, and $48.156 million to AIP.

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1.0 Introduction

1.1 Background

Research and Development (R&D) is the creative work undertaken on a systematic basis in order to increase the knowledge of man, culture, and society, and the use of this knowledge to devise new applications. This is critical to cementing the FAA's role as the world's premier aerospace body, and is essential for the continued evolution of the safe and efficient operation of the National Airspace System (NAS). It facilitates the introduction of aerospace industry innovations and resultant economic benefits by supporting the safe implementation of those innovations.

The FAA and aerospace community are facing numerous challenges as innovations introduce additional complexities to our aerospace system. These challenges include: adapting to novel safety issues and service demands resulting from increased activities of unmanned aircraft systems (UAS) and commercial space flight, countering the growing cybersecurity threats to aerospace's increasingly interconnected systems, and minimizing the increasing impact of aerospace activities on the environment. The FAA must act as an innovation catalyst during this transformative time, while continuing to maintain the safest, most dynamic, and most efficient aerospace system in the world.

The work the FAA does enables the aerospace industry to build up this country's infrastructure and increase economic prosperity. This work contributes to American prosperity through enabling new technologies and industries, and creating American jobs. According to the most recent data available, American aviation represents 5.1 percent of the U.S. Gross Domestic Product, yields 10.6 million U.S. jobs, stimulates $1.6 trillion in U.S. economic activity, and constitutes $446.8 billion in earnings.[1] The FAA has a substantial positive impact on aviation and, by extension, the U.S.

The FAA is statutorily required to conduct R&D to analyze information and identify, develop, improve, accelerate, or enhance methods, procedures and new technologies per Title 49, U.S. Code. This research is funded using three appropriations accounts: Research, Engineering, and Development (R,E,&D), Facilities and Equipment (F&E), and the Airport Improvement Program (AIP).

The FAA funds research to improve NAS operational effectiveness and reduce adverse environmental effects while maintaining or improving safety. These challenges must be met while, 1) standardizing the approach industry uses to show compliance with safety regulations, and 2) developing a better understanding of technologies, so FAA policy offices can craft updated regulations that might reduce the conservative approach built into the existing regulations and standards.

[1] Economic Impact of Civil Aviation: https://www.faa.gov/about/plans_reports/media/2017-economic-impact-report.pdf

The FAA actively partners with industry and academia to create innovative solutions that will lead to higher levels of safety and efficiency in the NAS. The FAA will continue these outreach efforts to nurture and strengthen relationships with our partners and stakeholders and determine the proper balance between government and private sector R&D investments.

The 2020 NARP describes the R,E,&D activities in 2020 and those planned for the next five years.

Important areas of focus and challenges of FAA R&D include:

- Evolving Operations
    - Understanding and acting upon unique opportunities and challenges to the NAS and its diverse set of stakeholders from new entrants such as UAS, and supersonic flight.
- Environmental Protection
    - Developing new technologies and operational procedures to mitigate systemic environmental impacts, including noise generated by aircraft, and help inform decision making on international noise standards for supersonic aircraft.
- Cybersecurity
    - Evaluating and testing promising new technologies and techniques for increased cyber resilience, taking advantage of new advances and emerging capabilities such as resilient self-adaptation and big data analytics.
- Workforce
    - Ensuring that the FAA's workforce has the leadership, technical, and functional skills necessary to safely and efficiently manage the needs of the future NAS. This includes providing grants to support the development of future aircraft pilots and aviation maintenance workforces per the FAA-Reauthorization Act of 2018 (P.L. 115-254), Section 625.
- NAS Sustainment
    - Ensuring the proper balance between meeting the demands of the ever-evolving aviation system, and investing in ATC facilities and equipment.
- NAS Resiliency
    - Ensuring the safe and continuous operation of the NAS during system outages or major catastrophes.

1.2 Mission and Vision

The FAA's **Mission** is to provide the safest and most efficient aerospace system in the world. The FAA's **Vision** is to reach the next level of safety, efficiency, environmental responsibility, and global leadership. The FAA is accountable to the American public and aviation stakeholders. Consequently, the FAA:

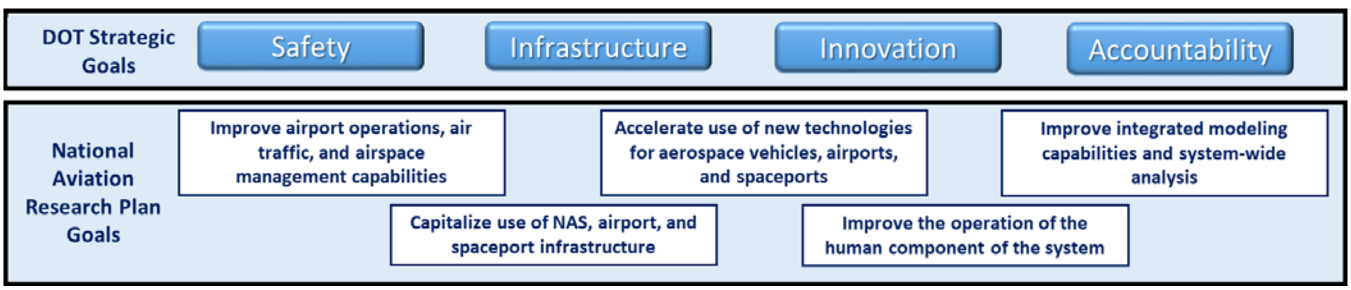
- Regulates civil aviation and U.S. commercial space transportation to promote safety;
- Encourages and develops civil aviation, aeronautics, air traffic control and commercial space through technological innovation and effective R&D;
- Develops and operates a system of air traffic control and navigation for civil aircraft;
- Develops and carries out programs to understand and reduce the environmental impacts of aviation and commercial space transportation on the U.S. public.

1.3 NARP Goals

As depicted in **Figure 1, NARP Goals**, the FAA focuses on researching and identifying solutions for:

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

Figure 1: NARP Goals



1.4 National Goals, Research Priorities, and Strategic Plans

The FAA's R&D portfolio is guided by national goals, research priorities, and strategic plans that inform the 2020 NARP. This includes OMB Memo 19-25 "Fiscal Year 2021 Administration Research and Development Budget Priorities," which provides the Administration's FY 2021 R&D Priorities, the Department of Transportation (DOT) RD&T Strategic Plan, and the FAA's Strategic Plan FY 2019-2022. The following sections highlight these national goals and strategic plans that inform the FAA 2020 NARP organized by source document.

1.4.1 White House R&D Budgetary Priorities

According to OMB Memo 19-25 "Fiscal Year 2021 Administration Research and Development Budget Priorities" there are five, high-level R&D Budgetary Priorities. The priorities detailed in this memo are:

- American Security,
- American Leadership in Industries of the Future,

- American Energy and Environmental Leadership,
- American Health and Bioeconomic Innovation, and
- American Space Exploration and Commercialization.

The following text outlines how FAA R&D aligns with these budgetary priorities.

American Security

According to the memo, "Departments and agencies should invest in critical infrastructure R&D that improves resilience to natural disasters and physical threats, including extreme terrestrial events, cyber and electromagnetic pulse attacks, and exploitation of supply chain vulnerabilities."

The FAA actively engages in projects that address American Security through **Critical Infrastructure Resilience**. For examples of notable research in this area, see NARP Goal 3: **Capitalize use of NAS, airport, and spaceport infrastructure**.

American Leadership in Industries of the Future

Industries of the future are industries that promise to fuel American prosperity, improve quality of life and national security, and create high-paying jobs for American workers. The FAA aligns with this priority through investment in areas such as **Artificial Intelligence** and **Computing**, **Advanced Communications Networks and Autonomy**, and **Advanced Manufacturing**. For examples of notable research being performed under this priority, see NARP Goal 2: **Accelerate use of new technologies for aerospace vehicles, airports, and spaceports** and NARP Goal 5: **Improve integrated modeling capabilities and system-wide analysis**.

American Energy and Environmental Leadership

The FAA conducts research designed to provide leadership on environmental matters and advance American energy production. This research includes overcoming challenges posed by noise to **support the reintroduction of civil supersonic flight;** maturing technologies to **reduce noise, emissions, and fuel burn;** developing an **unleaded fuel replacement;** and understanding **new electric propulsion systems** to enable their use by industry**.** For examples of notable research see NARP Goal 1: **Improve airport operations, air traffic, and airspace management capabilities**; NARP Goal 2: **Accelerate use of new technologies for aerospace vehicles, airports, and spaceports**; and NARP Goal 5: **Improve integrated modeling capabilities and system-wide analysis**.

American Health and Bioeconomic Innovation

The FAA conducts word-class research related to American health and Biomedicine through the Civil Aerospace Medical Institute (CAMI). This research includes **ribonucleic acid (RNA) sequencing, medical transport by helicopter, +Gz-induced loss of consciousness, disease transmission (biological agents), radiation effects of high-altitude flight, discovery of biomarkers that signal fatigue and hypoxia, helicopter crash survival, aviation toxicology research challenges, altitude hypoxia and associated life support systems, and biodynamics of head impact injuries**. For examples of notable research in this area, see NARP Goal 4: **Improve the operation of the human component of the system**.

American Space Exploration and Commercialization

The FAA enables American space exploration through efficient regulation of the launch operations of both Boeing and SpaceX, providers of the human rated launch vehicles and capsules that will launch the first U.S. astronauts into space from American soil since the Space Shuttle was retired in 2011. The FAA enables American space commercialization by efficiently applying a stable regulatory framework, overseeing all launch and reentry operations, and operations of launch and/or reentry sites, in the U.S., and by U.S. citizens. Current R&D priorities are the **safe introduction of commercial space in the NAS with improved safety analyses, developing methods to assess the effect of spaceports on the public and our national assets, and advanced vehicle safety technologies to prevent high consequence events and minimize launch constraints**. For examples of notable research in this priority area see NARP Goal 1: **Improve airport operations, air traffic, and airspace management capabilities**; NARP Goal 2: **Accelerate use of new technologies for aerospace vehicles, airports, and spaceports**; NARP Goal 3: **Capitalize use of NAS, Airport, and spaceport infrastructure**; and NARP Goal 5: **Improve integrated modeling capabilities and system-wide analysis**.

1.4.2 DOT Strategic Goals

The FAA invests in high priority research and development activities that are critical to the NAS and align with the goals of the FAA's parent organization, the DOT. The 2020 NARP aligns the FAA's R&D work to the DOT's following overarching strategic goals:

1. **SAFETY: Reduce Transportation-Related Fatalities and Serious Injuries Across the Transportation System**. Safety is DOT's top strategic and organizational goal. To improve transportation safety, DOT strives to work effectively with state, local, tribal, and private partners; address human behaviors to reduce safety risks; improve safety data analysis to guide decisions; continue to employ safety countermeasures; ensure that automation brings significant safety benefits; and pursue performance-based rather than prescriptive regulations.
2. **INFRASTRUCTURE: Invest in Infrastructure to Ensure Safety, Mobility and Accessibility and to Stimulate Economic Growth, Productivity and Competitiveness for American Workers and Businesses**. DOT seeks to work effectively with state, local, tribal, and private partners to guide investments that stimulate economic growth, improve the condition of transportation infrastructure, and enable the efficient and safe movement of people and goods. To achieve this goal, DOT provides guidance, technical assistance, and research that leverages federal funding, accelerates project delivery, reduces project lifecycle costs, and optimizes the operation and performance of existing facilities. By using innovative forms of financing and project delivery, encouraging partnerships between the public and private sectors, and strategically balancing investments across various modes of transportation to promote greater efficiencies, DOT maximizes the returns to the nation's economy and people.
3. **INNOVATION: Lead in the Development and Deployment of Innovative Practices and Technologies that Improve the Safety and Performance of the Nation's Transportation System.** Emerging technologies are transforming our transportation system. DOT seeks to continue its leadership role guiding research

investments and facilitating the deployment of beneficial transportation technologies. By engaging with the private and public sectors, DOT leverages Federal resources to support technology transfer and ensure the safety and security of new technologies.

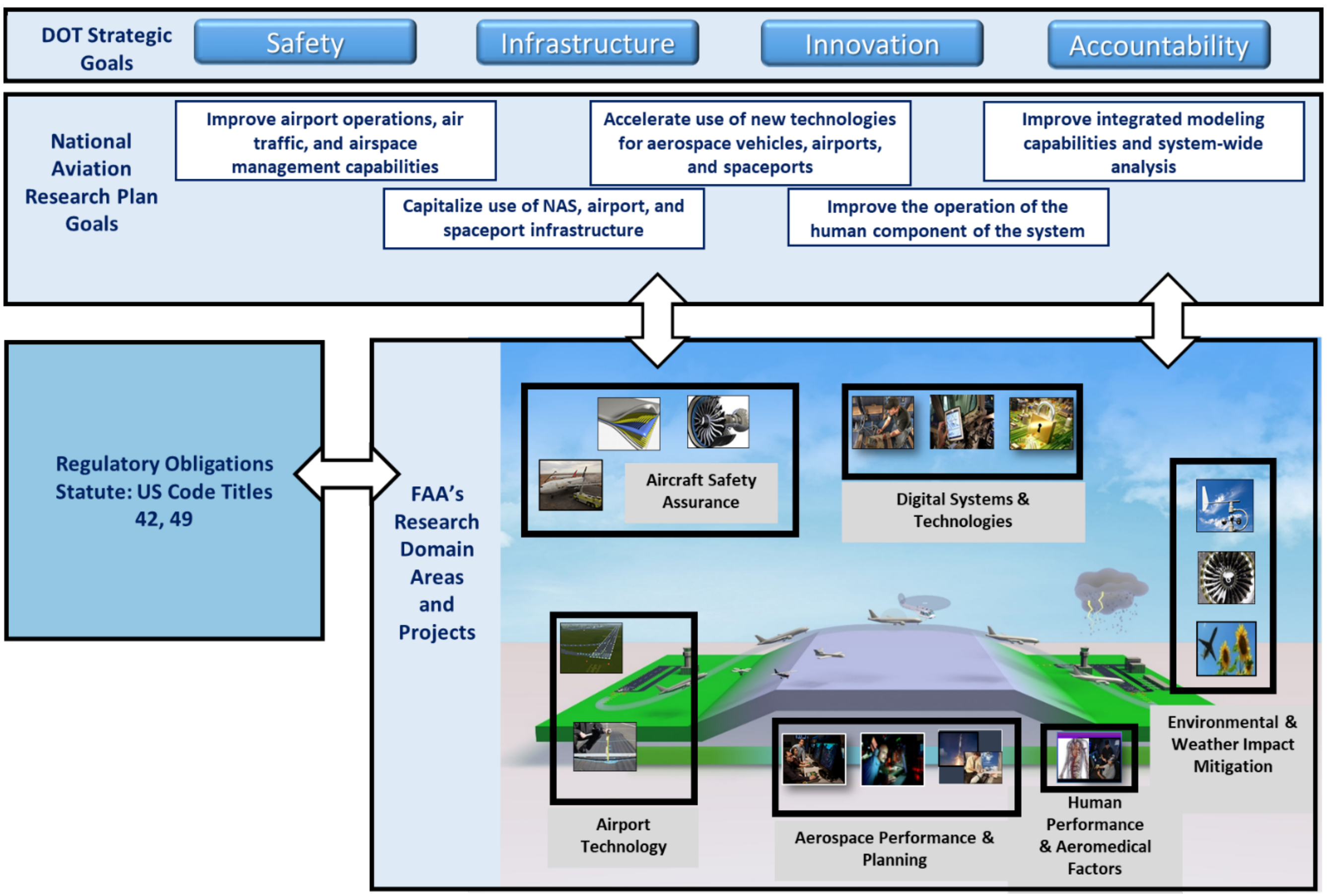
4. **ACCOUNTABILITY: Serve the nation with reduced regulatory burden and greater efficiency, effectiveness, and accountability**. DOT seeks greater accountability of sponsored RD&T programs, which helps ensure that results are publicly available. DOT supports technology transfer to maximize the impact of federally funded R&D by accelerating the transfer of new, innovative technologies from Federal agencies to the commercial marketplace.

2.0 FAA Research & Development

2.1 Holistic View of the Aerospace System

The major goals of the FAA's research support policymaking, planning, regulation, certification, standards development, mission support, and NAS modernization. The goals and objectives span the entire aviation and space enterprise with individual components within the NAS such as air vehicles, space vehicles, airports and airport systems, spaceports, human operators, air traffic systems, air traffic information, and the customers they service – the flying public. The NARP goals span multiple research domains that include Airport Technology, Aerospace Performance and Planning, Human Performance and Aeromedical Factors, Environmental and Weather Impact, Digital Systems and Technologies, and Aircraft Safety Assurance. **Figure 2, Holistic View of the Aerospace System** presents the FAA's NARP goals and research domain areas along with the overarching DOT strategic goals.

Figure 2: Holistic View of the Aerospace System



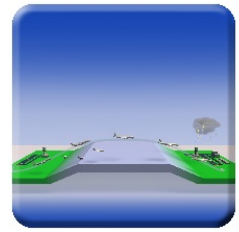
2.2 NARP Goals, Objectives and Outputs

The NARP goal areas contain multiple objectives or areas of emphasis as demonstrated in **Table 2.2, NARP Goals and Objectives** below.

Table 2.2 NARP Goals and Objectives

Goal 1: Improve airport operations, air traffic, and airspace management capabilities
Objectives: Air/Surface Traffic Management Separation Management Airport/Spaceport Systems Aerospace Vehicle Operation Noise and Emissions Integrated Weather Information Collaborative Decision Making
Goal 2: Accelerate use of new technologies for aerospace vehicles, airports, and spaceports
Objectives: Certification/Licensing Alternative Fuels Data Analysis Applied Innovation
Goal 3: Capitalize use of NAS, airport, and spaceport infrastructure
Objectives: Durability Resiliency Cybersecurity
Goal 4: Improve the operation of the human component of the system
Objectives: Human Factors Aeromedical Factors
Goal 5: Improve integrated modeling capabilities and system-wide analysis
Objectives: Scientific Acumen System Performance Data Engineering

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



Efficient airport and spaceport operations, and enhanced air traffic and airspace management capabilities, are keys to maintaining the world's most complex airspace system. Research under this goal supports airport and spaceport operations, air traffic and traffic management 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 the NAS continues to evolve, additional research, concept development, and validation are 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 including Unmanned Aircraft Systems (UAS).

Goal 1 Objectives

Air/Surface Traffic Management - ***Identify and develop new traffic management tools, operating procedures and/or requirements for the aerospace community's use of airborne and surface movement data to enable en route efficiency, more flexible arrival and departure operations, and to efficiently use runway capacity.***

Management of aircraft in the NAS and at our nation's airports is fundamental to a safe and efficient aerospace system. The FAA continues to conduct research geared towards a more harmonized approach to traffic flow management in the near-term by identifying high priority strategic and tactical operational integration issues or gaps. As traffic demand grows, the FAA performs R&D seeking to support integrated demand management using Traffic Flow Management Software (TFMS) tools and examining the operational procedures and automation systems used by air traffic controllers. For example, research into the air/ground trajectory synchronization prototype will leverage Scheduled Time of Arrival (STA) to improve accuracy of sector loading and arrival demand prediction.

Work is also being conducted to maximize tactical flow of surface movement at our nation's airports. This research includes the application of NASA's Airspace Technology Demonstration — 2 (ATD-2), a collaborative arrival and departure research capability in metroplex operations through the FAA's Integrated Departure Scheduling concept. The FAA also conducts research to understand the effects of using electronic flight bag (EFB) technologies to expand the participation of airspace users, especially in the general aviation and business jet communities. This participation enables enhanced data exchange and services to this important part of the aviation community.

Research into Trajectory Based Operations (TBO) continues to provide better operational procedures and requirements for the aerospace community. This research includes data and analyses to define a strategy for a future traffic flow management operational environment that enables increased en route efficiency and critical FAA mission areas such as new entrants.

The FAA also continues to optimize airport and airspace capacity to relieve congestion in the Northeast Corridor (NEC) of the United States — the busy airspace between Washington, D.C. and Boston that includes Philadelphia and New York City. This work is of high benefit to the NAS and its users, because the NEC causes more than 50% of all delays in the NAS.

Separation Management - ***Identify and develop new separation management tools, procedures, and/or requirements for the aerospace community to safely evolve separation management, improve access and flexibility in the NAS, enable the most efficient aircraft routes, and increase airspace capacity.***

With the ever-rising demand for air travel, the FAA must focus on increasing the amount of aircraft that can safely occupy our nation's limited airspace at any given time. Examining and modifying existing rules and procedures is critical to allow for decreased separation between aircraft in the NAS. For example, continuing research examines using the Established on Required Navigation Performance (EoR) concept to develop ways to decrease the amount of separation required between aircraft arriving at airports. These new separation standards will provide more flexibility in the NAS, and help increase the amount of aircraft in the skies without compromising safety.

