National Aviation Research Plan (NARP)

FY 2024–2028

Report of the Federal Aviation Administration (FAA) to the United States Congress pursuant to section 44501(c) of title 49, United States Code

The NARP is available online at: ***http://www.faa.gov/go/narp***

U.S. Department of Transportation
Federal Aviation Administration

Message from Acting FAA Administrator Polly Trottenberg

"Change has always been constant. But in aviation, it's happening faster and faster. We're seeing boundless new technology and tremendous innovation in this industry."

Polly Trottenberg, FAA Acting Administrator

The National Airspace System (NAS) is the world's most complex aerospace system, and it is constantly evolving. Not since the dawn of the jet age have we seen so many advances and changes in aviation and space. Our mission — to run the world's safest, most efficient aerospace system — requires us to adapt, learn, and innovate. We must think differently and find new ways to address current and future challenges.

The FAA is safely enabling the innovation we're seeing in aerospace today. And the research and development work we do is essential for success. We are harnessing predictive analytics, machine learning, and artificial intelligence to develop streams of data. These capabilities allow us to create new tools and techniques and adopt new technologies.

I am pleased to present the National Aviation Research Plan for Fiscal Years 2024–2028. This five-year plan outlines how the FAA's work encourages innovation while keeping America's air traffic operations safe and efficient.

The document shows how we work with our partners to deliver research solutions that maximize benefits to American taxpayers and the global flying public. The FAA remains committed to collaborating with stakeholders and the international aviation community to share data and best practices. Through the open sharing of safety information, we've made aviation safer worldwide. And we will continue to do so.

The plan demonstrates creative thinking and rigorous planning by our researchers throughout the country. I am especially proud of the great work at the FAA's William J. Hughes Technical Center in Atlantic City, NJ, and the Civil Aerospace Medical Institute (CAMI) in Oklahoma City, OK. Both are world leaders in aviation research.

Every key improvement in the NAS since 1958 has been developed or tested at the Technical Center. Additionally, I'd like to acknowledge CAMI for their timely research efforts surrounding communicable disease transmission risk onboard passenger aircraft.

I invite you to read on to learn more about the critical role that FAA research and development plays in the continuation and evolution of American and global aviation.

Executive Summary

Objective

The National Aviation Research Plan (NARP) presents the FAA's research and development (R&D) goals, highlights planned research in support of each goal, and details how the FAA works with partners outside the agency to best leverage each dollar of R&D funding.

Document Highlights

This congressionally-required document is divided into four sections.

- **The first section describes the importance of federally-funded R&D.**
- **The second identifies the FAA's research goals. This section also describes how the FAA structures R&D to ensure alignment of all research activities with these goals and priorities, giving highlights of past and expected results for select activities.**
- **The third section outlines the FAA's R&D partnerships and collaborations with other agencies, academia, and the aerospace industry. These include technology transfer initiatives, R&D partnerships, and interactions with external advisory committees.**
- **The final section details projected funding over a five-year timeframe for each R&D program.**

Key Takeaways

FAA research and development cultivates the innovation needed to:

- **Provide safe and efficient solutions to an evolving National Airspace System**
- **Prepare the aviation system for the next generation, making it more adaptable, sustainable, resilient, and equitable**
- **Advance aviation in an environmentally responsible and energy-efficient manner**