Current research is focused on concepts that will also dynamically reduce the amount of risk wake turbulence produces through automation and decision support tools. This research allows for reduction in wake encounter regulations, and subsequently decreases the separation needed between aircraft, while also increasing throughput. This research also includes wake turbulence considerations for new aircraft types entering service in the NAS. Additionally, the FAA is developing decision support tools that will increase throughput capacity and automation tools to allow for the safe relaxation of ATC wake encounter hazard regulations. With the more efficient separation and wake turbulence standards generated by this research, increased flexibility will be realized in the NAS by allowing different types of aircraft to be more closely spaced, which also is a consideration in efficient aircraft routing.

The FAA is also performing research to apply the global commercial aviation community's existing user preferred "4-dimensional (4D) oceanic trajectories" to enhance international TBO.

Airport/Spaceport Systems - ***Identify and develop guidelines for the design and implementation of airport/spaceport systems, infrastructure and procedures and their use to increase efficiency, optimize capacity, and enhance safety.***

The FAA conducts research to understand and mitigate challenges at our nation's airports and future spaceports. Among these challenges are the modernization of airport technologies, materials, and techniques. For example, the FAA is examining a classification system for airport paint markings that reflects how various paint materials perform under exposure to environmental factors and aircraft traffic. This research will lead to paint marking specifications and guidance for airport authorities.

Of all the challenges that the FAA faces at our nation's airports, runway incursions are one of the biggest safety issues to the flying public. The FAA is meeting the challenges of runway incursions and wrong-surface events in the airport environment through its portfolio of research efforts. For example, the FAA is currently in the process of acquiring the Runway Incursion Prevention Shortfall Assessment (RIPSA) test system(s) to conduct operational tests and evaluations (OT&E) at key candidate test sites. Additionally, the FAA is partnering with MIT Lincoln Laboratory to develop the Small Airport Surveillance Sensor (SASS) for airports in the NAS that currently lack surface surveillance systems. The agency is also investigating the use of Surface Taxi Conformance Monitoring Technologies that can be used to prevent runway incursions. The FAA is focused on the technology transfer of these elements of runway incursion research, and their combined utility in developing a concept of operations for preventing wrong-surface events. The FAA aims to accomplish this through the development of a prototype Situational Awareness for Runway Entrances (SAFRE) system that will use cooperative surveillance sensors and speech recognition technologies with advanced ground surveillance.

As commercial space travel becomes more prevalent, the need to understand how to fundamentally incorporate commercial space users into existing air traffic patterns will become paramount. In preparation for this, the FAA is conducting forward-looking research in the airport and spaceport environments of the future. The FAA currently has airport technology research projects associated with understanding gaps in commercial space regulations and vehicle profiles and performance characteristics. In addition, research is being conducted into the development of design standards for vertiports used by future aircraft with vertical takeoff and landing (VTOL) systems.

Aerospace Vehicle Operation ***- Identify, develop, and validate new and enhanced tools, procedures, and/or requirements for the aerospace community to effectively and safely manage the expanded operation of existing and future aerospace vehicles in the evolving NAS.***

The FAA faces challenges incorporating newer aerospace vehicles into an already congested NAS as the aviation industry rapidly evolves. The FAA is conducting research to enable these advances in areas such as Urban Air Mobility (UAM) and Class E Upper Airspace Traffic Management (ETM). The FAA is also developing a Concept of Operations (ConOps) including UAM, which will allow for air taxi services in some of our nation’s most crowded urban areas. This ConOps describes a vision for emerging flight operations and their interaction with UAS Traffic Management (UTM) and Air Traffic Management (ATM). Similarly, the FAA is developing a ConOps for Class E Upper Airspace Traffic Management (ETM) that describes a vision for upper airspace operations. This airspace will encompass a wide range of operational mission characteristics including extreme velocity operations and long duration operations.

This objective also covers the research of novel fuel types to support the safe, efficient, and environmentally responsible integration of new technologies and missions into the NAS. The FAA is currently examining research and test data to support the safe use and integration of electric, hybrid electric, and fuel cell electric propulsion systems and aircraft into the NAS. This research on novel fuel types also includes new alternative fuels and supporting technologies for general aviation (GA) aircraft.

Noise and Emissions - ***Identify and develop tools, methods, and procedures and/or requirements for the aerospace community to reduce the noise and emissions from aerospace vehicle operations.***

The aerospace industry has made many improvements and advancements in the areas of reducing noise and emissions. Advances in aircraft technologies, operational procedures, and noise abatement programs at airports work synergistically to mitigate noise produced by aircraft. This includes FAA research on procedural concepts that could reduce community noise exposure while maintaining safe flight operations and guidance for airspace planners on how to incorporate these concepts.

Integrated Weather Information - ***Identify and develop high quality weather analysis and forecast capabilities for the aerospace community to support efficient airport operations and air traffic management decision-making to safely mitigate the impacts of adverse weather.***

Weather predictability is paramount in complex systems like the NAS because larger numbers of aircraft carry more air passengers than ever before. Weather continues to be the biggest source of uncertainty and affects the aerospace community daily. The FAA and its partners conduct research that seeks to improve and enhance weather forecasts and the tools used to deliver them to aerospace industry stakeholders and the flying public. This includes developing a 36-hour forecast for the onset and cessation of restricted ceiling and visibility conditions categorized by Instrument Flight Rules (IFR) and a global-scale probabilistic turbulence forecast capability for implementation by the National Weather Service.

The FAA continues forward-looking research that investigates the introduction of weather information into the cockpit for use by pilots. This program researches minimum weather service recommendations for convective weather, turbulence, and icing to resolve weather information gaps attributed to safety hazards and operational inefficiencies.

Weather is also a safety concern for emerging areas of research like UAS, UAM, and commercial space. Regarding UAS and UAM, the FAA is developing an initial inflight icing diagnosis and forecast capability tailored to the specific needs of UAS operations. This includes resolution of microclimates and urban environments. The FAA is also researching a terrestrial and space weather model that improves the prediction of environmental conditions for safe and efficient launch and re-entry operations tailored to commercial space transportation industry needs.

Collaborative Decision Making - ***Identify and develop methods for better access to, and exchange of, aerospace information for the aerospace community to make the best use of available airspace and airport/spaceport capacity, and improve NAS efficiency through greater flexibility, predictability, user preference accommodation, and timely coordination/collaboration.***

The NAS is a complex system with an extensive list of stakeholders including military users, commercial space users, commercial airlines, and the flying public. The FAA strives to improve information sharing in our increasingly data-driven world. To achieve this, the FAA is identifying and developing methods for better access to - and exchange of - aerospace information for the aerospace community. The ultimate goal is to make the best use of airspace and airport/spaceport capacity and improve NAS efficiency.

The FAA is currently researching strategic flow management to develop a ConOps to improve airport operations, air traffic, and airspace management capabilities through maturing smaller applications related to balancing demand and capacity. This includes research on the dynamic use of operator-submitted trajectory preferences.

The FAA also seeks to enable spaceport operations by developing a spaceport-site location prototyping tool. This tool will be used to assess spaceport site integration and safety challenges through data on air traffic and airport operations, space vehicle trajectories and hazard areas, other transportation modes, population centers, and critical national assets.

Table 2.2.1 Goal 1 Outputs

The table below details the principal planned work products or outputs that will result from R&D conducted at the FAA and/or with collaborators. The ‘Collaborators’ column identifies partners performing the research. A ‘YES’ in the ‘Long-Term R&D’ column represents foundational research that will be applied beyond the five-year horizon. An ‘X’ in a ‘Fiscal Year’ column indicates the approximate fiscal year timeframe the research output will be delivered. An ‘X’ in multiple ‘Fiscal Year’ columns indicates that multiple research outputs will be issued in that timeframe.

Note: The outputs shown are not comprehensive; rather, they are representative of significant outputs of the R&D work that is being conducted.

The FAA maintains partnerships with over 300 stakeholders representing federal agencies, academia, industry, international entities, and technical organizations. Our partners include aircraft and aircraft part manufacturers, design and engineering companies, external testing facilities, domestic and international organizations, and representatives of large and small business. Together these collaborations support the DOT strategic mission goals of promoting safety, infrastructure, innovation, and accountability.

The FAA leverages agreements with federal, academic, industry, and international partners to promote technical innovation, technology transfer, and science, technology, engineering, and mathematics (STEM) initiatives. Among the primary vehicles that the FAA employs are Interagency Agreements (IAs), Memoranda of Agreement (MOA), Centers of Excellence (COE) and Aviation Research grants, Cooperative Research and Development Agreements (CRADAs), Other Transaction Agreements, and International Agreements. These agreements are further described in Section 4.0 of this document, ‘Technology Transfer,’ and can also be accessed 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

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 1a: Identify and develop new traffic management tools, operating procedures and/or requirements for the aerospace community’s use of airborne and surface movement data to enable en route efficiency, more flexible arrival and departure operations, and to efficiently use runway capacity.								
Recommendations for integrated demand management and preconditioning based on lab and/or field trials assessing the feasibility of using strategic traffic flow management tools.	MITRE CAASD, NASA		X					

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Air traffic operational concepts to optimize airspace and airport capacity in the highly congested northeast corridor of the U.S.	Airspace user technical experts	YES	X					
Recommendations for preliminary air/ground trajectory synchronization implementation and integration of air traffic management functions to enable trajectory-based operations.			X					
Air/ground trajectory synchronization prototype version 1.0, which leverages Scheduled Time of Arrival (STA) from Time Based Flow Management (TBFM) and En Route Automation Modernization (ERAM) field 10b to improve accuracy of sector loading and arrival demand prediction in Traffic Flow Management System (TFMS).			X					
Technical feasibility assessment for air/ground trajectory synchronization prototype version 1.0 to conclude prototype development and validation activities and also to provide recommendations for future implementation.			X					
Benefits analysis for air/ground trajectory synchronization prototype version 1.0.			X					
Documentation of safety measures justifying procedural changes to reduce the Minimum Radar Separation (MRS) separation within 10 Nautical Miles (NM) of the runway threshold from 2.5 NM to 2.0 NM.			X					
Development of methods and procedures for aircraft operating in Non Transgression Zones (NTZs) to increase the efficiency of future controller tools and inform procedure and tool development for monitoring departure NTZs.			X					

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Identification of the highest strategic-tactical traffic flow management operational integration issues/gaps that require identifying near-term solutions for a harmonized approach to traffic flow management.	MITRE CAASD		X	X	X			
Strategy for a future traffic flow management operational state that accounts for trajectory based operations and other key FAA mission areas (e.g., new entrants).	MITRE CAASD, NEXTOR		X	X	X	X		
Report on the application of NASA's Air Traffic Demonstration (ATD)-2 collaborative arrival/departure/surface metering capability metroplex operations research to the FAA's Integrated Departure Scheduling concept.				X				
Report on findings of mobile/electronic flight bag (EFB)-based solutions that enable participation in integrated departure scheduling and enhanced data exchange with other types of flight operators (regional, cargo, international, etc.).					X			
Capability gap report for operational trajectory-based operations that outlines procedures, changes to the Air Traffic Handbook, use of interdependent data between automation systems and/or operational procedures.	MITRE CAASD, NASA					X	X	
OBJECTIVE 1b: ***Identify and develop new separation management tools, procedures, and/or requirements for the aerospace community to safely evolve separation management, improve access and flexibility in the NAS, enable the most efficient aircraft routes, and increase airspace capacity.***								
Technical report on safety assessment of the dynamic wake risk mitigation solution.			X					

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Validation plan for Established-on-Required Navigation Performance (EoR) pure duals independent operation concept.			X					
Validation studies on the Established-on-Required Navigation Performance (EoR) radius-to-fix (RF) concept for independent duals and triples at launch sites.	NATCA, MITRE CAASD		X	X				
Wake risk mitigation separation recommendations provided to ATC for new aircraft types entering service in the NAS.	EASA, aircraft manufacturers		X	X	X	X	X	X
Assessment of the global commercial aviation community's existing user preferred "4-dimensional (4D) oceanic trajectories" to enhance international oceanic trajectory based operations (TBO).	Commercial air carriers, commercial air navigation service providers (U.S. and International)		X	X	X			
Benefit analysis on the multiple airport route separation concept.				X				
Simulation plan on the dynamic wake risk mitigation solution.				X				
Consultation and enhancements for dynamic wake risk mitigation separation algorithms implemented in the airport tower, terminal radar approach, and en-route controller's decision support tools based on feedback from controllers, pilots, and technicians.	EASA, aircraft manufacturers						X	
Dynamic wake risk mitigation separation algorithms that use NextGen real time aircraft observed weather data for developing advanced ATC terminal and en route decision support tools.	EASA, aircraft manufacturers					X	X	

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 1c: ***Identify and develop guidelines for the design and implementation of airport/spaceport systems, infrastructure and procedures and their use to increase efficiency, optimize capacity, and enhance safety.***								
Technical transfer to industry (through report documentation) of Small Airport Surveillance Sensor (SASS) cooperative surveillance capability for Mode S and Air Traffic Control Radio Beacon System (ATCRBS) targets.	MIT Lincoln Lab, Air Force	YES	X					
Gap analysis between 1) applicable commercial space regulations, vehicle profiles and performance characteristics and 2) current airport design guidance, standards, regulations.			X					
Prototype algorithms and human interfaces for taxi conformance monitoring used in prototype cockpit-based and tower-based taxi conformance monitoring system to reduce runway incursions at controlled airports.	MITRE CAASD	YES	X	X	X			
Classification system for airport paint markings that reflects how various paint materials perform under exposure to the environment and aircraft traffic in support of paint marking specifications and guidance to airport authorities.		YES	X	X	X	X		
Development of design standards for vertiport used by vertical takeoff and landing (VTOL) aircraft.			X	X	X	X		
Technical transfer to industry (through report documentation) of prototype algorithms and human interfaces for taxi conformance monitoring used in prototype cockpit-based and tower-based taxi conformance monitoring systems to reduce runway incursions at controlled airports.	MITRE CAASD	YES		X	X	X		

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Technical transfer (through report documentation) to the Air Traffic Organization Program Management Office of advanced ground surveillance sensor technologies used in Runway Incursion Prevention Shortfall Assessment (RIPSA) technologies test systems.		YES					X	X
A detailed, comprehensive mapping of significant events in the history of U.S. spaceports, including: governmental, legal, financial, technical, and industrial contributions.	NMSU	YES						X
Demonstration of prototype Situational Awareness For Runway Entrances (SAFRE) system using cooperative surveillance and speech recognition technologies with advanced ground surveillance sensor technology.	MIT Lincoln Lab, MITRE CAASD	YES						X
Concept of operations for preventing wrong surface operations using prototype taxi conformance monitoring technologies and Situational Awareness For Runway Entrances (SAFRE) systems.	MIT Lincoln Lab, MITRE CAASD	YES						X
OBJECTIVE 1d: ***Identify, develop, and validate new and enhanced tools, procedures, and/or requirements for the aerospace community to effectively and safely manage the expanded operation of existing and future aerospace vehicles in the evolving NAS.***								
Needs analysis document that reflects the current state of demand for UAS users (to prioritize NAS system requirements development areas).			X					
Technical contributions summary and research into UAS operations standards development leading to the development of the UAS Integration Pilot Program (IPP).			X					

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Concept of operations (ConOps) for urban air mobility to develop an airspace management concept that describes a vision for emerging flight operations and their interaction with UAS Traffic Management and Air Traffic Management.			X					
UAS traffic management flight information management for integrated operations use cases, operational views, information flows and exchanges, and roles and responsibilities allocation tables.			X					
Concept of Operations (ConOps) document for integrated Unmanned Aircraft Traffic Management (UTM) operations.			X					
Technical deep dive analysis report on UAS automation systems.			X					
Concept of Operations (ConOps) document for UAS lost link procedures.			X					
Draft separation standards for improved airspace management of launch/reentry vehicles, such as hybrids and manned stratospheric balloons, during non-explosive phases of flight.	Lincoln Labs, MIT		X	X				

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Data from performance and fit-for-purpose testing of alternative fuels and new supporting technologies for integration into the general aviation fleet.	Aircraft Owners and Pilots Association (AOPA), American Petroleum Institute (API), Experimental Aircraft Association (EAA), General Aviation Manufacturers Association (GAMA), National Business Aviation Association (NBAA), National Air Transportation Association (NATA), Shell Global, Afton Fuels/Phillips 66, Mobil/Exxon, BP-Total/Hjelmco (JV), Swift Fuels, Calumet/Haltermann, Lyondell Chemical Co, Lycoming Engines, Continental Motors Group, BRP-Rotax GmbH & Co KG, Textron Aviation, Robinson Helicopter Company, Cirrus Aircraft, Cape Air, McCauley Propeller Systems, Hartzell Propeller, Radial Engines Ltd, Coordinating Research Council		X	X	X	X		

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Reports to support the safe use and integration of electric, hybrid electric, and fuel cell electric propulsion systems and aircraft into the NAS.	U.S. manufacturers of electric, hybrid electric, and fuel cell components and engines; Propulsion and Power Systems Alliance (PPSA); NASA	YES	X	X	X	X	X	X
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.				X				
Finalization of an update to the UAS Traffic Management (UTM) system prototype for integrating UAS into the NAS.							X	
OBJECTIVE 1e: ***Identify and develop tools, methods, and procedures and/or requirements for the aerospace community to reduce the noise and emissions from aerospace vehicle operations.***								
Systems analysis of noise dispersion technologies for noise mitigation in the NAS.			X	X				
Report documenting 1) advanced operational procedural concepts that could reduce community noise exposure while maintaining safe flight operations and 2) guidance for air space planners on how these concepts could be incorporated.	Industry, NASA, Massachusetts Institute of Technology MITRE CAASD		X	X	X	X		

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 1f: ***Identify and develop high quality weather analysis and forecast capabilities for the aerospace community to support efficient airport operations and air traffic management decision-making to safely mitigate the impacts of adverse weather.***								
A high-resolution turbulence forecast capability that integrates new diagnostics for clear-air, mountain-wave and low-level turbulence as well as the high-resolution rapid refresh (3 kilometer) numerical weather prediction model.	NWS		X	X				
Minimum Weather Service content definitions for weather information sent to the cockpit via Aircraft Access to SWIM (AATS) to support Data Comm clearance requests.	RTCA	YES	X	X	X			
Minimum Weather Service recommendations report on minimum convective weather information, and associated parameters of this information, needed in the cockpit to resolve gaps attributable to safety hazards and operational inefficiencies.	Airlines	YES	X	X	X	X		
Minimum Weather Service recommendations report to determine minimum turbulence and icing information needed in the cockpit, and associated parameters of this information to resolve gaps attributable to safety hazards and operational inefficiencies.	Boeing, Airlines	YES	X	X	X	X		
Minimum Weather Service Recommendations report on the minimum unique weather information and cockpit rendering of the information to support various helicopter operations (tourist, medical, oil rig, etc.) to resolve safety related gaps and risks identified by gap analyses and other sources.	Air Force, FAA General Aviation Center of Excellence (PEGASAS), Industry		X	X	X	X	X	X

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
Development of a 36-hour forecast for the onset and cessation of restricted ceiling and visibility conditions categorized by Instrument Flight Rules (IFR) at the Core 30 airports to enhance safety and support more efficient traffic flow management.	NWS	YES				X		
An automated Offshore Precipitation Capability (OPC) that blends weather satellite imagery, lightning data, and numerical weather prediction model data, along with a "machine learning technique," to produce a near real-time estimate of precipitation including thunderstorms.	AJM					X	X	
Development of an initial inflight icing diagnosis and forecast capability tailored to the specific needs of Unmanned Aircraft System (UAS) operations including resolution of micro-climates and urban environments.	NWS						X	
Terrestrial and space weather model for improved prediction of environmental conditions for safe and efficient launch and re-entry operations tailored to commercial space transportation industry needs.	NOAA						X	
Part 121 Minimum Weather Service (MinWxSvc) gap analyses on updates to NAS, new entrant aircraft, and increased use of automation.	RTCA, Industry	YES					X	X
Development of a global-scale probabilistic turbulence forecast capability for implementation by the National Weather Service to reduce aircraft encounters with unacceptable levels of turbulence, increasing passenger safety and airspace capacity.	NWS	YES						X

Output	Collaborators	Long-Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 1g: ***Identify and develop methods for better access to, and exchange of, aerospace information for the aerospace community to make the best use of available airspace and airport/spaceport capacity and improve NAS efficiency through greater flexibility, predictability, user preference accommodation, and timely coordination/collaboration.***								
Collaborative platform development for NAS traffic flow management performance planning, monitoring and alerting.	Commercial air lines, business aviation		X					
Development of scenarios to use operator-submitted trajectory preferences dynamically.			X					
Report on concept validation activities on dynamic use of operator-submitted trajectory preferences.				X				
Concept of Operations (ConOps) designed to improve airport operations, air traffic, and air space management capabilities by maturing smaller applications related to balancing demand and capacity.							X	
Spaceport site location prototyping tool for assessing site integration and safety challenges using data on air-traffic and airport operations, space vehicle trajectories, hazard areas, other transportation modes, population centers, and critical national assets.	MITRE CAASD						X	

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

The advancement and introduction of non-traditional aerospace industries are pushing the boundaries of technology into all corners of the National Airspace System. Research under this goal supports: (i) certificating, licensing, and permitting aerospace operators and vehicles, (ii) the study of alternative fuels, (iii) providing decision-makers essential data and analysis of data to shape the future of the NAS, and (iv) applied innovation that identifies and demonstrates new aerospace vehicles, airport and spaceport technologies. 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 Objectives

Certification/Licensing- ***Identify, develop, and validate technologies, procedures, and methods for the aerospace community to effectively and efficiently certificate and license aerospace operators and vehicles in different environmental conditions and envelopes.***

Pursuant to its statutory obligation in Subtitle VII of title 49, United States Code, the FAA must oversee and regulate civil aviation safety. The FAA issues and enforces regulations and minimum standards covering manufacturing, operating, and maintaining aircraft. The FAA also certificates airmen and airports that serve air carriers. Consistent with regulatory reform objectives, FAA research programs continuously explore and develop improved methods of safety assurance, demonstration, and certification. There are numerous outputs in this NARP related to certification and licensing under programs researching advanced materials structural safety, aircraft icing, digital systems safety, airport technology, fire research, continued airworthiness, and system safety in the terminal area.

The FAA performs research to ensure that advanced materials used in the manufacture and repair of aircraft and aircraft components are safe. This includes the generation of guidance documents, published databases, and documented best practices for material and process controls in support of certification of non-metallic additively-manufactured materials. This also includes research that is pertinent to the durability and certification of bonded joints and repairs for rotorcraft applications. An annual update is planned to the Metallic Materials Properties Development Standardization (MMPDS) Handbook and derivative products.

The FAA is conducting research to document criteria for safe certification for the use of Distributed Integrated Modular Avionics (DIMA) in modern aircraft systems. This research includes new test capabilities for freezing rain supercooled large drop (SLD) icing conditions and improved engineering tools for SLD computational and analysis capabilities to support new guidance materials.

The FAA conducts numerous research projects to improve the safety of air travelers in a potential aircraft fire. The FAA is currently evaluating more realistic methods of generating smoke for certification testing to better detect and suppress fires on freighter aircraft. More forward-looking research will be used to develop and validate a computational fluid dynamics (CFD) model of transport of combustion products throughout the interior spaces of aircraft and begin examination of the effects of aircraft skin penetrating nozzle (ASPN) discharge on the thermal balance during an interior aircraft fire. This research enables the development of training and guidance materials, and advisory circular support for research that leads to proposed new aircraft material flammability standards.

Upgrades and advances continue for the Design Assessment of Reliability with Inspection (DARWIN®) engine design and life prediction software tool. The envisioned upgrades allow for significantly increased functionality. This includes assessing damage tolerance of rotor-turned surfaces, fracture and life prediction on nickel rotor components, analysis of rotor blade slots using auto-modeling, improved user interfaces, methods to account for residual stress, analysis of additively manufactured materials, and the capability to conduct high cycle fatigue (HCF) and life analysis of integrally bladed rotors or blisks.

Research continues related to Electroluminescent Lighting Technology (ELT) evaluation on airport vehicle numbers to improve visibility, data analysis to update go-around regulations and guidance, and the development of proposed criteria for Point-In-Space (PInS) approaches and other types of helicopter flight operations. Last, the FAA continues to research and review the current regulation and standards for the safe and timely integration of UAS into the NAS through recommended changes for improving UAS visibility and regulatory guidance.

Alternative Fuels *- Identify and evaluate alternative fuels that provide equivalent safety and improved performance relative to conventional fuels.*

Research on alternative fuels is being conducted by the FAA to obtain critical information to ensure the safety of these fuels and ensure that they are being adequately credited under international standards.

In part due to the research funding provided by the FAA, five alternative jet fuel pathways have been approved by ASTM International as being safe for use by commercial aviation. Commercial flights are operating on a daily basis from Los Angeles International airport using one of these approved fuels. Work is underway to approve additional fuel pathways and streamline the ASTM approval process, thus expanding the opportunities for fuel production at greater blend percentages and at lower costs. The FAA is also considering whether changes to jet fuel chemistry could improve engine performance.

The FAA is also developing analytical tools that are providing data to evaluate the environmental, economic, and social sustainability of lower carbon aviation fuels, produced from fossil resources, and sustainable aviation fuels, produced from renewable and waste resources. This research is facilitating the evaluation of new fuel pathways for possible inclusion within the International Civil Aviation Organization (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Data Analysis ***- Provide data and analyses to decision-makers to inform development of guidance, standards, and policy measures.***

Data drives the FAA as it does the modern world. Data is key to the FAA making informed decisions about everything from integration of new entrants, maintaining the FAA's world class safety record, and improving operational efficiency. The FAA applies data analytics across its research portfolio from structural integrity data to predictive safety analytics using Artificial Intelligence (AI) and Machine Learning (ML).

For the current fiscal year, the FAA is documenting structural integrity data for composite and metal bonded structures, evaluating industry process quality control procedures, and examining the tests and analysis methods used for structural integrity to provide training and detailed background on best industry practices. This includes documentation of safety issues with highly integrated digital aircraft systems, gaps in guidance/standards, and recommendations on the assurance of such systems.

The FAA relies on its research and development programs to provide the tools and data that inform the decision making within ICAO's Civil Aviation Environmental Protection (CAEP) committee. The current focus of ICAO CAEP is the evaluation of noise from civil supersonic transport aircraft to inform the development of standards and recommended practices for landing and takeoff noise as well as en-route noise from supersonic flight. Without international agreements on these two standards, U.S. supersonic aircraft will not be able to land in other countries. As such, the FAA has placed considerable resources, alongside NASA, to support the decision-making this effort.

Over the last 12 years, the FAA has used data from this program to inform its decision-making on standards for subsonic aircraft and engines for non-volatile particulate matter (nvPM), fuel economy, noise, and nitrogen oxide (NO_X) emissions. Comprehensive datasets were used to inform the development of regulatory levels, fuel composition corrections for non-volatile particulate matter, development of methods to estimate nvPM emissions from out-of-production engines and characteristic values of engine emissions.

The FAA, through its Federally Funded Research and Development Center (FFRDC), the MITRE Center for Advanced Aviation Systems Development (CAASD), uses data analytics in an effort to increase safety in the NAS. This research seeks to develop a prototype ML predictive safety analytics capacity to support continued NAS operational safety. AI approaches, particularly those based on recent advances in ML, will be incorporated into the FY 2020 model. This research will explore using ML to assess overall suitability, performance, and operational workflow issues. This new prototype model will be developed and used with proprietary airline data from NAS operations and aircraft equipment to assess the potential of these AI-based techniques. The techniques could advance the cause of aviation safety in a variety of ways including analyses to uncover precursors to safety issues, and addressing safety problems before critical failures occur.

Data is also crucial to developing an inclusive and integrated system for the introduction of new entrants in the NAS, such as UAS. The FAA is currently documenting and analyzing UAS experimental data to make UAS highly visible to manned aircraft pilots, and understanding the implications these results have in supporting regulatory guidance for UAS integration into the NAS. This research includes supporting UAS Human-Automation Interaction requirements for regulatory guidance.

Applied Innovation ***- Identify and demonstrate new aerospace vehicle and airport/spaceport technologies that could be adopted by the aerospace community to improve safety, increase efficiency, and reduce environmental impacts.***

Technology is evolving at a rapid pace as evidenced by advances by the aerospace industry. The FAA constantly seeks to identify and conduct innovative research that enables the rapid transformation of the NAS in response to advancements by industry. The FAA has a large portfolio of innovative concepts, technologies, and research areas spanning the aerospace enterprise (e.g., airports, aircraft, flight deck, ATC, commercial space, and environmental).

Airport innovations are critical to the safety of the NAS and traveling public. The FAA continues research on how to best mitigate hazardous and high-risk bird strikes in the airport environment. This includes research on the effectiveness of various new techniques and technologies for habitat management and wildlife control techniques at our nation's airports and documentation of the applied effectiveness of implementing and providing bird concentration advisories to air traffic controllers. These controllers can then provide this critical information to affected pilots. The FAA also continues to maintain and upgrade the National Wildlife Strike Database to enable the aerospace community to collect, aggregate, analyze, and share bird strike data in the NAS and improve system-wide safety.

The FAA is conducting research that supports a more environmentally responsible NAS with fewer impacts to the public (e.g., visual and acoustical noise, environmental stewardship, etc.). The FAA's annual report on using solar power for various airport lighting systems will culminate in performance data on various instrument solar powered airport lighting systems, such as Medium Intensity Runway Lights (MIRL), taxiway lights, obstruction lights, signs, wind cones, elevated runway guard lights (ERGLs), and wireless controllers at a general aviation airport with specific radiant and environmental conditions. Separate data and analyses will support the integration of sensory ecology, physiology, and behavior information to understand animal reactions to vehicles, with the goal of developing onboard systems that elicit earlier alert and escape behaviors in response to high-speed aircraft.

Because of advancements in technology, there has been a 95 percent reduction in the number of people exposed to significant noise (compared to 1975) and more than a 70 percent improvement in fuel efficiency (compared to 1970). The vast majority of these improvements have come from enhancements in engine and airframe design. However, because of factors such as the growth in the number of operations and the implementation of new flight procedures, community concerns about noise remains a considerable challenge.

Through the public-private partnership of the Continuous Lower Energy, Emissions and Noise (CLEEN) Program (http://faa.gov/go/cleen), the FAA and industry are working together to develop technologies that will enable manufacturers to create aircraft and engines with lower noise and emissions as well as improved fuel efficiency. The technologies being accelerated by the CLEEN program have relatively large technological risk. Government resources help mitigate this risk and incentivize aviation manufacturers to invest, and develop these technologies. By cost sharing the development with the FAA, industry is willing to accept the greater risk associated with this technological development. Once entered into service, the CLEEN technologies will realize their noise, fuel burn, and emissions benefits throughout the fleet for years to come.

Innovative research also focuses on continued airworthiness. Long-term research includes ensuring the safe introduction and proliferation of adhesively bonded structures into modern aircraft with report results of the various methods for inspection of aged in-service repairs.

The FAA is also examining ways to improve how pilots receive weather information so that they can make informed, proactive decisions, and attain situation awareness of environmental conditions that affect their safe transit. This innovative research aims to directly provide weather information to pilots in the cockpit. The FAA leverages data from new advanced aircraft-centric weather radars, and the proliferation of new weather sensors to support UAS and provide pilots or cockpit automation with new, enhanced, and timely weather information.

Aircraft safety during icing is a major concern with all types of aircraft in service today. To address this, the FAA provides snow testing in a controlled, repeatable test environment that serves as a surrogate for snow testing under natural conditions. This advanced equipment and methodology supports the FAA Winter Weather Deicing Program’s annual notice for revenue service operations. This research project provides an efficient, cost effective alternative to variable, outdoor testing.

There are few applications of new technology that challenge the NAS and aviation enterprise more than integration of UAS. The FAA is currently conducting research to develop technical guidance and concepts of operation for using UAS for specific airfield applications. The goal of this research is to develop standardized methods and procedures for safely, effectively, and efficiently using UAS to perform on-airfield applications.

Table 2.2.2 Goal 2 Outputs

The table below details the principal planned work products or outputs that will result from R&D conducted at the FAA and/or with collaborators. The 'Collaborators' column identifies partners performing the research. A 'YES' in the 'Long-Term R&D' column represents foundational research that will be applied beyond the five year horizon. An 'X' in a 'Fiscal Year' column indicates the approximate fiscal year timeframe the research output will be delivered. An 'X' in multiple 'Fiscal Year' columns indicates that multiple research outputs will be issued in that timeframe.

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The FAA leverages agreements with federal, academic, industry, and international partners to promote technical innovation, technology transfer, and science technology engineering and mathematics (STEM) initiatives. Among the primary vehicles that the FAA employs are Interagency Agreements (IAs), Memoranda of Agreement (MOA), Centers of Excellence (COE) and Aviation Research grants, Cooperative Research and Development Agreements (CRADAs), Other Transaction Agreements, and International Agreements. These agreements are further described in Section 4.0 of this document, 'Technology Transfer,' and can also be accessed 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

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 2a: Identify, develop, and validate technologies, procedures, and methods for the aerospace community to effectively and efficiently certificate and license aerospace operators and vehicles in different environmental conditions and envelopes.								
Training videos, guidance material and advisory circular support for research that leads to proposed new aircraft material flammability standards.	Airframe manufacturers		X					

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Evaluation of more realistic methods of generating smoke for certification testing.	Manufacturing industry		X	X				
Annual updates to the Composite Manual Handbook-17 contents on Sandwich Disbond testing and modeling methodologies.	COE for Advanced Materials (Univ of Utah, Wichita State Univ, Univ of Washington), National Institute of Aerospace		X	X				
Annual update to the Metallic Materials Properties Development Standardization (MMPDS) Handbook and derivative products.	MMPDS Government Steering Group, industry consortium	YES	X	X	X	X	X	
Generation of data to address certification and continued airworthiness issues arising from industry introduction of new emerging metallic structures technology including advanced materials and new fabrication and construction methods.	Alcoa, Constellium, Boeing, Bombardiar, Embraer, COE for Advanced Materials (Wichita State Univ/NIAR)	YES	X	X	X	X	X	
Generation of data to assess the applicability of existing regulations and develop the framework needed to safely certify additive manufacturing (AM) parts.	Kansas Aviation Research, Technology Consortium	YES	X	X	X	X	X	
Documentation of criteria for safe certification in the use of Distributed Integrated Modular Avionics (DIMA) in modern aircraft systems.				X	X			
Compilation of simulation results as well as training and technology recommendations to update go-around regulations and guidance.	NASA, Honeywell, Embry-Riddle Aeronautical University				X	X		

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Capability enhancement within the DARWIN® life prediction software tool to conduct fracture and life prediction on nickel rotor components containing inherent anomalies.	U.S. Turbine Engine Manufacturers, Southwest Research Institute, DoD, NASA	YES				X		
Evaluations of improved fire detection and suppression systems for freighter aircraft.	Boeing, Airbus						X	
Analysis capabilities to enable the DARWIN® life prediction software tool to address damage tolerance of rotor-turned surfaces.	U.S. Turbine Engine Manufacturers, Southwest Research Institute, DoD, NASA	YES					X	
Development of proposed criteria for Point-In-Space (PInS) approaches and other types of helicopter flight operations.	USHST, Elbit Systems, Thales, MaxViz, Leonardo, Sikorsky, Hensodt, Rockwell Collins, Lifeflight of Maine, Iowa University, Rowan University	YES					X	
Documentation of UAS automation/autonomy experimentation to support regulatory guidance.			X					
Review current regulations and standards and recommend changes for the UA visibility enhancement.			X	X				
Development of new firefighting performance requirements for the use of compressed air foam system (CAFS) technologies in aircraft rescue and firefighting.	DOD - USAF		X	X				
Determination of the effects of aircraft skin penetrating nozzle discharge on the thermal balance during an interior aircraft fire.			X	X				

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Guidance documents, published databases, and documented best practices for material and process controls in support of certification of non-metallic additively manufactured materials.	COE for Advanced Materials (University of Washington, Wichita State University)	YES	X	X	X	X	X	X
Documentation of best practices for certifying bonded joints and repairs, including test and analysis methods to investigate bonded joint durability in rotorcraft applications.	COE for Advanced Materials (Wichita State University)	YES	X	X	X	X	X	X
Development of the methodologies required to establish safe and realistic freeplay limits for transport category aircraft to avoid freeplay-induced vibrations and manage the consequent risks.	Univ of Washington, Milan Polytechnic Institute		X	X	X	X	X	X
Development and validation of a computational fluid dynamics (CFD) model of the transport of combustion products throughout the interior spaces of aircraft.	NIST	YES		X	X	X	X	X
New test capabilities for freezing rain supercooled large drop icing conditions.	Rail Tec Arsenal, NASA, Science Engineering Associates					X		
Improved engineering tools for supercooled large drop computational and analysis capabilities to support new guidance materials.	NASA, University of Washington, Baylor University						X	
Capability enhancement of the DARWIN® life prediction software tool to conduct high cycle fatigue and life analysis of integrally bladed rotors or blisks.	U.S. Turbine Engine Manufacturers, Southwest Research Institute, DoD, NASA	YES						X
OBJECTIVE 2b: ***Identify and evaluate alternative fuels that provide equivalent safety and improved performance relative to conventional fuels.***								

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Safety/cost-benefit analysis of the environmental impacts, health effects, capital costs, and operator costs for a change in the composition of conventional jet fuels.	Industry, NASA, DOD, international stakeholders, ASCENT COE		X					
Technical analyses to support the inclusion of sustainable aviation fuels, created from waste and biomass feedstocks, and lower carbon aviation fuels, created from fossil feedstocks, within the International Civil Aviation Organization (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).	ASCENT COE, industry, USG, international stakeholders		X					
Testing of novel jet fuel pathways to support the development of research reports within the American Society of Testing and Materials (ASTM) International certification process to ensure these fuels are safe for use.	ASCENT COE, industry, USG, international stakeholders		X	X	X	X	X	
Analyses to support the evaluation of new fuel pathways for potential inclusion within the ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).	ASCENT COE, industry, USG, international stakeholders		X	X	X	X	X	X
OBJECTIVE 2c: ***Provide data and analyses to decision-makers to inform development of guidance, standards, and policy measures.***								
Evaluation of current state of research supporting UAS Human-Automation Interaction requirements to support regulatory guidance.			X					
Summary of experimental data and analyses to inform the development of an engine particulate matter (PM) emissions standard in the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP).	Industry, USG, international stakeholders		X					

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Documentation of safety issues with highly integrated digital aircraft systems, gaps in guidance/standards, and recommendations on the assurance of such systems.	Industry		X	X				
Documentation of 1) UAS experiments for investigating ways to make unmanned aircraft highly visible to manned pilots, 2) analysis of the experimental data addressed by research questions of this study, and 3) implications of the research results for supporting regulatory guidance for UAS integration into the NAS.			X	X				
Data and forecasts of expanded and non-segregated operations facilitating UAS integration.	ASSURE COE		X	X				
Prototype of machine learning-based predictive safety analytics to support continued operational safety.	Commercial airline safety offices		X	X	X			
Software tool and supporting documentation to improve methodologies and successful implementation of probabilistic methods for risk assessment and risk management of general aviation's fatigue-failure safety concerns.	Univ of Texas, Textron Aviation		X	X	X	X		
Documentation of structural integrity data for composite and metal bonded structures, evaluations of industry process quality control procedures, and the tests and analysis methods used for structural integrity and to provide training and detailed background on best industry practices.	COE for Advanced Materials (Washington State Univ, Florida International Univ, Univ of Washington, Univ of Utah)	YES	X	X	X	X	X	

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Research on technologies to reduce supersonic aircraft noise, public reaction to advanced supersonic aircraft noise, and procedures needed to certify aircraft noise to create the body of knowledge to support the development of en route noise standards for airplanes that exceed Mach 1.	Industry, USG, international stakeholders	YES	X	X	X	X	X	X
Summary of data and analyses to inform the development of new noise and emissions standards in ICAO CAEP.	Industry, USG, international stakeholders	YES	X	X	X	X	X	X
Experimental test, and analysis regarding super cooled large droplets (SLD) conditions along with test, analysis, and validation of engineering tools under development to be used for confirmation of the formation of SLDs.	NASA			X				
Evaluation of current industry repair design characteristics, and quality control procedures of aircraft composite structures, resulting in advanced training guidance and improved composite maintenance practices used by industry.	COE for Advanced Materials (Wichita State University)	YES		X	X			
Validation of the compatibility and interoperability tests and assessment of satellite Control and Non-Payload Communications (CNPC) Link performance characteristics to support the RTCA SC-228 standards.				X	X			
OBJECTIVE 2d: ***Identify and demonstrate new aerospace vehicle and airport/spaceport technologies that could be adopted by the aerospace community to improve safety, increase efficiency, and reduce environmental impacts.***								
Continuous Lower Energy, Emissions and Noise Phase II (CLEEN II) activities to demonstrate certifiable aircraft and engine technologies and enable industry to expedite introduction of these technologies into current and future aircraft.	Industry, NASA, DOD		X					

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Annual report evaluating solar power for various airport lighting systems.			X	X	X	X		
Data and analyses to support the integration of sensory ecology, physiology, and behavior information to understand animal reactions to vehicles, with the goal of developing onboard systems that elicit earlier alert and escape behaviors in response to high-speed aircraft.	USDA	YES	X	X	X	X		
Analyses to support the development of innovative means to reduce noise, emissions, and fuel burn.	ASCENT COE, industry, USG	YES	X	X	X	X		
Research to ensure the safe introduction and proliferation of adhesively bonded structure into modern aircraft and report results of the various methods for inspection of aged in-service repairs.	COE for Advanced Materials (Wichita State Univ/NIAR)	YES	X	X	X	X	X	
Continuous Lower Energy, Emissions and Noise Phase III (CLEEN III) activities to demonstrate certifiable aircraft and engine technologies, and enable industry to expedite introduction of these technologies into current and future aircraft.	Industry, NASA, DOD	YES	X	X	X	X	X	
Documentation of the effectiveness of various new techniques and technologies for habitat management and wildlife control techniques for minimizing wildlife strikes with aircraft at and away from all airports nationwide.	USDA	YES	X	X	X	X	X	X
FAA National Wildlife Strike Database maintenance to provide the aerospace community the ability to collect, aggregate, analyze and share bird strike data in the NAS and to improve system-wide safety.	USDA, Smithsonian Institution	YES	X	X	X	X	X	X
Technical guidance and concept of operations for UAS airport applications.		YES	X	X	X	X	X	X

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Summary of the research activity for Fuel Cell (hydrogen based) system installations on civil aircraft.	Boeing, Honeywell, Teledyne, Infinity			X	X			
Verification of performance and fit-for-purpose testing of novel and emerging propulsion technology for integration into the general aviation fleet.							X	
A software prototype that enables immediate (within 24 hours) flight simulator training based on an incident to prevent a reoccurrence of it as an accident.		YES					X	
Completion of an artificial snow machine to replace natural conditions in testing for snow holdover times.	Transport Canada, APS Aviation, Inc.							X
Evaluation of information generated by new onboard (e.g., digital forward looking weather radar) and non-onboard remote weather sensors to determine its utility for pilots or cockpit automation.	Industry, AOPA, airlines	YES						X

2.2.3 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 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 Objectives

Durability ***- Identify and develop methods for the aerospace community to increase useful life of airport/spaceport infrastructure, NAS materials, and equipment to reduce maintenance, repairs, and replacement costs.***

Durability is a critical aspect of airport infrastructure. Durable infrastructure reduces maintenance, repair, and replacement costs while mitigating potential delays, disruptions, and adverse safety effects. Airport pavement is a key component in the NAS that enables the safe parking, taxiing, takeoff, and landing of aircraft that weigh upwards of one million pounds. These aircraft operate in a complex system of aprons, taxiways, and runways that must withstand enormous loads in all weather conditions. Maintenance, repairs, and replacement of these surface elements has a direct economic impact to the user community by causing delays, missed connections, and diversions to other airports.

The current portfolio of airport durability improvement projects will deliver better predictive models, design models, and materials based on pavement, traffic, and environmental factors that yield extended pavement life performance indexes. Similarly, a new pavement roughness index will help alert airport maintainers of pavement degradation, and allow the scheduling of pavement repairs, reducing subsequent down time at airports.

Resiliency ***- Identify, develop, and validate procedures for the aerospace community that enable recovery of NAS operations following a disruptive event and ensure continued safe operations.***

The NAS, its technologies, and its equipment continue to evolve at a rapid pace. Although new equipment and technologies may be more reliable than their predecessors, they can pose new challenges to maintaining NAS operations. The FAA is evaluating the application of alternate concepts to assess and accept new technologies into existing airborne system architectures and identify, demonstrate, and evaluate the ability of alternate concepts to assess and establish the airworthiness of novel, airborne system architectures.

In FY 2020, the FAA is undertaking a critical technical analysis for reliable, resilient, and robust overall service to back up the Global Navigation Satellite System (GNSS). This analysis is a collaboration between the Department of Defense (DoD), DOT, and Homeland Security to develop a plan for carrying out a backup Global Positioning System (GPS) capability and complementary Position, Navigation and Timing (PNT) demonstration. The potential for loss or compromise of PNT capability is a critical issue for the NAS and many other public sectors. The result of this work will be a detailed technical analysis and set of recommendations for a robust timing backup solution.

Cybersecurity - *Identify, develop, and validate new and enhanced tools, procedures, and strategies to enhance the aerospace community's ability to prevent, deter, detect, and respond to cyber-attacks to ensure continued safe operations.*

Cybersecurity is one of the biggest emerging challenges the FAA and our nation faces. Although the motivations behind cyber-attacks vary depending on the actor, the goal behind these potential attacks remains the same — to disable, disrupt, and exploit systems through unauthorized access. The FAA must be increasingly vigilant and forward-looking in this area due to the critical function of FAA systems, and the critical nature of its mission, which is to provide safe and efficient travel to the flying public. Because of the rapid evolution of these threats, the FAA must position itself to not only prevent known cyber exploits, but also to model and forecast future cyber-attacks. This is a challenging endeavor as FAA systems evolve with an ever-increasing interconnectedness that makes it more vulnerable to bad actors.

The FAA heavily invests in research to prevent the cyber exploitation of the NAS. These efforts support the development of new and advanced cyber risk analytical tools to enhance the NAS ability to prevent, deter, detect, and respond to cyberattacks to ensure continued safe operations. This research includes demonstration of virtual dispersive networks, a multi-layered approach of context-aware behavioral analytics, and implementation of cloud-based integrity improvement methods in the NAS. New FAA research in FY 2020 is aimed at understanding and mitigating cyber threats to the flight deck through the identification of gaps and alternate strategies for secure flight deck data exchange.

Table 2.2.3 Goal 3 Outputs

The table below details the principal planned work products or outputs that will result from R&D conducted at the FAA and/or with collaborators. The 'Collaborators' column identifies partners performing the research. A 'YES' in the 'Long-Term R&D' column represents foundational research that will be applied beyond the five year horizon. An 'X' in a 'Fiscal Year' column indicates the approximate fiscal year timeframe the research output will be delivered. An 'X' in multiple 'Fiscal Year' columns indicates that multiple research outputs will be issued in that timeframe.

Note: The outputs shown are not comprehensive; rather, they are representative of significant outputs of the R&D work that is being conducted.

The FAA maintains partnerships with over 300 stakeholders representing federal agencies, academia, industry, international entities, and technical organizations. Our partners include aircraft and aircraft part manufacturers, design and engineering companies, external testing facilities, domestic and international organizations, and representatives of large and small business. Together these collaborations support the DOT strategic mission goals promoting safety, infrastructure, innovation, and accountability.

The FAA leverages agreements with federal, academic, industry, and international partners to promote technical innovation, technology transfer, and science technology engineering and mathematics (STEM) initiatives. Among the primary vehicles that the FAA employs are Interagency Agreements (IAs), Memoranda of Agreement (MOA), Centers of Excellence (COE) and Aviation Research grants, Cooperative Research and Development Agreements (CRADAs), Other Transaction Agreements, and International Agreements. These agreements are further described in Section 4.0 of this document, 'Technology Transfer,' and can also be accessed 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

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 3a: ***Identify and develop methods for the aerospace community to increase useful life of airport/spaceport infrastructure, NAS materials, and equipment to reduce maintenance, repairs, and replacement costs.***								
Pavement prediction modeling tools based on pavement, traffic, and/or environmental inputs that yield extended pavement life performance indexes.			X					

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Development of a new airport pavement roughness index based on accelerometer values acquired from inertial profiling systems to help airports schedule pavement repairs and minimize downtime at the airport.			X	X				
Design model that will be incorporated into the FAARFIELD airfield pavement design program, for use in predicting reflection crack damage when designing airport pavement HMA thickness concrete overlays.			X	X	X			
FAARFIELD airfield pavement design program improvement based on airport pavement performance data.		YES	X	X	X	X		
Guidance on the use of geosynthetics, geogrids, and geotextiles as reinforcing base/subbase layers, separation layers, and/or drainage layers in the airport pavement structure.		YES	X	X	X	X		
OBJECTIVE 3b: ***Identify, develop, and validate procedures for the aerospace community that enable recovery of NAS operations following a disruptive event and ensure continued safe operations.***								
Evaluation of the application of alternate concepts to assess and accept new technologies into existing airborne system architectures; and identification, demonstration, and evaluation of the ability of alternate concepts to assess and establish the airworthiness of novel, airborne system architectures.	NASA Langley		X	X				
Technical analysis for reliable, resilient, and robust overall timing service to back up the Global Navigation Satellite System (GNSS).	DOT, DoD, DHS, USCG, civil users of GPS		X	X	X			

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Guidance regarding advisory circular AC 150/5370-17 to provide alternative heated pavement technologies (e.g., geothermal, electrically conductive materials, and nanotechnology) and design guidance to reduce negative impact to airport operations while increasing safety and efficiency during adverse winter weather conditions.		YES	X	X	X	X		
OBJECTIVE 3c: ***Identify, develop, and validate new and enhanced tools, procedures, and strategies to enhance the aerospace community's ability to prevent, deter, detect, and respond to cyber-attacks to ensure continued safe operations.***								
Establishment of a Cyber Integrated Mitigation Identification and Evaluation Process (MIDEP) for application to selected safety risk assessment (SRA) risks.	MIT/LL, ACA		X					
Analysis of initial demonstration of Big Data Cyber Analytics and data collection proof of concept.	DHS, DOD		X	X				
Documentation of mission support and NAS demonstration of advanced analytical methods and visualization methods for predicting and responding to cyber events.	DHS, DOD		X	X				
Periodic cyber safety risk assessment (SRA) reports identifying apertures, vulnerabilities, and risks associated with individual avionics SRA subjects, along with assessment conclusions and recommendations.	MIT/LL, ACA		X	X	X	X		
Cyber Technical findings from applying the Mitigation Identification and Evaluation Process (MIDEP) to identified aircraft cyber safety risks.	MIT/LL, ACA, Intelligence Agencies, DoD	YES	X	X	X	X		
Cybersecurity risk assessment report on flight deck electronic flight bag (EFB) and aircraft interface device technologies and architecture.	Industry	YES		X				

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Cybersecurity risk assessment report on flight deck internet protocol (IP) Data-Link technologies and architecture.	Industry	YES		X				
Documentation of flight deck data exchange requirements concept operational framework to identify operational gaps in existing environment and develop use cases and scenarios to illustrate authentication and performance parameters for flight deck data exchange.	Industry	YES		X				
Technical analysis for securing commercial Multi-Protocol Label Switching (MPLS) networks using a zero trust approach to develop recommendations for application to NAS operations.	Commercial telecom service providers, commercial financial sector		X	X				
Demonstration of virtual dispersive networks capabilities.	DOD, DHS	YES		X				
Demonstration of context-aware behavioral analytics capabilities.	DOD, DHS	YES		X				
Demonstration of cyber applications of self-healing networks.	DOD, DHS	YES		X				
Demonstration of cloud-based integrity improvements methods.	DOD, DHS	YES		X	X			
Cyber data science algorithms to detect Advanced Persistent Threats.	DOD, DHS	YES		X	X	X	X	X
Demonstration of context-aware behavioral analytics with multiple layer approach.	DOD, DHS	YES			X			
Development of best-in-class security capabilities to support the transition to the FAA Enterprise Network Services.	DOD, DHS	YES			X			
Development of cloud based integrity improvement methods for integration into the NAS.	DOD, DHS	YES			X	X		

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Concept paper on virtual dispersive networks.	DOD, DHS	YES				X		
Demonstration of an advanced machine-learning tool for context-aware behavioral analytics.	DOD, DHS	YES				X		
Demonstration of virtual dispersive networks within a NAS domain.	DOD, DHS	YES					X	
Demonstration of a multiple layered approach for context-aware behavioral analytics with improved visualization techniques.	DOD, DHS	YES					X	
Demonstration of the integration of cloud-based integrity improvements methods into the NAS.	DOD, DHS	YES						X
Demonstration of the use of virtual dispersive networks for integration into the NAS.	DOD, DHS	YES						X

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

Human performance is critical to system resilience, making up for technical systems' limitations, and keeping systems functioning if and when technology fails. Still, human performance has limitations. Optimized human performance in the NAS is fundamental to the safe operation of the NAS and inherent to the safety of the aerospace community, especially the flying customer, who relies on the FAA to provide the safest transportation system in the world. 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 area looks first to optimize human performance in these various roles through capability assessments, training, and operational evaluations. Secondly, research addresses aeromedical factors related to an individual's inability to meet flight demands.

Goal 4 Objectives

Human Factors – *Identify, develop and validate new technologies, policies, training methodologies, personnel selection tools and procedures to improve the performance of humans in the operation of the aerospace systems.*

While technology and equipment are evolving at a rapid pace, humans remain fundamental to the air traffic control (ATC) system. The FAA's human factors research portfolio seeks to expand our fundamental understanding of human information processing within the context of the complex and ever-evolving NAS. The FAA continues its work proactively to ensure that the human component is accounted for when developing or modifying existing tools, systems, procedures, and technologies. An example of this work is a human factors assessment of the Trajectory Based Operations (TBO) environment, which provides guidance on human performance considerations to concept development and validation teams to ensure the usability, acceptability, and safety of TBO concepts and systems.

The FAA conducts research that seeks to identify innovative concepts, procedures, and technologies used in the NAS. Remote tower operations research is an example of an innovative method to provide requirements for remote tower systems. The intent is to provide or improve the services provided by air traffic controllers at airports in the NAS that are traditionally unstaffed, or only partially staffed during busy times. This research will provide guidance to address the impact that factors associated with remote tower systems (such as display monitor configuration and staffing) have on air traffic controller situational awareness and workload. The FAA is also conducting research to better understand how speech recognition technology can be used to interpret and inform traffic flow management decision making in the ATC environment. These results will be used to make decisions on future research iterations, including technology transfer to industry. Finally, the FAA is currently developing an empirically validated color palette useful to color vision deficient controllers. This color palette will be referenced in the ATC Display Color Standard for use in future ATC display acquisitions.

A competent and well-trained workforce is essential to a safe, effective, and efficient NAS. The FAA's Human Factors research aims to ensure that only well-suited candidates are selected to control air traffic and maintain our nation's critical air traffic control systems and infrastructure. The FAA is currently developing new approaches to air traffic controller aptitude testing for use in the hiring process to improve efficiency in the selection of air traffic controllers and identify more efficient training technologies and practices that improve the training of newly hired air traffic controllers. This includes the development of a Cognitive Workload Aptitude Test that measures cognitive workload capabilities of potential student controllers and selection tools that better predict performance at the controller's first field facility. FAA research also supports the development of best practices that new controllers use when visually scanning the air traffic operational environment.

The FAA's human factors research portfolio also includes research on the effects of the changing NAS and operational culture on pilot performance. The FAA seeks to further understand and evaluate the pilot-performance impacts of multi-segment short-haul, long-haul, and ultra-long range flight operations. This work also includes minimum weather service recommendations for inclusion of weather in the cockpit, as well as the identification, demonstration, and validation of weather-related training and testing required for pilots.

The FAA is proactively identifying and addressing operational integration issues that could result from the implementation of future NAS procedures and advanced flight deck procedures. This includes research that helps anticipate and mitigate potential pilot performance impacts related to flying NextGen instrument flight procedures in high-density airspace. Concurrently, the FAA is conducting research regarding training and operational effectiveness of contemporary training methods and devices, including guidance on emerging technologies (for example, virtual reality or augmented reality and mobile devices) and risk management strategies for risks associated with the changing pilot workforce.

Aeromedical Factors *– Identify, develop and validate medical, computational biology, forensic sciences, and biomedical engineering tools and procedures, to optimize human protection and survival in aerospace operations.*

The FAA's Aerospace Medical Research programs have three principal contributions that aim to optimize human protection and survivability in aerospace operations. These principal contributions are Continued Operational Safety, Hazard Risk Management, and Certification Standards and Policy.

Continued Operational Safety seeks to maximize the strengths and minimize the limitations of the human link through evidence-based medicine. Helpful in both the areas of accident prevention and aeromedical accident forensic investigation, biomedical engineering research will be conducted across multiple types of sleep deprivation. This research will identify biological markers for time awake and markers for cognitive impairment to aid in safety and help prevent fatigue-related accidents and injuries in the NAS.

Hazard Risk Management identifies hazards and investigates injury and death patterns in civilian flight accidents, to support an aeromedical safety management system that optimizes protection and survivability. Research continues that focuses on in-service legacy rotorcraft models that do not meet emergency landing in dynamic condition code requirements. This research will help determine the feasibility of improving the safety of legacy rotorcraft by assessing new safety equipment and technology that potentially can be retrofitted onto legacy rotorcraft for use in emergency landings. Research is underway that will discover and compare gene expression responses to hypoxic environments to provide knowledge for altitude training and research strategies including hypoxia-related life support systems.

Certification Standards & Policy research helps formulate criteria that leads to improved knowledge management and decision-making processes in aircraft certification, flight standards, and accident investigation and prevention programs. An example of this research is photoluminescent floor proximity escape path marking systems. The results from this research support flight standards and aircraft certification efforts to ensure the level of safety intended by regulations for floor proximity escape path markings is maintained by the new generation of photoluminescent systems. Continuing research in this area also seeks to document anthropomorphic test device (ATD) (also known as ‘crash test dummy’) construction to harmonize production of ATDs. New research efforts seek to identify and test new alternative clothing needs for frictional performance in aerospace crash testing. This effort will provide potential updates to the aerospace crash testing paradigm and potential updates to FAA Advisory Circular 25.562-1B and SAE standard AS 8049-C. Additional new research will investigate the impact of minimum pitches and widths on passenger egress times to determine if any changes to existing regulations or new regulations are needed, and to examine the impact of alternative seating configurations on egress times to inform regulations and guidance.

Table 2.2.4 Goal 4 Outputs

The table below details the principal planned work products or outputs that will result from R&D conducted at the FAA and/or with collaborators. The 'Collaborators' column identifies partners performing the research. A 'YES' in the 'Long-Term R&D' column represents foundational research that will be applied beyond the five year horizon. An 'X' in a 'Fiscal Year' column indicates the approximate fiscal year timeframe the research output will be delivered. An 'X' in multiple 'Fiscal Year' columns indicates that multiple research outputs will be issued in that timeframe.

Note: The outputs shown are not comprehensive; rather, they are representative of significant outputs of the R&D work that is being conducted.

The FAA maintains partnerships with over 300 stakeholders representing federal agencies, academia, industry, international entities, and technical organizations. Our partners include aircraft and aircraft part manufacturers, design and engineering companies, external testing facilities, domestic and international organizations, and representatives of large and small business. Together these collaborations support the DOT strategic mission goals promoting safety, infrastructure, innovation, and accountability.

The FAA leverages agreements with federal, academic, industry, and international partners to promote technical innovation, technology transfer, and science technology engineering and mathematics (STEM) initiatives. Among the primary vehicles that the FAA employs are Interagency Agreements (IAs), Memoranda of Agreement (MOA), Centers of Excellence (COE) and Aviation Research grants, Cooperative Research and Development Agreements (CRADAs), Other Transaction Agreements, and International Agreements. These agreements are further described in Section 4.0 of this document, 'Technology Transfer,' and can also be accessed 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

CAMI is at the forefront of aviation medical science and ensures America's position as the global technological leader in Aerospace Medicine. This includes the establishment of the Aerospace Medicine Research Alignment and Collaboration Council (AMRAC) consisting of (NASA, U.S. Army, U.S. Navy, U.S. Air Force, and the FAA), which enables collaborative activities and resource allocation.

CAMI also partners with manufacturers of consumer/medical grade health monitoring devices by exposing medical devices to pressure altitudes that could be experienced in the aviation environment to see if the devices pose a hazard and to ensure they continue to perform their designated functions correctly at pressure altitudes. This provides knowledge to the device manufacturer about the safety and performance of the device in an aviation environment, and provides data to the FAA about which designs perform well in aviation environments without posing a safety risk.

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 4a: Identify, develop and validate new technologies, policies, training methodologies, personnel selection tools and procedures to improve the performance of humans in the operation of the aerospace systems.								
Development of an empirically validated color palette useful to color vision deficient controllers, to be referenced in the ATC Display Color Standard, for use in future ATC display acquisitions.			X					
Development of a Cognitive Workload Aptitude Test that measures cognitive workload capabilities of a student (which will provide a strong predictive tool for student success at the academy).			X					
Initial report on operational analysis of speech recognition technology application for traffic flow management.	NASA		X					
Evaluations of prototype awareness displays and alerting systems used in Boeing and Airbus flight simulators.	NASA	YES	X	X				
Recommendations for alternative, more efficient training technologies and practices to improve training of newly hired air traffic control personnel over the next decade.	MITRE CAASD, Universities		X	X	X			

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Recommendations regarding training and operational effectiveness of contemporary training methods and devices, including guidance on emerging technologies (e.g., virtual reality or augmented reality and mobile devices) and risk management strategies for risks associated with the changing pilot workforce.	Universities	YES	X	X	X			
Specific human factors operational measures to assess and validate the visual advantage values associated with Enhanced Flight Vision Systems in current and future NAS operations.	Operators	YES	X	X	X			
Recommendations to inform the design and evaluation (e.g. workload, cognition, and usability) of emerging NAS concepts, NAS procedures, and flight deck procedures.	Volpe, Operators	YES	X	X	X			
Report describing human factors recommendations for the Cockpit Display of Traffic Information (CDTI) for use in validating the minimum CDTI requirements (RTCA D0-361A and D0-3288) during multiple runway operations.	MITRE CAASD, Industry	YES	X	X	X			
Minimum Weather Service recommendations specifying minimum rendering requirements to enable and ensure effective pilot interpretation of weather information in the cockpit.	AOPA, Industry	YES	X	X	X	X		
Identification, demonstration, and validation of weather-related training and testing required for pilots, and for recommendations for pilot trainers/demonstrators (standalone and online) capabilities.	AOPA, Industry	YES	X	X	X	X		
Recommendations for updating pilot fatigue-related advisory circulars and educational materials.	Industry	YES	X	X	X	X		

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Human Factors assessment of the TBO environment to provide proactive guidance on human performance considerations to concept development and validation teams. The identification of potential human performance issues at the concept development and validation stages is essential to the usability, acceptability, and safety of TBO concepts and systems.		YES	X	X	X	X	X	
Development of minimum equipment operational requirements for the operational use of advanced vision systems and head-up (HUD)/head-mounted displays (HMD) in low visibility conditions.	Zedasoft Cherokee CCRC, LLC Rockwell Collins Gulfstream Honeywell Elbit Thales	YES	X	X	X	X	X	
Experimentation to address the human performance impacts of features and functions of cardio-vascular systems.	Sierra Nevada NASA Cherokee CCRC, LLC Rockwell Collins Gulfstream Honeywell Fedex	YES	X	X	X	X	X	
Development of new approaches to air traffic controller aptitude testing for use in the hiring process to improve efficiency.	MITRE CAASD, APTMetrics	YES	X		X		X	
Guidance to address the impact that factors associated with remote tower systems (such as display monitor configuration and staffing) have on air traffic controller situation awareness and workload.		YES	X	X	X	X	X	X
Final report on analysis of using speech recognition technology for traffic flow.	NASA			X				

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Development of a Technical Operations Talent Acquisition Process, including new selection tools, to aid in the selection of ATO technician position applicants to evolve the maintenance culture.		YES		X	X		X	
Development of controller selection tools that predict performance at first field facility.	MITRE CAASD	YES		X	X	X	X	
Identification of best practices for visual scanning in tower and remote tower facilities, and development of guidance and training for new controllers in the most effective means to visually scan in an effort to improve controller performance and safety in the NAS.	Universities	YES		X	X	X	X	
Documentation of the duties and rest requirements specific to air carrier operations containing experimental results and analysis for air carrier UAS remote pilots based on prior research work.					X	X		
Recommendations and guidance regarding design of Personal Electronic Devices to deliver specialized training to the aviation workforce.	Industry, Universities	YES			X	X	X	
Assessment of viability of Augmented Reality and Virtual Reality for maintenance training and remote inspection.		YES			X	X	X	
Simulator scenarios that operators can use in line-oriented training that reveal how biases negatively impact decision making.	Industry, Academia							X
OBJECTIVE 4b: ***Identify, develop and validate medical, computational biology, forensic sciences, and biomedical engineering tools and procedures, to optimize human protection and survival in aerospace operations.***								
Study outlining guidance, training and research strategies to improve human physiologic response in three different hypoxic environments.	USAF School of Aerospace Medicine		X					

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Study of transportation accident rates involving operators at various concentrations of cannabinoids (DELTA-9-THC and/or 11-NOR-9-CARBOXY-THC).			X					
Safety data regarding the hazards of medically certificated pilots to BasicMed flight operations.			X	X				
Study of the effect of cabin seat pitch and alternative seat configurations on evacuation.			X	X				
Documentation of photoluminescent floor proximity escape path marking systems.			X	X				
Report containing analysis of rotorcraft injury mechanism.	USHTS (Vertical Flight Society), GAJSC		X	X	X			
Recommendation of new safety equipment and technology for occupant protection for legacy rotorcraft.	USHTS (Vertical Flight Society), GAJSC		X	X	X			
Documentation regarding occupant protection for legacy rotorcraft.			X		X			
Report comparing multiple types of sleep deprivation markers to determine pilot fitness for duty.	Cross-Agency Fatigue Working Group	YES	X	X	X	X	X	X
Update to FAA Advisory Circular and SAE standard modernizing anthropomorphic test device (ATD) apparel.				X				
Documentation of anthropomorphic test device (ATD) construction harmonization.				X	X			
New and updated advisory material regarding expanded use of analytical modeling in cabin safety applications.	ASME				X			

2.2.5 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 Objectives

Scientific Acumen – *Identify and develop a sufficient scientific understanding of aerospace systems to enable the aerospace community's development of solutions to enhance safety, improve efficiency, and reduce environmental impacts.*

The FAA conducts research to expand the scientific understanding of aerospace systems and enable the development of innovative solutions that enhance safety, improve efficiency, and reduce the environmental impacts of aerospace operations. The FAA seeks to understand damage tolerance and vulnerability of aircraft parts in off nominal instances such as bird strikes, engine fan blade off events, and crashes. This includes a vulnerability analysis to update the uncontained engine and open rotor engine vulnerability analysis toolkit, and guidance for certification by analysis of turbine engine fan blade off requirements. This work also includes an evaluation of new material models to predict multiple failure modes. Much of this work informs development, verification, and guidance documentation for the LS-DYNA® Aerospace Working Group. This group represents a long-term partnership among the aviation industry, government, and academia to improve simulation capabilities and advance regulatory acceptance of analysis for certification.

The FAA is responsible for examining and minimizing any potentially adverse effects the aerospace system has on the health and safety of the public. For example, research is underway that considers the impact that aerospace vehicle noise has on the quality of life of the general public. This research includes a national sleep study to collect representative data on the relationship between aerospace vehicle noise exposure and residential sleep disturbance. It also includes a national evaluation of the potential impact of aerospace vehicle noise exposure on cardiovascular health.

Other key research under this objective focuses on the area of continued airworthiness. The FAA is currently producing documentation of methodologies to enable the evaluation of flutter. Flutter is an oscillation caused by interaction of aerodynamic forces, structural elasticity and inertial effects. Active Flutter Suppression (AFS) could lead to major weight savings and more efficient and versatile airframes. Research is also under way that will synthesize data to ensure that more complex, increased voltage, and highly integrated electrical system technology is safely introduced onto traditional, current, and future aircraft electrical architecture.

System Performance ***– Identify and develop tools, methods, studies, reports, and assessments for use by the aerospace community that evaluate, in an integrated manner, the system-wide performance, and impacts of new and existing aerospace vehicles, air traffic concepts, and airport/spaceport operations.***

System-wide performance research seeks to develop tools and methods, and evaluate data related to the impacts of new and existing aerospace vehicles, Air Traffic Management (ATM) concepts, and airport and spaceport operations. For example, the FAA is researching the integration of closely spaced arrival/departure runway operations, and will provide documentation on minimum radar separation for aircraft on approach operations.

The FAA has long-term R&D efforts to provide the tools needed to ensure advanced materials have the highest levels of structural safety. This research includes an updated Composite Failure Analysis Handbook and a Handbook for Composite Aircraft Accident Investigation.

The FAA is currently researching ways to improve analytical capabilities and computational models to ensure continued safe operations and lessen the impact aerospace has on the general U.S. population. This research includes improved analytical capabilities of aerospace environmental analysis tools by expanding the computational models for vehicle performance, noise, and emissions. It also includes a probabilistic modeling tool that estimates wake encounter risk resulting from proposed changes in the NAS.

Data Engineering ***– Identify, develop, and validate new methods and analytical and predictive capabilities for the aerospace community to collect, aggregate, analyze, and share NAS data to effectively monitor and improve system-wide performance.***

Data engineering is an area of significant focus within the FAA. Data engineering focuses on practical applications of data collection and analysis for use in real-world operations. Due to the large amount of data generated by NAS systems, the applications of data engineering within the FAA are numerous.

The FAA’s primary goal is safety. Efforts are continuing or underway to leverage data engineering to understand and mitigate safety risks. Related new work in this area includes adaptation of safety risk models to accommodate "bottom-up" risk assessments by using non-contextual, unconditional data, and quantifying the contribution to risk in the contextual, conditional format of the safety model scenarios and by appropriately representing common cause failures across all of the scenarios or dependencies between scenarios. The FAA is currently developing a semantic data-mining tool to better detect risk and provide insight into the trends and locations of events that negatively affect safety. Related work is underway to develop predictive methodologies and survey Artificial Intelligence applications and hardware across industry and academia. This work will evaluate existing approaches that can be adapted to safety analytics. Work continues on the Integrated Domain — Safety Risk Evaluation Tool (ID-SRET). This tool will include a model of NAS systems and air traffic control procedures, as well as their interfaces, linked to NAS safety data.

Research is continuing to leverage data engineering to understand and improve system capacity and systems. For example, the FAA is developing data mining and analysis tools, capacity studies, performance metrics, and modeling to identify constraints in the NAS and assess the predictability of capacity and flight trajectory efficiency for operators. New research is also being conducted to deploy an enhanced simulation modeling framework across the NAS enterprise cloud infrastructure.

Data engineering will play a critical role in enabling the integration of new entrants, such as UAS, into the NAS. Current ongoing research includes the development of UAS analysis tools and techniques required to integrate UAS Flight Data Monitoring (UFDM) into the Aviation Safety Information Analysis and Sharing (ASIAS) system. Related new work in this area focuses on the understanding and documentation of the UAS-manned aircraft collision risk in the NAS.

Table 2.2.5 Goal 5 Outputs

The table below details the principal planned work products or outputs that will result from R&D conducted at the FAA and/or with collaborators. The 'Collaborators' column identifies partners performing the research. A 'YES' in the 'Long-Term R&D' column represents foundational research that will be applied beyond the five year horizon. An 'X' in a 'Fiscal Year' column indicates the approximate fiscal year timeframe the research output will be delivered. An 'X' in multiple 'Fiscal Year' columns indicates that multiple research outputs will be issued in that timeframe.

Note: The outputs shown are not comprehensive; rather, they are representative of significant outputs of the R&D work that is being conducted.

The FAA maintains partnerships with over 300 stakeholders representing federal agencies, academia, industry, international entities, and technical organizations. Our partners include aircraft and aircraft part manufacturers, design and engineering companies, external testing facilities, domestic and international organizations, and representatives of large and small business. Together these collaborations support the DOT strategic mission goals promoting safety, infrastructure, innovation, and accountability.

The FAA leverages agreements with federal, academic, industry, and international partners to promote technical innovation, technology transfer, and science technology engineering and mathematics (STEM) initiatives. Among the primary vehicles that the FAA employs are Interagency Agreements (IAs), Memoranda of Agreement (MOA), Centers of Excellence (COE) and Aviation Research grants, Cooperative Research and Development Agreements (CRADAs), Other Transaction Agreements, and International Agreements. These agreements are further described in Section 4.0 of this document, 'Technology Transfer,' and can also be accessed 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

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
OBJECTIVE 5a: ***Identify and develop a sufficient scientific understanding of aerospace systems to enable the aerospace community's development of solutions to enhance safety, improve efficiency, and reduce environmental impacts.***								
National sleep study to collect nationally representative data on the relationship between aircraft noise exposure and residential sleep disturbance.	University of Pennsylvania, HMMH	YES	X	X	X			

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Analysis to quantify the potential impacts of aviation noise on human health.	ASCENT COE, USG	YES	X	X	X			
Documentation of methodologies that will enable the FAA to evaluate Active Flutter Suppression (AFS) control synthesis with special attention on uncertainty in modeling and interaction with other active control systems in operation.	Univ of Washington, Milan Polytechnic Institute			X	X			
Guidance for Certification by Analysis of Turbine Engine Fan Blade Off requirements and evaluation of new material models in LSDYNA to predict multiple failure modes from a single input deck.	LSTC LSDYNA AWG	YES			X	X		
Documentation of information and data that ensures more complex, increased voltage, and highly integrated electrical system technology is safely introduced onto traditional, current and future aircraft electrical architecture.	NASA, SAE, RTCA				X	X		
Vulnerability analysis to update uncontained engine and open rotor engine vulnerability analysis toolkit with improved impact accuracy, and revised fragment model that includes new events.	Naval Air Warfare Center	YES				X	X	
Development of methods and sample problems for modeling bird strike impact to aircraft structures and engines.	SAE G28 Simulants for Impact and Ingestion Committee	YES				X	X	

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Material models, test problems, and associated guidance updates for the LS-DYNA Aerospace Working Group (AWG).	LSTC LS-DYNA AWG: Boeing, P&W, GE, Honeywell, Rolls Royce, Williams, Honda, Cessna, Gulfstream, Airbus	YES						X
OBJECTIVE 5b: ***Identify and develop tools, methods, studies, reports, and assessments for use by the aerospace community that evaluate, in an integrated manner, the system-wide performance, and impacts of new and existing aerospace vehicles, air traffic concepts, and airport/spaceport operations.***								
Probabilistic modeling tool set for estimating the decreased/increased wake encounter risk resulting from proposed changes in NAS airspace design or ATC procedures.	NASA, NRC Canada, NEXTOR II, CSSI		X					
Development of recommendations for accelerating airspace access in Higher Airspace for integration of Commercial Space Operations in the near term by leveraging current NAS capabilities.			X					
Improved analytical capabilities of aviation environmental analysis tools by expanding the computational models for aircraft performance, noise and emissions source generation processes, and noise and emissions propagation processes.	ASCENT COE, Industry, Volpe, USG, International stakeholders		X	X	X	X		
Documentation of integrated closely spaced arrival departure operations.					X	X		

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Forensic Toolset that, at a minimum, includes an updated Composite Failure Analysis Handbook and a Handbook for Composite Aircraft Accident Investigation.	Air Force Research Lab, Airbus, Exponent	YES			X	X	X	
Documentation of minimum radar separation for aircraft on approach operations.							X	
OBJECTIVE 5c: ***Identify, develop, and validate new methods and analytical and predictive capabilities for the aerospace community to collect, aggregate, analyze, and share NAS data to effectively monitor and improve system-wide performance.***								
Semantic data mining tool development for the enhancement of the FAA's ability to detect risk and provide insight into the trends and locations of unsafe events.			X					
Development of predictive methodologies and a survey of Artificial Intelligence applications and hardware across industry and academia to evaluate existing approaches that can be adapted to safety analytics.			X					
Integrated Domain – Safety Risk Evaluation Tool (ID-SRET) that will include a model of NAS systems and air traffic control procedures as well as their interfaces linked to the NAS safety data.			X					
Enhanced simulation modeling framework deployable across the NAS enterprise cloud infrastructure.			X					

Output	Collaborators	Long Term R&D	Fiscal Year					
			20	21	22	23	24	25
Safety Oversight Management System tool that will include a data-driven closed-loop system outlining Air Traffic Safety Oversight Service (AOV) oversight activities, targets, and data collection parameters based on emerging safety trends associated with ATC systems at the facility and NAS levels.			X	X				
UAS analysis tools and techniques required to integrate UAS Flight Data Monitoring (UFDM) into Aviation Safety Information Analysis and Sharing (ASIAS).	ASSURE COE		X	X				
Development of data mining and analysis tools, capacity studies, performance metrics and modeling to identify constraints in the NAS and assess capacity, the predictability of capacity, and flight trajectory efficiency for operators.	GRA, VA Tech, MIT	YES	X	X	X	X		
Documentation of the UAS/manned aircraft collision risk in the NAS.				X				
Improved analytical capabilities to conduct safety risk assessments by incorporating common cause failures and dependencies.	Airline CMOs, Aviation Safety Information Analysis and Sharing (ASIAS) program			X	X	X		

3.0 R&D Portfolio Planning

The FAA must balance its R&D investments between those that are strategic and those that are mission-oriented. Strategic investments may include understanding and enabling emerging technologies, new business models, and understanding the changing needs of system users, while mission-oriented investments include agency priorities and continued FAA enhancements. The R&D portfolio is governed internally by the Research, Engineering, and Development Executive Board (REB) members, who oversee and coordinate the R&D investment planning. The FAA's R&D portfolio is reviewed externally by the R,E&D Advisory Committee (REDAC), a group of aviation and aerospace industry experts that serves to channel valuable feedback from customer and stakeholder groups.

3.1 REDAC Recommendations with the FAA's Response

The FAA's REDAC provides advice and recommendations to the FAA Administrator on the needs, objectives, plans, approaches, content, and accomplishments of the aerospace research portfolio. The REDAC also assists in ensuring FAA research activities are coordinated with other government agencies and industry. The REDAC considers aerospace research needs in five areas: NAS operations, airport technology, aviation safety, human factors, and environment and energy. Committee members represent corporations, universities, associations, consumers, and government agencies.

The REDAC met in the fall of 2018 and in the spring of 2019. During the fall meeting, the committee provided advice to the FAA on developing the FY 2021 R&D portfolio. The committee then reviewed and provided recommendations on the proposed FY 2021 R&D Portfolio during the spring 2019 meeting.

The REDAC provided 42 recommendations for the FY 2021 R&D portfolio. Of the 42 total recommendations, 30 are categorized as programmatic and 12 as research specific. Programmatic recommendations relate to the overall research program such as roadmaps, program plans, funding, and staffing. Specific recommendations are intended to result in actual research activities within the overall FAA R&D portfolio. The tables in section 3.2 provide a summary of the 12 research-specific REDAC recommendations for the FAA's FY 2021 R&D portfolio. They also highlight research activities the FAA is conducting to support the recommendations, including references to the planned work products or outputs resulting from those activities. The FAA concurred with all 12 research-specific recommendations.

3.2 Summary REDAC Recommendations and Implementation Status by the FAA

Summary of Research Specific REDAC Recommendations - Fall 2018			
Subcommittee	**REDAC Recommendation**	**Supportive Research Activity**	**Reference**
Environment and Energy	**Noise Research**: The Subcommittee strongly supports the prioritization of the noise research that will support informed decision-making and enable NextGen deployment. We believe that the focus should be on impacts of subsonic, Urban Air Mobility (UAM)/UAS, supersonics and then commercial space vehicles, in that order. The FAA should therefore aggressively move forward with its research efforts.	FAA intends to continue these research efforts in the forthcoming budget submissions. Some of these efforts will address noise provisions in the 2018 FAA reauthorization. We are also working in close collaboration with NASA to address noise from subsonic aircraft, helicopters, UAS, UAM and supersonic aircraft. This includes domestic efforts as well as efforts in International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP). Noise reduction from gas turbine powered fixed wing aircraft will also be an area of emphasis for the third phase of the CLEEN program, which will start in 2020.	Noise and Emission - Objective 1e Outputs Data Analysis - Objective 2c Outputs Applied Innovation – Objective 2d Outputs Scientific Acumen – Objective 5a Outputs System Performance – Objective 5b Outputs
	Alternative Jet Fuels: Since the maturation of the AJF program will be a major environmental benefit for the public, will create a new industry within the U.S. that benefits rural America, and will benefit the U.S. aviation industry, we strongly recommend that either RE&D A13.a or A13.b budget line items have an allocation for the continuation of research on AJF.	FAA approved several research and development projects to conduct testing and analysis on alternative jet fuels within the Aviation Sustainability Center (ASCENT) Center of Excellence.	COE Research Grants: 13-C-AJFE-UTENN-009 & 13-C-AJFE-WaSU-019 and Alternative Fuels - Objective 2b Outputs
	Global Leadership: The Subcommittee recommends the prioritization of all research efforts/programs that will allow the FAA and the U.S. to maintain its current global leadership position at ICAO CAEP. It is the belief of the Subcommittee that if the FAA/U.S. does not maintain its leadership position at the ICAO CAEP, it will not be able to influence policy/rulemaking and this could have a significant negative impact on the U.S. aviation industry.	FAA prioritized research efforts include developing the modeling capabilities, and generating the data to support the decision-making process within ICAO CAEP. Efforts are also continuing in ICAO CAEP on supersonic aircraft.	Data Analysis - Objective 2c Outputs System Performance - Objective 5b Outputs

Summary of Research Specific REDAC Recommendations - Fall 2018			
Subcommittee	**REDAC Recommendation**	**Supportive Research Activity**	**Reference**
NAS Operations	**Commercial Space Transportation:** The FAA should accelerate its investment in near-term solutions (not requiring new tools) to minimize operational impact of commercial space launches on all NAS users. Investment in research for longer term solutions, such as TBO and integration R&D relate to surveillance, aircraft separation, and airspace management during space operations needs to be accelerated. Technology, data, and processes should be developed for objectively mediating the relative costs and priorities between space and air operations requesting access to the same airspace.	The FAA has two programs underway to address the committee's recommendation – the Space Data Integrator (SDI) and Acceptable Level of Risk (ALR): - Space Data Integrator (SDI): The SDI program is an investment in near-term solutions that minimizes operational impact of commercial space launches on all NAS users. SDI automates the FAA's currently manual, time consuming, and resource-intensive procedures to support commercial launch and reentry operations. - Acceptable Level of Risk (ALR): ALR is another approach designed to mitigate NAS efficiency and capacity impacts resulting from airspace segregation. To support this impact mitigation, three key elements of the ALR approach are application of an intermediate adjustment in individual risk, operational restrictions, and a new collective risk limit.	Aerospace Vehicle Operation- Objective 1d Outputs
Airports	**PFAS:** The Subcommittee strongly recommends that the FAA expedite completion of ongoing research efforts relating to foam proportioning systems. The Subcommittee also strongly encourages the FAA to revisit firefighting foam research and ensure that there are scientifically based mechanisms/testing protocols for evaluating fluorine-free foams in the civil aviation sector, ideally using the newly commissioned and state-of-the-art fire testing facility at the FAA Technical Center.	Research efforts completed.	Report available at http://www.airporttech.tc.faa.gov/Products/Airport-Safety-Papers-Publications/Airport-Safety-Detail/ArtMID/3682/ArticleID/1484/Evaluation-of-Input-Based-Foam-Proportioner-Testing-Systems
		Investigating currently available fluorine-free products for viable candidates for future fire extinguishing performance testing.	Selection of potential candidate products for fire testing will begin Qtr. 3 2019. Certification/Licensing - Objective 2a Outputs
		Fire extinguishing performance testing using the new fire research facility constructed in 2019.	Anticipating report on viable candidate replacement chemistries by Qtr. 4 2021. Certification/Licensing - Objective 2a Outputs

Summary of Research Specific REDAC Recommendations - Fall 2018			
Subcommittee	**REDAC Recommendation**	**Supportive Research Activity**	**Reference**
Human Factors (HF)	**Flight Crew Information Management:** The FAA should fund research on Flight Crew Information Management to address the identified gaps in the HF R&D portfolio. The research should document current practices, identify actual/potential threats, and identify mitigation strategies. The research should also include but should not be limited to the following: • Managing information across systems such as: Controller-pilot data link communications (CPDLC), Aircraft communications addressing and reporting system (ACARS), Radar, EFB, aircraft systems, external (non-aircraft) applications, etc. • Identify strategies for mitigating information overload and distraction, • Methods for understanding the accuracy, integrity, (i.e., trustworthiness), and timeliness of information, • Effective information management for operational, tactical, and strategic decision-making.	Identification of potential human performance issues impacting usability, acceptability, and safety of trajectory based operation (TBO) concepts and systems.	Human Factors - Objective 4a Outputs

Summary of Research Specific REDAC Recommendations - Spring 2019			
Subcommittee	**REDAC Recommendation**	**Supportive Research Activity**	**Reference**
Environment and Energy	**Noise Research:** The Subcommittee strongly supports the prioritization of the noise research that will support informed decision-making and enable NextGen Deployment. We believe that the focus should be on impacts of Subsonic, Urban Air Mobility /Unmanned Aircraft Systems (UAM/UAS), Supersonics and then Commercial Space vehicles, in that order. The FAA should aggressively move forward with its research efforts as research is the key to establishing sound policy.	Continued research efforts to address noise provisions in the 2018 FAA reauthorization & close collaboration with NASA to address noise from subsonic aircraft, helicopters, UAS, UAM and supersonic aircraft. Continued development of the Aviation Environmental Design Tool (AEDT) to ensure it can quantify aircraft noise at further distances from airports, where some communities are expressing concerns.	Noise and Emissions - Objective 1e Outputs Data Analysis - Objective 2c Outputs Applied Innovation – Objective 2d Outputs Scientific Acumen – Objective 5a Outputs System Performance – Objective 5b Outputs

Subcommittee	REDAC Recommendation	Supportive Research Activity	Reference
	Summary of Research Specific REDAC Recommendations - Spring 2019		
Environment and Energy	**Alternative Jet Fuels:** Since the maturation of the Alternative Jet Fuels (AJF) program will be a major environmental benefit for the public, will create a new industry within the U.S. that benefits rural America, and will benefit the U.S. aviation industry, we strongly recommend that either RE&D A13.a or A13.b budget line items have an allocation for the continuation of research on AJF.	Several approved research and development projects to conduct testing and analysis on alternative jet fuels within the Aviation Sustainability Center (ASCENT) Center of Excellence. These projects will ensure that innovative new fuels are safe for use by the commercial fleet and that domestically produced aviation fuels can be used by airlines towards meeting their offsetting requirements under ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).	COE Research Grants: 13-C-AJFE-UTENN-009 & 13-C-AJFE-WaSU-019 and Alternative Fuels - Objective 2b Outputs
	Global Leadership: The Subcommittee recommends the prioritization of all research efforts/programs that will allow the FAA and the U.S. to maintain its current global leadership position at ICAO/CAEP and to expedite university research grants that support the U.S. work in ICAO/CAEP. It is the belief of the Subcommittee that if the FAA/U.S. does not maintain its leadership position at ICAO/CAEP, it will not be able to influence policy/rulemaking and this could have a significant negative impact on the U.S. aviation industry.	FAA research projects include developing the modeling capabilities and generating the data to support the decision-making process within ICAO CAEP. Efforts are also continuing in ICAO CAEP on supersonic aircraft.	Data Analysis - Objective 2c Outputs System Performance - Objective 5b Outputs
	The Subcommittee recommends the FAA continue the simultaneous balanced development of usability improvements, enhanced features, and increased accuracy of the AEDT in the near term. The FAA should make a point of emphasis to improve the dispersion modeling that is used by AEDT to evaluate air quality impacts. We also recommend that the FAA reach out to airports that use air quality and noise monitors and partner with them in order to get their emissions and noise data that would support their modeling efforts.	Approved research and development projects within the Aviation Sustainability Center (ASCENT) Center of Excellence to develop a new AEDT component that addresses the dispersion modeling deficiencies that are currently in the EPA's AERMOD tool. Research is also underway to develop interim solutions to improve the accuracy within the limits of the current EPA model and identify means for airports to show their projects are in compliance with air quality standards through the use of their monitoring data.	COE Research Grant Number 13-C-AJFE-UNC-010 and Applied Innovation - Objective 2d Outputs
NAS Operations	Weather Technology in the Cockpit (WTIC) should include research activities in their FY2021 portfolio that address weather information requirements and minimum service criteria for pilotless passenger aircraft, particularly when these operate in urban airspace over people, structures or ground vehicles. Unique meteorological aspects of the urban environment, for example blockage and/or channeling of winds which could affect safety of ascent or descent should be considered.	Continued research and analyses on minimum weather service resulting in NAS modernization, increased automation, and new entrant aircraft	Integrated Weather Information - Objective 1f Outputs

	Summary of Research Specific REDAC Recommendations - Spring 2019		
Subcommittee	**REDAC Recommendation**	**Supportive Research Activity**	**Reference**
	The Subcommittee recommends that the Enterprise Concept Development project for Notice to Airmen (NOTAM) modernization engage HF experts to help develop and validate effective concepts that adequately address human performance issues.	The FAA will address HF aspects in the NOTAMs modernization and continue to provide the Subcommittee with status and rationale on the portfolio priorities for funded research in order to obtain feedback on areas that require reconsideration.	Not yet available

The fall 2018 report titled ‘FAA Response to REDAC Guidance for the Fiscal Year (FY) 2021 Research and Development (R&D) Portfolio’ is available at: https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/GuidanceResponse-FY2021.pdf.

The spring 2019 report titled ‘FAA Response to Research, Engineering and Development Advisory Committee (REDAC) Recommendations for the Fiscal Year (FY) 2021 Research and Development (R&D) Portfolio’ report is available at: https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/RecommendationsResponse-FY2021.pdf.

4.0 Technology Transfer

Every year, the FAA provides services to over 44,000 flights and 2.7 million airline passengers across more than 29 million square miles of airspace.[2] The agency accomplishes this while maintaining the safest and most efficient airspace in the world. In meeting this enormous challenge, the FAA relies heavily on innovative research and development conducted by its talented workforce. The FAA recognizes the importance that innovations in science and technology have played in benefiting the American public and in the economic progress of the United States. As such, the agency continues to encourage the transfer of federally funded innovations for public and private use.

Federal technology transfer is the process of sharing knowledge, facilities and capabilities developed with federal research and development (R&D) funds to fulfill public and private needs. The FAA achieves this transfer by leveraging FAA expertise and state-of-the-art research laboratories in close collaboration with academia, industry, and other government entities. The resulting innovative products, capabilities, and services help the FAA maintain its mission of having the safest and most efficient aerospace system in the world. The technology transfer program benefits the public, industry, and the U.S. market.

4.1 FAA Technology Transfer Program

In October 1989, FAA Order 9550.6 established the Office of Research and Technical Applications (ORTA) at the William J. Hughes Technical Center (WJHTC) for the purpose of managing and directing the FAA’s Technology Transfer Program. This order (and its successor orders FAA Order 9550.6A and 6B) delegated to the WJHTC Laboratory Director the authority to, *inter alia*, enter into Cooperative Research and Development Agreements (CRADA) with private industry, academia, and state and local governments, and to license and assign intellectual property as well as to receive and distribute royalties obtained therefrom. Since that initial step, the Director has continued to foster the sharing of federally funded knowledge, facilities and capabilities via CRADAs as well as multiple other avenues (*discussed in more detail below – 4.2 Transfer Mechanisms*).

The FAA R&D innovation centers from which most of the technology transfer arises include the one-of-a-kind laboratories located at the WJHTC in Atlantic City, and the Civil Aerospace Medical Institute (CAMI) in Oklahoma City. These two government-owned, government-operated, (GOGO) research centers address the technical challenges of an evolving aviation industry. The FAA Technical Center includes six divisions and serves as the national scientific hub for research and development, test and evaluation, and verification and validation of air traffic control, communications, navigation, airports, aircraft safety, and security systems. As noted previously, it is the focal point for the FAA Technology Transfer Program. CAMI is the medical certification, education, research, and occupational medicine branch of the Office of Aerospace Medicine (AAM) under the auspices of the FAA’s Office of Aviation Safety (AVS).

[2] https://www.faa.gov/air_traffic/by_the_numbers/

CAMI includes two research divisions, Aerospace Human Factors and Aerospace Medical Research. These divisions research issues that influence human performance and health in the aerospace environment, identify mechanisms and opportunities for increased safety, and then communicate these to the aviation community. Each of the GOGO research labs serves an essential function in ensuring the FAA's mission of providing the safest, most efficient aerospace system in the world.

4.2 Transfer Mechanisms

As discussed above, the FAA accomplishes its technology transfer mandate in a comprehensive manner through various mechanisms that promote collaboration with industry, academia, and other government agencies. Partnerships are implemented through Cooperative Research and Development Agreements (CRADA), Centers of Excellence (COEs), Interagency Agreements (IAs), patent license agreements, and other avenues. These mechanisms provide our collaborating parties access to FAA facilities and subject matter experts to conduct advanced research.

4.2.1 Cooperative Research and Development Agreements

One of the FAA's prime technology transfer mechanisms is the Cooperative Research and Development Agreement (CRADA). These agreements are highly effective in meeting the congressionally mandated Technology Transfer requirements. They are essential in providing the CRADA collaborating partner with a means to access intellectual property rights and other federal resources that might not otherwise be available to the partner. Furthermore, CRADAs are sensitive to the business needs of the collaborating partner party allowing the party to protect commercially valuable information, including protecting from disclosure any trade secrets, commercial, and/or financial information developed during the course of the CRADA for up to five (5) years after such information's development. Practically, CRADAs can be developed and implemented much more rapidly than traditional contracts and procurements; however, unlike such contracts, no federal funds may be provided to the collaborating partner.

CRADAs might include the development of new technologies and processes, result in the issuance of patents to either the FAA or the CRADA collaborating partner, and/or further the body of aviation system knowledge. Exemplary collaboration efforts under past FAA CRADAs include research on material fatigue, nondestructive inspection, flammability standards for testing aircraft components, airframe integrity, and aircraft rescue and firefighting technologies. Active FY 2019 CRADAs are presented here:
https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/FAA_Active_FY2019_Agreements.pdf

4.2.2 Centers of Excellence

Centers of Excellence (COEs) are established by statute 49 USC Section 44513. The FAA partners with more than 80 academic institutions through this program, including universities, colleges, and institutes that have resulted in a network of cost-sharing industry partners. Unlike CRADAs, which do not provide collaborators any federal funding, the selected COE university teams generate 1:1 matching contributions from non-federal sources to augment FAA research capabilities. Once core and affiliate university members and industry partners are selected, they serve the FAA as a primary source of subject-matter-expertise over a period of 10 years, or as mandated by Congressional direction. By matching funds, collaboration with these partners enables the FAA to maximize its resources while leveraging the knowledge, experience, skill and resources of the FAA and academic institutions. Over the life of the program, the COE universities with their non-federal affiliates have provided more than $300 million in matching contributions to augment FAA research efforts. Through long-term cost-sharing activities, the government joins with university-industry teams to share resources and advance the technological future of the Nation's aviation industry along with educating and training the next generation of aviation scientists and professionals. The primary COE focal areas include:

- Technical Training and Human Performance;
- Unmanned Aircraft Systems;
- Alternative Jet Fuels and Environment;
- General Aviation Safety, Accessibility and Sustainability;
- Commercial Space Transportation;
- Advanced Materials;
- Airliner Cabin Environment and Intermodal Transportation Research;
- Aircraft Noise and Aviation Emissions Mitigation;
- General Aviation Research; Airworthiness Assurance;
- Operations Research;
- Airport Technology Research; and
- Computational Modeling of Aircraft Structures.

Details on active partnerships, including COE grants, are presented here: https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/FAA_Active_FY2019_Agreements.pdf).

The research topics include pavements, composite materials, advanced materials, safety implications of emergency vehicle colors, alternative jet fuels, integration of unmanned aircraft in the NAS, augmented weather interfaces, and rotorcraft wire strikes. The program provides a unique opportunity for focusing education, research, and technology transfer resources to substantially promote and expand transportation education and research opportunities in America.

4.2.3 Interagency and Other Agreements

4.2.3.1. Interagency Agreements

Interagency agreements leverage resources from other agencies to support technology transfer efforts. This fiscal year the FAA collaborated with multiple agencies including the Department of Agriculture, Department of Defense, Department of Energy, Department of Homeland Security, Department of Justice, and the National Aeronautics and Space Administration. The range of organizations include the Air Force Civil Engineering Center, Ames Research Center, Battelle, Baylor College of Medicine, Brigham and Women's Hospital-Harvard University, Department of Defense, Department of Energy, Department of Homeland Security, Department of Justice, Langley Research Center, MIT Lincoln Labs, South Jersey Transit Authority, US Coast Guard, Walter Reed, and Will Rogers Airport Rescue and Firefighting.

4.2.3.2 Other Industry Partnerships

The CLEEN program under the Office of Environment and Energy (AEE) demonstrates one example of the FAA's close collaboration with industry. The FAA/Industry partnership is developing certifiable aircraft and engine technologies that reduce noise and emissions while increasing fuel efficiency, thus supporting the overarching environmental performance goal for NextGen to achieve environmental protection that allows sustained aviation growth. The CLEEN Program is implemented in five-year phases, each with specific improvement goals for noise, fuel burn, and emissions. The third phase of the program is included in the FY 2020 President budget with a planned start in 2020. To receive funding, industry partners need to contribute at least 100% cost share to the program. Through the first two phases, industry has contributed $388 million of cost share to the CLEEN Program, which has far exceeded the FAA contribution of $225 million. More details about interagency and other agreements (including aviation research grants) can be found here: https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/FAA_Active_FY2019_Agreements.pdf

4.2.3.3. International Agreements

FAA agreements with international partners are critical to global harmonization efforts and to ensure the United States remains a global leader in influencing and driving international standards. The FAA engages with multiple international partners through international agreements and CRADAs. The FAA has partnered with Transport Canada, National Research Council of Canada, EUROCONTROL, Civil Aviation Authority (CAA) – United Kingdom, CAA- Singapore, Brazil Air Navigation Service Provider, Bureau of Meteorology (BOM) Australia, and the Technical University of Denmark. Areas of research include aircraft icing, wake turbulence, and air traffic management (ATM). Recently initiated partnerships will investigate ATM harmonization efforts with SESAR, FAA/EUROCONTROL to establish operational performance metrics for gate-to-gate performance and cost efficiency, and ionospheric disturbances and its effect on the performance of Ground-Based Augmentation Systems. Details about active international agreements and their objectives can be found at: https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/FAA_Active_FY2019_Agreements.pdf

4.2.4 Patents and Licenses

The FAA's Technology Transfer Program Office (TTPO) promotes and coordinates the commercialization of the agency's patents. The agency encourages its inventors, engineers, and scientists to patent their novel inventions through the U.S. Patent and Trademark Office (USPTO). Inventions patented by FAA inventors are available for commercial licensing, and might result in royalty payments shared with the inventor and the agency. Legislation allows an inventor to receive up to $150,000 per year over the inventor's salary from royalty payments, continuing even after the inventor separates from federal service. In 2019, the FAA's TTPO had four active income bearing license agreements for Patent No. 6,464,391 entitled "Heat release rate calorimeter for milligram samples." The inventor on this patent is a Federal Aviation Administration (FAA) employee, in the Aviation Research Division, Fire Safety Branch, located at the William J. Hughes Technical Center. Royalties warranted from the FAA's Capital Budget

Division between May 2018 and December 2019 amounted to just over $7,000, of which 25%, was paid to the inventor.

4.3 Dissemination of FAA Research

FAA R&D initiatives promote the advancement of technologies for a safer, more efficient, and more economically accessible NAS. An important aspect of this activity is the transfer of these technologies and knowledge for the benefit of the U.S. public, industry, and economy. To accomplish this, the agency engages a variety of outreach mechanisms including:

- Publishing technical products to the DOT National Transportation Library.
- Participating in aviation and safety related working groups and forums.
- Informing Smart Regulations, Advisory Circulars (ACs), and other governance.
- Authoring meaningful publications and ensuring broad dissemination.
- Presenting technical findings at conferences and forums.
- Providing training to targeted communities and providing assistance in the development and use of new aviation-related technologies.

The FAA has established and implemented means to provide public access to COE publications and digital data in compliance with the White House Office of Science and Technology Policy memorandum. The Technology Transfer Program Office continues to expand this policy to ensure a comprehensive and complete public record of R&D products. The following sections outline some of the technical and programmatic technology transfer products.

4.3.1 Technical Products

The objective of the FAA Technology Transfer Office is to promote the transfer of agency knowledge, facilities, and capabilities to Federal agencies, academia, and industry for the benefit of the public and U.S. economy. In support of this objective, FAA funded R&D programs include, as one of their central goals, dissemination of research results according to legal and strategic guidelines. FAA experts participate in industry trade groups, create and participate in workshops, present briefings and information at conferences and seminars, and publish research documents. As a result, the FAA contributes substantially to the R&D community. FAA researchers delivered over 400 technical products including technical reports, journals, conference presentations, and other publications such as Advisory Circulars and CertAlerts. The FAA compiles information on these products and provides it to the Office of the Secretary of Transportation on a quarterly basis, along with additional technology transfer metrics. In addition to the dissemination of research results, FAA experts work closely with industry partners to conduct research. Examples of these types of Technology Transfer include:

- One team partnered with Shell and researched alternative fuels for general aviation aircraft to develop a standardized series of test procedures and completed tests for 10 aircraft and 15 engine models. As a result, the team identified shortfalls. Progress has already been made to resolve these items. The goal of this effort is to replace the current leaded avgas supply chain with a safe unleaded alternative for the global market.

- The Civil Aerospace Medical Institute (CAMI) developed CARI-7A software for calculating the effective dose of galactic cosmic radiation received by an individual on an aircraft. This tool is being used by NOAA-SWPC for space weather requirements, USAF-AFRL high altitude researchers, and Boeing/Old Dominion researchers for rocket flight dosimetry estimation.
- Members of the FAA Fire Safety Branch participate in U.S. and international bodies related to aircraft fire. Members participate in accident investigation, SAE/ISO/RTCA standards committees, and the ICAO Dangerous Goods panel. In addition, the Branch plans and chairs five international forums annually, focused on aircraft materials fire testing and aircraft fire protection.
- The aeromedical research program participates in several forums including: 1.) Aerospace Medicine Research Alignment and Collaboration Council (AMRAC: NASA/USA/USN/USAF/FAA); 2.) NASA Living with A Star Institutes program; 3.) Inter-Agency Federal Fatigue Management & Research Working Group; 4.) DOD Blue Team of the Biotechnologies for Health and Performance Council; and 5.) DOJ/HHS/OSTP Medico legal Death Investigation Working Group.

4.3.2 Programmatic Products

In addition to delivering technical products, the FAA meets Federal and Department of Transportation requirements by formally documenting technology transfer activities. Among the reports that describe FAA Technology Transfer initiatives and outcomes are the Annual Federal Technology Transfer Program record of activities, NARP, Annual Modal Research Plan, COE Annual Report, and the FAA Annual Research Review. The FAA also provides the OST information regarding the number of R&D awards receiving funding, total funding, project status, milestones, use of FAA developed technology, success stories, and number and types of technical products.

5.0 Research & Development Budget and Management

This chapter reviews the FAA R&D portfolio according to the FY 2021 President's Budget submission. It summarizes the three budgetary accounts under which R&D is currently being conducted, shows how much the FAA is spending or plans to spend on R&D, and describes the R&D program execution.

The FAA R&D portfolio supports regulation, certification, and standards development along with modernization of the NAS and policy and planning. In order to support FAA R&D goals, and objectives, the R&D portfolio addresses the specific needs of sponsoring organizations, including (a) Aviation Safety, (b) Air Traffic Organization, (c) Airports, (d) NextGen, (e) Policy, International Affairs and Environment, and (f) Commercial Space. The R&D Management Division under the Assistant Administrator for NextGen manages the FAA R&D portfolio for the Agency.

5.1 Budgetary Accounts

Three of the four FAA budgetary accounts fund the R&D portfolio: R,E&D; F&E; and AIP. The following sections summarize these three accounts[3] and show how the R&D portfolio is derived from each.

5.1.1 Research, Engineering and Development (R,E&D)

The R,E&D account funds R&D programs that improve the NAS by increasing its safety, security, productivity, capacity, and environmental compatibility in order to meet the expected air traffic demands of the future.

5.1.2 Facilities and Equipment (F&E)

The F&E account funds capital investments relating to air navigation facilities and equipment, aviation safety systems (including acquisition costs, installation, testing, and laboratories), initial maintenance contracts and training for equipment, facilities, and other construction projects. The F&E account funds R&D in two areas: 1.) Advanced Technology Development and Prototyping, and 2.) within the NextGen Portfolios. Typically, programs in these two areas are in the concept development or demonstration phases prior to an FAA investment decision.

Advanced Technology Development and Prototyping R&D Programs develop and validate technology and systems that support air traffic services, including requirements associated with the evolving air traffic system architecture and improvements in airport safety and capacity. NextGen Portfolio R&D programs comprise the other half of the F&E R&D program and have broad applicability across NextGen.

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[3] FAA Order 2500.8B, Funding Criteria for Operations, F&E, and R,E&D Accounts, dated October 1, 2006.

5.1.3 Airport Improvement Program (AIP)

The AIP account provides grants to local and state airport authorities to help ensure the safety, capacity, and efficiency of U.S. airports. Through the AIP, the FAA funds a range of activities to assist in airport development, preservation of critical facilities, economic competitiveness, and environmental sustainability.

5.2 R&D Summary Budget Tables

This section provides two tables presenting the FAA R&D budget by (a) account, and (b) DOT strategic goal. It presents the FY 2019 and 2020 Enacted and FY 2021 President’s Requests, and planned funding for FY 2022 through 2025 (which are estimates and subject to change). The amounts shown for F&E programs in FY 2018 and beyond reflect the entire budget for those portfolios. This is a change made from prior years due to the reclassification of existing work to better align with OMB Circular A-11 Research Definitions.

5.2.1 Budgetary Accounts

Table 5.2.1, Planned R&D Budget by Account, shows the FAA R&D FY 2019 and 2020 Enacted and FY 2021 President’s Request budgets and the estimated funding through FY 2025, grouped by account. The F&E account also has programs that are not part of the R&D portfolio. The NARP only presents R&D information.

5.2.2 DOT Strategic Goal

Table 5.2.2, Planned R&D Budget by DOT Strategic Goal shows the FAA R&D budget by the DOT strategic goals defined in Exhibit II of the FAA President’s Request for FY 2021.

The R&D programs apply to all four of the goals in the *U.S. Department of Transportation Strategic Plan for FY 2018 –2022*: Safety, Infrastructure, Innovation, and Accountability. Many R&D programs apply to more than one DOT goal. However, for budgeting purposes, most programs are included under only one DOT goal. **Table 5.2.2, Planned R&D Budget by DOT Strategic Goal** provides information on funding for contract costs and personnel costs requested for FY 2021.

Table 5.2.1 Planned R&D Budget by Account

Program	Account	2019 Enacted ($000)	2020 Enacted ($000)	2021 Request ($000)	2022 Estimate ($000)	2023 Estimate ($000)	2024 Estimate ($000)	2025 Estimate ($000) /1
Research, Engineering and Development (RE&D)								
Fire Research and Safety	RE&D	7,200	7,200	7,136	7,217	7,289	7,362	7,438
Propulsion and Fuel Systems	RE&D	2,100	2,100	4,215	4,232	4,246	4,261	4,276
Advanced Materials/Structural Safety	RE&D	14,720	14,720	1,003	1,036	1,065	1,094	1,124
Aircraft Icing/Digital System Safety	RE&D	9,253	9,000	6,426	6,432	6,438	6,443	6,448
Continued Airworthiness	RE&D	11,269	10,269	9,642	9,607	9,578	9,547	9,516
Aircraft Catastrophic Failure Prevention Research	RE&D	1,570	1,565	0	0	0	0	0
Flightdeck/Maintenance/System Integration Human Factors	RE&D	7,305	7,300	7,469	7,551	7,623	7,698	7,774
System Safety Management	RE&D	5,500	4,500	5,485	5,516	5,543	5,571	5,600
Air Traffic Control/Technical Operations Human Factors	RE&D	5,800	5,800	5,685	5,869	6,031	6,199	6,370
Aeromedical Research	RE&D	9,080	7,919	10,235	10,398	10,541	10,689	10,840
Weather Program	RE&D	15,476	12,911	6,236	6,146	6,068	5,987	5,904
Unmanned Aircraft Systems Research	RE&D	24,035	24,035	24,035	24,028	24,022	24,015	24,008
Alternative Fuels for General Aviation	RE&D	1,900	1,900	2,524	2,467	2,417	2,365	2,312
Commercial Space Transportation	RE&D	2,500	2,500	5,840	5,708	5,592	5,472	5,350
NextGen - Wake Turbulence	RE&D	6,831	5,000	3,698	3,719	3,736	3,755	3,774
NextGen - Air Ground Integration Human Factors	RE&D	6,757	5,300	6,757	6,768	6,777	6,787	6,796
NextGen - Weather Technology in the Cockpit	RE&D	3,644	3,144	1,982	2,015	2,043	2,073	2,103
NextGen - Flightdeck Data Exchange Requirements	RE&D	1,035	1,005	1,000	997	995	992	990
NextGen - Information Security	RE&D	1,232	2,675	4,769	4,756	4,745	4,733	4,721
Environment and Energy	RE&D	18,013	18,013	17,911	17,653	17,427	17,194	16,954
NextGen - Environmental Research - Aircraft Technologies, Fuels, and Metrics	RE&D	29,174	29,174	27,009	26,968	26,932	26,895	26,857
Aircraft Cabin Environment Research	RE&D	0	1,000	0	0	0	0	0
System Planning and Resource Management	RE&D	2,135	12,135	8,022	7,923	7,834	7,744	7,653
William J. Hughes Technical Center Laboratory Facility	RE&D	4,571	3,500	2,921	2,994	3,058	3,124	3,192
RE&D TOTAL	**RE&D**	**191,100**	**192,665**	**170,000**	**170,000**	**170,000**	**170,000**	**170,000**

Table 5.2.1 Planned R&D Budget by Account (cont'd)

Program	Account	2019 Enacted ($000)	2020 Enacted ($000)	2021 Request ($000)	2022 Estimate ($000)	2023 Estimate ($000)	2024 Estimate ($000)	2025 Estimate ($000) /1
Facilities & Equipment (F&E) /2								
Advanced Technology Development & Prototyping	F&E	33,000	40,900	26,600	31,700	30,700	32,700	32,700
William J. Hughes Technical Center Facilities	F&E	21,000	20,000	16,900	16,900	16,900	16,900	16,900
William J. Hughes Technical Center Infrastructure	F&E	15,000	15,000	10,000	10,000	10,000	10,000	10,000
Next Generation Transportation System - Separation Management Portfolio	F&E	16,000	20,500	21,200	27,500	29,500	23,700	18,000
Next Generation Transportation System - Traffic Flow Management Portfolio	F&E	14,000	19,800	8,000	10,000	10,000	10,000	9,000
Next Generation Transportation System - On Demand NAS	F&E	21,000	8,500	10,500	10,000	7,500	7,500	10,000
Next Generation Transportation System - NAS Infrastructure	F&E	20,000	11,500	15,000	14,500	14,500	14,400	14,500
Next Generation Support Portfolio	F&E	12,800	11,000	8,400	10,000	10,000	10,000	11,000
Next Generation Transportation System - Unmanned Aircraft Systems (UAS)	F&E	25,000	51,900	22,000	27,000	26,000	27,000	24,000
Next Generation Transportation System - Enterprise, Concept Development, Human Factors, & Demonstrations Portfolio	F&E	16,500	19,000	15,000	15,000	15,000	15,000	13,500
Center for Advanced Aviation System Development (CAASD)	F&E	57,000	57,000	57,000	57,000	57,000	57,000	57,000
William J Hughes Technical Center Laboratory Improvement	F&E	0	0	0	0	0	0	0
F&E TOTAL	**F&E**	**251,300**	**275,100**	**210,600**	**229,600**	**227,100**	**224,200**	**216,600**
Grants-In-Aid for Airports (AIP)								
Airport Cooperative Research Program - Capacity	AIP	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Airport Cooperative Research Program - Environment	AIP	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Airport Cooperative Research Program - Safety	AIP	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Airport Technology Research Program - Capacity	AIP	15,560	15,567	19,500	19,500	19,500	19,500	19,500
Airport Technology Research Program - Environment	AIP	400	332	500	500	500	500	500
Airport Technology Research Program - Safety	AIP	17,250	17,257	20,718	20,718	20,718	20,718	20,718
AIP TOTAL	**AIP**	**48,210**	**48,156**	**55,717**	**55,717**	**55,717**	**55,717**	**55,717**
GRAND TOTAL		**$490,610**	**$515,921**	**$436,317**	**$455,317**	**$452,817**	**$449,917**	**$442,317**

The funding levels listed for years 2022 to 2025 are estimates and subject to change.
The budget amounts shown for F&E programs reflect the entire budget for those portfolios, including R&D activities as well as acquisition,

Table 5.2.2 Planned R&D Budget by DOT Strategic Goal

Program		Account	2021 Contract Costs ($000)	2021 Personnel Costs ($000)	2021 Other In-house Costs ($000)	2021 Request ($000)	
DOT Goal: Safety							
Fire Research and Safety		RE&D	2,828	4,205	103	7,136	
Propulsion and Fuel Systems		RE&D	2,229	1,933	53	4,215	
Advanced Materials/Structural Safety		RE&D	12	935	56	1,003	
Aircraft Icing/Digital System Safety		RE&D	3,736	2,608	82	6,426	
Continued Airworthiness		RE&D	6,369	3,170	103	9,642	
Flightdeck/Maintenance/System Integration Human Factors		RE&D	3,018	4,359	92	7,469	
System Safety Management		RE&D	2,727	2,676	82	5,485	
Air Traffic Control/Technical Operations Human Factors		RE&D	135	5,437	113	5,685	
Aeromedical Research		RE&D	3,232	6,828	175	10,235	
Weather Program		RE&D	5,315	875	46	6,236	
Unmanned Aircraft Systems Research		RE&D	22,393	1,487	155	24,035	
Commercial Space Transportation		RE&D	5,840	0	0	5,840	
	Subtotal	**RE&D**	60,358	34,513	1,060	95,931	
Airport Cooperative Research Program - Safety		AIP	5,000	0	0	5,000	
Airport Technology Research Program - Safety		AIP	18,656	2,062	0	20,718	
	Subtotal	**AIP**	23,656	2,062	0	25,718	
	Safety TOTAL		**84,014**	**36,575**	**1,060**	**121,649**	
DOT Goal: Infrastructure							
Environment and Energy		RE&D	15,281	2,518	112	17,911	
NextGen - Environmental Research - Aircraft Technologies, Fuels, and Metrics		RE&D	26,136	862	11	27,009	
	Subtotal	**RE&D**	41,417	3,380	123	44,920	
William J. Hughes Technical Center Infrastructure Sustainment		F&E	10,000	0	0	10,000	
Center for Advanced Aviation System Development (CAASD)		F&E	57,000	0	0	57,000	
	Subtotal	**F&E**	67,000	0	0	67,000	/2
Airport Cooperative Research Program - Capacity		AIP	5,000	0	0	5,000	
Airport Technology Research Program - Environment		AIP	450	50	0	500	
Airport Technology Research Program - Capacity		AIP	17,559	1,941	0	19,500	
Airport Cooperative Research Program - Environment		AIP	5,000	0	0	5,000	
	Subtotal	**AIP**	28,009	1,990	0	29,999	
	Infrastructure TOTAL		**136,426**	**5,370**	**123**	**141,919**	
DOT Goal: Innovation							
NextGen - Wake Turbulence		RE&D	2,828	773	97	3,698	
NextGen - Air Ground Integration Human Factors		RE&D	5,956	758	43	6,757	
NextGen - Weather Technology in the Cockpit		RE&D	943	1,018	21	1,982	
NextGen - Information Security		RE&D	4,769	0	0	4,769	
NextGen - Flightdeck Data Exchange Requirements		RE&D	1,000	0	0	1,000	
	Subtotal	**RE&D**	15,496	2,549	161	18,206	
Advanced Technology Development & Prototyping		F&E	26,600	0	0	26,600	
William J. Hughes Technical Center Laboratory Sustainment		F&E	16,900	0	0	16,900	
Next Generation Transportation System - Separation Management Portfolio		F&E	21,200	0	0	21,200	
Next Generation Transportation System - Traffic Flow Management Portfolio		F&E	8,000	0	0	8,000	
Next Generation Transportation System - On Demand NAS Portfolio		F&E	10,500	0	0	10,500	
Next Generation Transportation System - NAS Infrastructure Portfolio		F&E	15,000	0	0	15,000	
Next Generation Support Portfolio		F&E	8,400	0	0	8,400	
Next Generation Transportation System - Unmanned Aircraft Systems (UAS)		F&E	22,000	0	0	22,000	
Next Generation Transportation System - Enterprise, Concept Development, Human Factors, & Demonstrations Portfolio		F&E	15,000	0	0	15,000	
	Subtotal	**F&E**	143,600	0	0	143,600	/2
	Innovation TOTAL		**159,096**	**2,549**	**161**	**161,806**	
DOT Goal: Accountability							
System Planning and Resource Management		RE&D	6,564	1,411	47	8,022	
William J. Hughes Technical Center Laboratory Facility		RE&D	459	2,417	45	2,921	
	Accountability TOTAL		**7,023**	**3,828**	**92**	**10,943**	
	GRAND TOTAL		**$386,559**	**$48,322**	**$1,436**	**$436,317**	

/1 Many R&D programs apply to more than one goal area; however, for budgeting purposes most programs are included in only one goal area.
/2 The budget amounts shown for F&E programs reflect the entire budget for those portfolios, including R&D activities as well as acquisition, operational testing, and other non-R&D activities.

Acronyms and Abbreviations

Acronym	Definition
A	
AACE	Airworthiness Assurance
AATS	Aircraft Access to SWIM
ACERite	Airline Cabin Environment and Intermodal Transportation Research
AAM	Office of Aerospace Medicine
ACFTF	Aircraft Components Fire Test Facility
AC	Advisory Circular
ACRP	Airport Cooperative Research Program
AEDT	Aviation Environmental Design Tool
AFEL	Arc Fault Evaluation Lab
AFRL	Air Force Research Laboratory
AFS	Active Flutter Suppression
AGL	Above Ground Level
AGHME	Aircraft Geometric Height Measurement Element
AI	Artificial Intelligence
AIP	Airport Improvement Program
AITF	Airflow Induction Test Facility
AM	Additive Manufacturing
AMS	Acquisition Management System
ANSP	Air Navigation Service Provider
AOPA	Aircraft Owners and Pilots Association
AOV	Air Traffic Safety Oversight Service
ARFF	Aircraft Rescue and Fire Fighting
ASBS	Anti-Skid Brake System
ASCENT	Aviation Sustainability Center of Excellence
ASIAS	Aviation Safety Information Analysis and Sharing
ASPIRE	Asia and Pacific Initiative to Reduce Emissions
ASPN	Aircraft Skin Penetrating Nozzle
AST	FAA Office of Commercial Space Transportation
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
ATD	Anthropomorphic Test Device
ATD-2	Airspace Technology Demonstration Two
ATD&P	Advanced Technology Development and Prototyping
ATM	Air Traffic Management
ATM	Air Traffic Modernization
ATRP	Airport Technology Research Program
AVS	Office of Aviation Safety
AVSI	Aviation Vehicle Systems Institute
B	
BVI	Blind and Visually Impaired
BVLOS	Beyond Visual Line of Sight

Acronym	Definition
C	
CAAFI	Commercial Aviation Alternative Fuels Initiative
CAASD	Center for Advanced Aviation Systems Development
CAEP	Committee on Aviation Environmental Protection
CAFS	Compressed Air Foam System
CAMI	Civil Aerospace Medical Institute
CARATS	Collaborative Actions for Renovation of Air Traffic Systems
CAST	Commercial Aviation Safety Team
CEAT	Airport Technology Research
CFD	Computational Fluid Dynamics
CLEEN	Continuous Lower Energy, Emissions and Noise
CMSL	Chemistry and Materials Science Laboratory
COE	Center of Excellence
COMSTAC	Commercial Space Transportation Advisory Committee
ConOps	Concept of Operations
CONUS	Continental United States
CORSIA	Carbon Offsetting and Reduction System for International Aviation
CP	Collaborating Partner
CRADA	Cooperative Research and Development Agreement
CSF	Cockpit Simulation Facility
CVS	Combined Vision System
D	
DARWIN	Design Assessment of Reliability with Inspection
DHS	Department of Homeland Security
DFW	Dallas Fort Worth International Airport
DIMA	Distributed Integrated Modular Avionics
DOC	Department of Commerce
DoD	Department of Defense
DOJ	Department of Justice
DOT	Department of Transportation
DST	Decision Support Tool
E	
EDR	Eddy Dissipation Rate
EFB	Electronic Flight Bag
ELT	Electroluminescent Lighting Technology
EMAS	Engineered Materials Arresting System
ENFS	Engine Nacelle Fire Simulator
EOR	Established on Required Navigation Performance
EPDS	Electronic Power Distribution System
ERGL	Elevated Runway Guard Lights
ETM	Class E Upper Airspace Traffic Management
EVS	Enhanced Vision System
F	
F&E	Facilities and Equipment

Acronym	Definition
F&R	Finding and Recommendation
FAA	Federal Aviation Administration
FASTER	Full-Scale Aircraft Structural Test Evaluation and Research
FATS	Future Air Transport System
FFRDC	Federally Funded Research and Development Center
FHWA	Federal Highway Administration
FICAN	Federal Interagency Committee on Aviation Noise
FIM	Flight-deck Interval Management
FRMP	Fatigue Risk Management Plan
FRMS	Fatigue Risk Management System
FSFTF	Full Scale Fire Test Facility
FTB	Florida Test Bed
G	
GAJSC	General Aviation Joint Steering Committee
GNSS	Global Navigation Satellite System
GOGO	Government Owned, Government Operated
GPS	Global Positioning System
GUI	Graphic User Interface
H	
HCF	High Cycle Fatigue
HDD	Head Down Display
HF	Human Factors
HHS	Department of Health and Human Services
HI	Honeywell International
HITL	Human-in-the-Loop
HMD	Head-Mounted Display
HSI	Human Systems Integration
HUD	Head-Up Display
HWD	Head-Worn Display
I	
IA	Interagency Agreement
IAA	Intra-agency Agreement
IARPC	Interagency Artic Research Policy Committee
ICAO	International Civil Aviation Organization
ICME	Integrated Computational Materials Engineering
ID-SRET	Integrated Domain-Safety Risk Evaluation Tool
IFR	Instrument Flight Rule
IOT	Internet of Things
IPO	Interagency Planning Office
IPP	Integration Pilot Program
ISO	International Organization for Standardization
ISS	Information Systems Security
J	
JCAB	Japan Civil Aviation Bureau

Acronym	Definition
JRC	Joint Resources Council
JUP	Joint University Program
L	
LED	Light Emitting Diode
M	
MARS	Maintenance and Repair Forecasting System
MEA	More Electric Aircraft
MFTF	Materials Fire Test Facility
MMAC	Mike Monroney Aeronautical Center
MIDEP	Mitigation Identification and Evaluation Process
MIRL	Medium Intensity Runway Lights
ML	Machine Learning
MMPDS	Metallic Materials Properties Development Standardization
MOA	Memorandum of Agreement
MOC	Memorandum of Cooperation
MOU	Memorandum of Understanding
N	
NARP	National Aviation Research Plan
NAS	National Airspace System
NAS	National Aerospace System
NASA	National Aeronautics and Space Administration
NEB	NextGen Executive Board
NEC	Northeast Corridor
NextGen	Next Generation Air Transportation System
NEXTOR	National Center of Excellence for Aviation Operations Research
NGA	National Geospatial-Intelligence Agency
NHTSA	National Highway Traffic Safety Administration
NIEC	NextGen Integration and Evaluation Capability
NMA	Non-Movement Area
NOAA	National Oceanic and Atmospheric Administration
NPN	NextGen Prototyping Network
NSF	National Science Foundation
NTSB	National Transportation Safety Board
nvPM	Non-volatile Particulate Matter
O	
ODNI	Office of the Director of National Intelligence
OEM	Original Equipment Manufacturer
OMB	Office of Management and Budget
OPC	Offshore Precipitation Capability
OST	Office of Science and Technology
OSTP	White House Office of Science and Technology Policy
OTA	Other Transaction Agreement
P	
PED	Personal Electronic Device

Acronym	Definition
PInS	Point-in-Space
PM	Particulate Matter
PNT	Position, Navigation, and Timing
POWER	Propulsion and airpOWer Engineering Research
R	
R&D	Research and Development
RDHFL	Research and Development Human Factors Laboratory
REB	Research and Development Executive Board
R,E&D	Research, Engineering and Development
REDAC	Research, Engineering and Development Advisory Committee
RNA	Ribonucleic Acid
RF	Radius-to-Fix
RIPSA	Runway Incursion Prevention Shortfall Assessment
RTCA	Radio Technical Commission for Aeronautics
RTTS	Real-Time Tracking System
S	
SAE	Society for Automotive Engineering
SAFRE	Situational Awareness for Runway Entrances
SALS	Smart Airport Landing System
SARP	Standards and Recommended Practices
SASS	Small Airport Surveillance Sensor
STA	Scheduled Time of Arrival
SWPC	Space Weather Prediction Center
SDSS	Surface Decision Support System
SEI	Software Engineering Institute
SESAR	Single European Sky Air Traffic Management Research
SLD	Super Cooled Large Droplets
SML	Structures and Materials Lab
SMS	Safety Management System
SRA	Safety Risk Assessment
STEM	Science, Technology, Engineering and Mathematics
SunKeyST	SunKeyboard System Translator
SVS	Synthetic Vision System
T	
TBO	Trajectory Based Operations
TGF	Target Generation Facility
TSAS	Terminal Sequencing and Spacing
U	
UAS	Unmanned Aircraft Systems
UFDM	UAS Flight Data Monitoring
U.S.	United States
USGCRP	U.S. Global Change Research Program
UTM	UAS Traffic Management
V	

Acronym	Definition
VFR	Visual Flight Rules
W	
WJHTC	William J. Hughes Technical Center
WTIC	Weather Technology in the Cockpit

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.

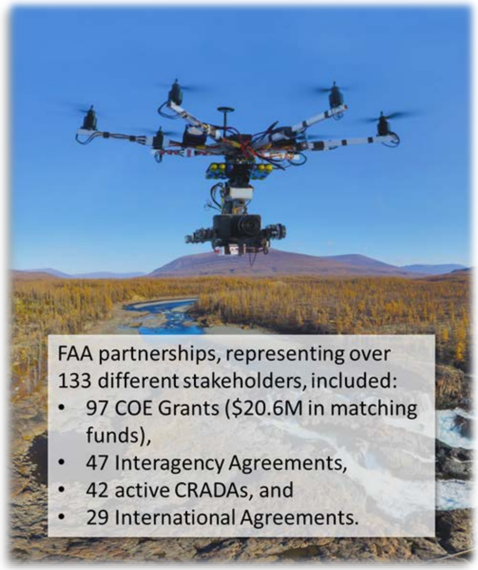
The FAA's Research and Development (R&D) Management Division is charged with supporting the development of the agency's R&D portfolio, and tracking R&D program goals and activities to ensure their alignment with Department of Transportation (DOT) and FAA strategic goals for the National Airspace System (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)
** https://www.airlines.org/dataset/a4a-presentation-industry-review-and-outlook/

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

16 Federal Agreements in 2019

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 (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 Organisation 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.

Performance Results

Overview

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.

The FAA's R&D goals are focused on researching and identifying solutions for:

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.

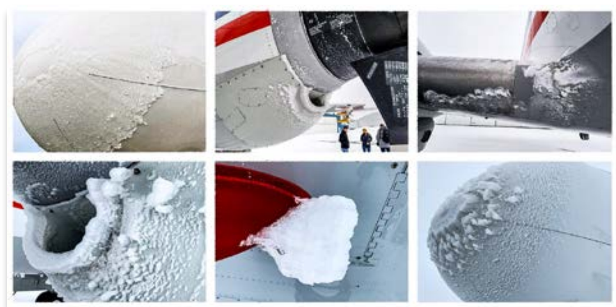
Goal 1 Output Status

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 Atmospherics 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.

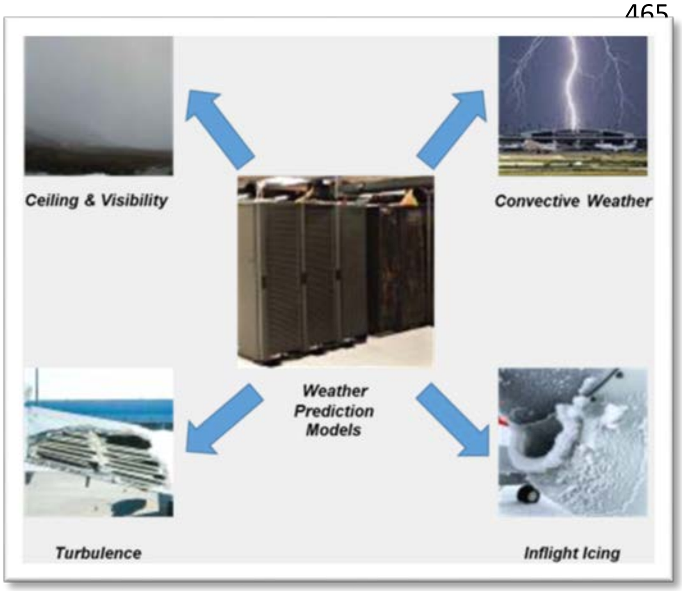
Major Airspace Redesign – *Separation Standards* **–** Separation minima due to safety concerns is a major source of constraints on capacity at airports. The development and implementation of lower minima standards for runway 09/17 using Simultaneous Converging Instrument Approach procedures at Philadelphia 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

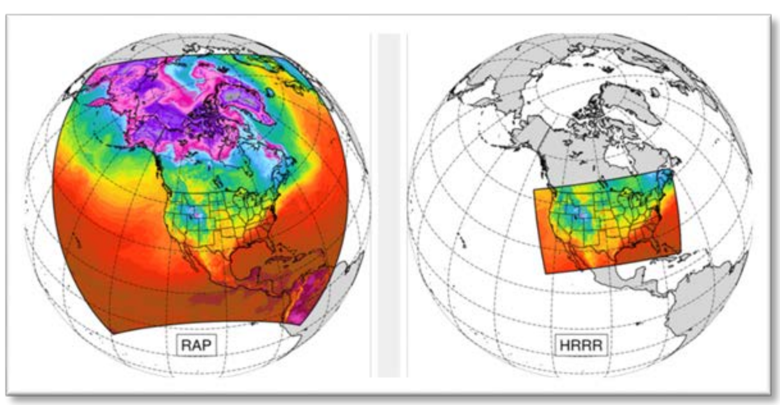
Airport (CLT). The research associated with the IADS demonstration and lessons learned from operations at CLT will inform future enhancements of the surface traffic flow automation system (e.g., Terminal Flow Data Manager) that is scheduled for deployment at the largest airports starting in FY 2020.



***Weather** – Numerical Weather Predication 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.

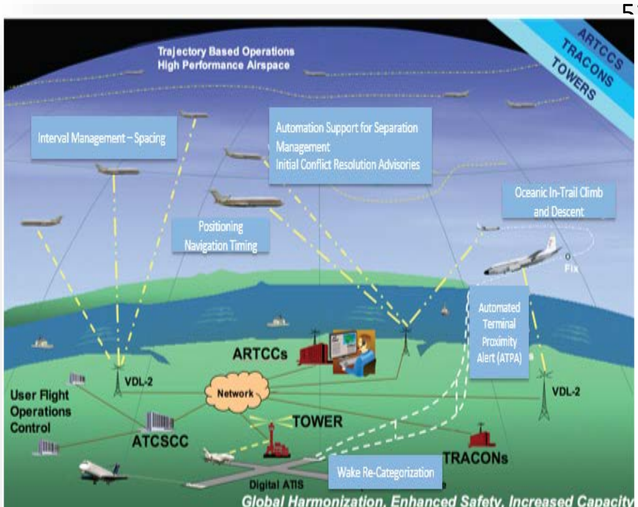
The RAP is a Northern Hemispheric regional model and the HRRR is a Continental United States model that uses the RAP to provide finer resolution of weather features. The RAP provides direct input to Weather program-developed capabilities such as the Graphical Turbulence Guidance product, the Current 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.

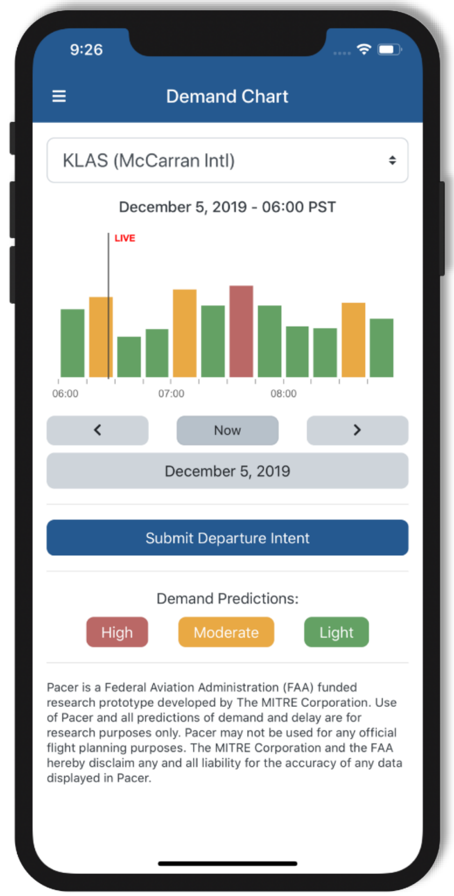
NextGen – NAS Infrastructure Portfolio – *Completion of the Trajectory Synchronization Prototype Development, Modeling and Simulation Plan* **–** This plan represents the modeling and simulation body of work that will be performed in order to determine the best and most cost effective approaches for 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.

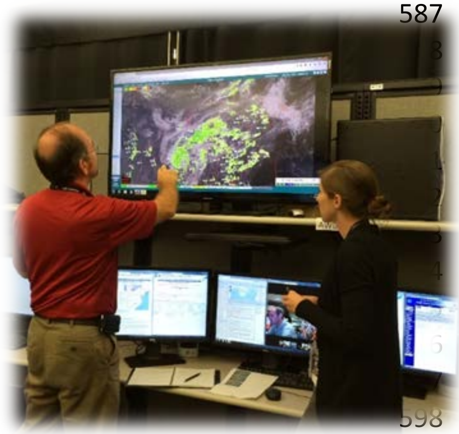
NextGen – WTIC – *Tactical Turbulence Information in the Cockpit* – The WTIC program completed and delivered a final report for research evaluating the use of the Terminal Flow Data Manager (TFDM) stream to replace the obsolete ASDI data stream and updating algorithms for predicting which aircraft are 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.

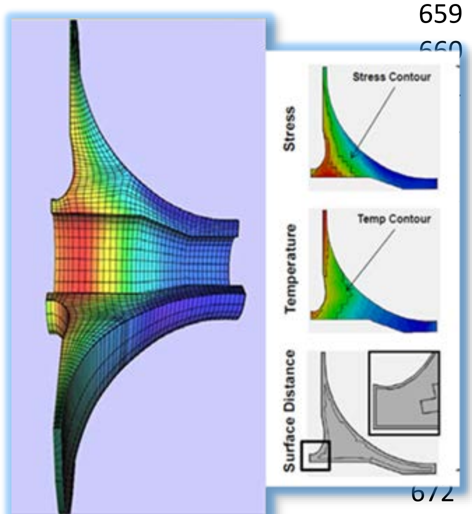
Goal 2 Output Status

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.

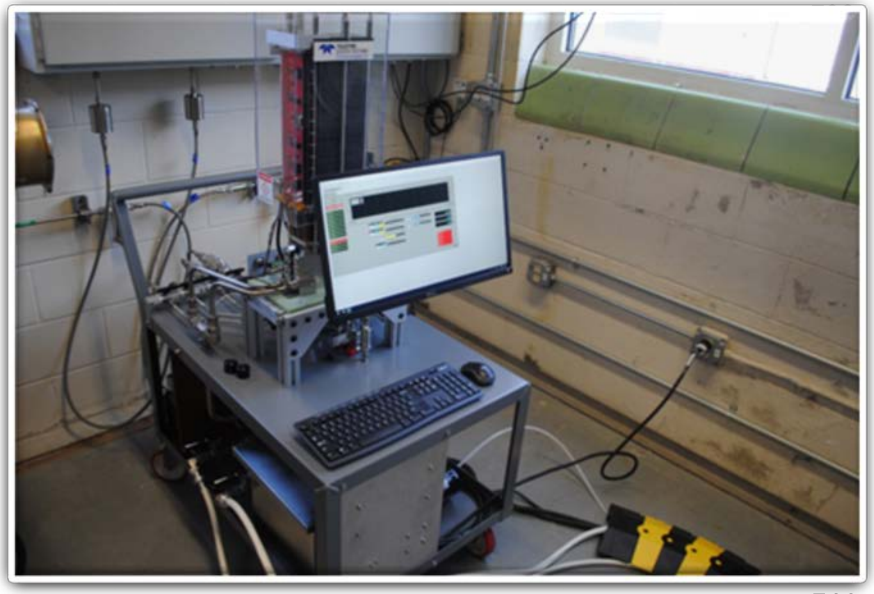
The creation of an artificial bird substitute will help harmonize test standards between developmental and certification testing and reduce test variability. The development of an artificial simulant will also help create a better understanding of the mechanics of bird to aircraft impact thereby aiding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



Environment & Energy – *Aviation Environmental Design Tool (AEDT)* – Development was completed on the first version of the new series of the AEDT, AEDT 3a. External release of this version is pending and is dependent on the licensing procedure for the new Base of Aircraft Data (BADA) v.4 aircraft performance model to be finalized by EUROCONTROL, the entity responsible for its development and underling data sources.

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.

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

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

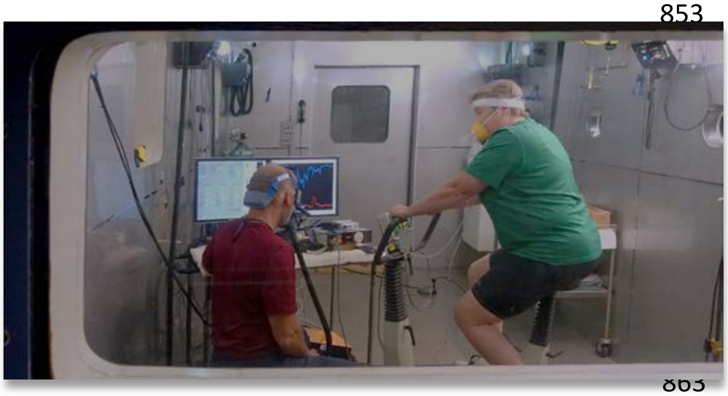
Humans, serving as aircrew (including UAS remote pilots), cabin crew, maintenance personnel, air traffic controllers, and in other NAS roles, are inevitably at risk of psychophysiological breakdown, and therefore less than optimal performance, during both normal and emergency events. Research in this 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.

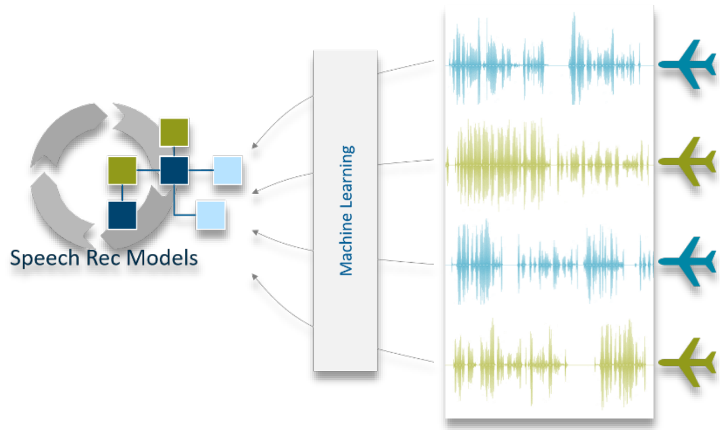
System Capacity, Planning, and Improvements – *Hurricane Reporting* – The FAA developed and implemented standardized reporting on the impact of hurricanes on NAS operations. The reporting is designed to inform air traffic managers of operational impacts experienced during these events in order to enable 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.

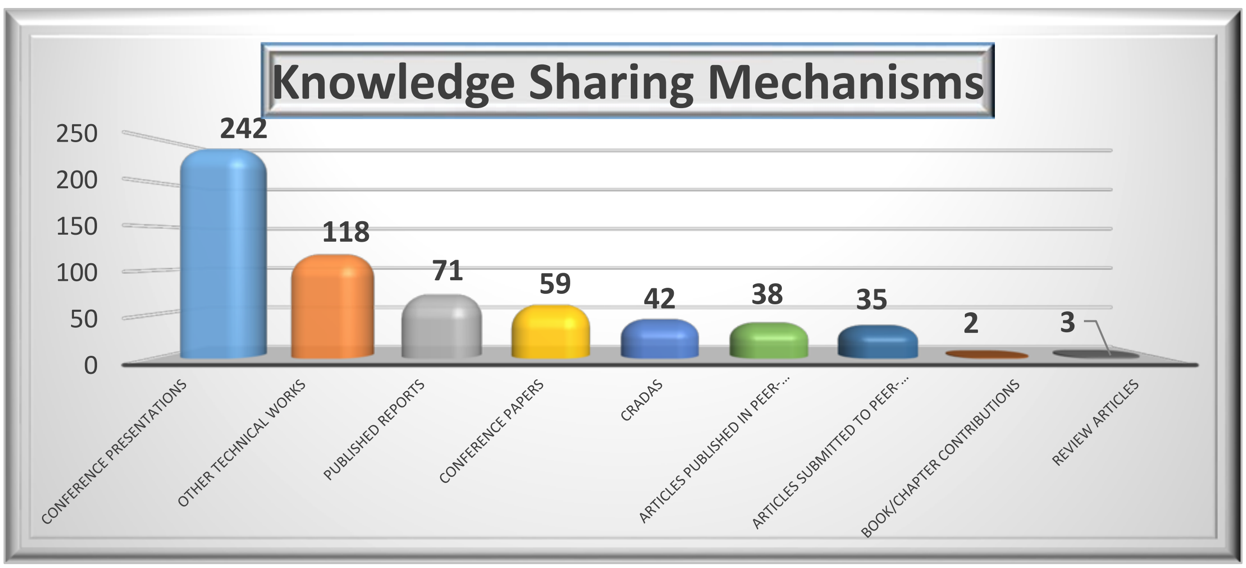
UAS Concept Validation & Requirements Development – *Integration of UAS* – UAS efforts included integrating UAS under Air Traffic Management (ATM) and the development of UAS Traffic Management (UTM). These efforts will inform changes to FAA automation needs, impact rulemaking and operations, and ultimately 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 ranges 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 FAAs 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 methodolgy 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 Organisation 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