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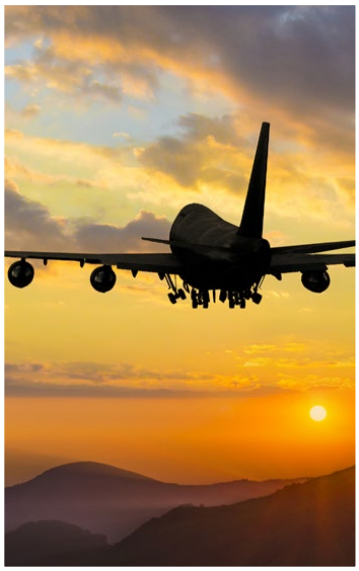
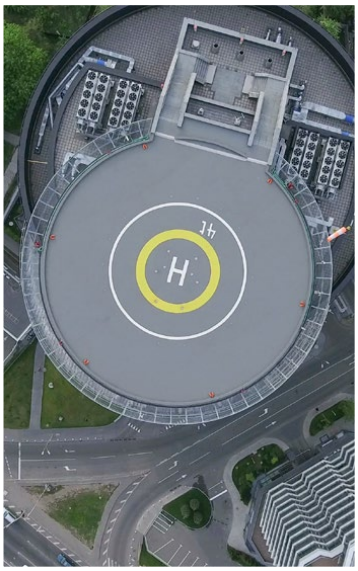




1.0 Introduction

The National Aviation Research Plan (NARP) describes how the FAA's investments in research and development (R&D), as defined by the Office of Management and Budget Circular A-11, address national aerospace priorities through careful management and delivery of results. Section 44501(c) of title 49 of the U.S. Code requires the FAA Administrator to submit the NARP to Congress annually with the President's Budget.

The document features a framework of R&D goals that support the strategic visions laid out by the President, Secretary of Transportation, and FAA Administrator regarding safety, fostering economic strength, and transforming the nation's infrastructure while focusing on equity, sustainability, and climate protection.

This approach enables the FAA to address the current challenges of operating the world's safest, most efficient aerospace transportation system while building a foundation for the future with an environmentally conscious approach.

The NARP provides a close-up view of a selection of the *FAA's R&D priorities*, which collectively support and drive innovation, represent areas of congressional or public interest, support near-term regulatory actions, and have a global impact. The highlighted research areas are designed to produce results in support of the agency by:

- **Considering noise, emissions, and other environmental issues to advance aviation in an environmentally-responsible and energy-efficient manner**
- **Using informed decision-making and data-driven approaches to prioritize safety and public health**
- **Preparing transportation systems for the next generation by making them more adaptable, sustainable, resilient, and equitable**

The document details the *FAA's R&D partnerships and collaborations* with other agencies, academia, and industry. It focuses on how technology transfers out of the agency, the many ways the FAA partners with outside groups to maximize every R&D dollar invested, and the role of external advisory committees.

The FAA funds R&D in three budgetary accounts: Research, Engineering, and Development (RE&D); Facilities and Equipment; and the Airport Improvement Program. FAA R&D activities in these accounts enable great innovation while ensuring that all aerospace safety needs are met. The FAA *R&D Funding Profile* in Section 4.0 of the NARP describes the RE&D investment plan details for the five-year period, 2024–2028.

FAA Research and Development Investments

In FY 2024, the FAA plans to invest a total of $505.1 million in the R&D portfolio, distributed across three budgetary accounts:

- **$255.1 million for Research, Engineering, and Development**
- **$193.2 million for Facilities and Equipment**
- **$56.8 million for the Airport Improvement Program**

1.1 Why FAA Research and Development Matters

FAA research is primarily applied R&D designed to help the agency develop policies, regulations, certifications, guidance, and standards that increase safety and modernize the National Airspace System (NAS). Outputs of this R&D include:

- **Provision of research data and analyses to modernize NAS operations**
- **Evaluation and validation of requirements, procedures, and methods**
- **Production of useful materials, devices, systems, tools, and technologies**

R&D is critical to reinforcing the FAA's role as the world's premier aerospace body and is essential for the continued evolution of the NAS.

FAA R&D enables the aerospace community to adapt to new safety issues and service demands resulting from increased activities of unmanned aircraft systems and commercial space flight, counter the growing cybersecurity threats from increasingly interconnected systems, and minimize the impact of aerospace activities on the environment.

The FAA has a substantial positive impact on aviation and space and, by extension, the U.S. economy. R&D enables the aerospace industry to modernize this country's infrastructure and fuel economic growth. It further contributes to American economic competitiveness by enabling new technologies and industries and creating American jobs.

FAA Research Facilities

The FAA operates state-of-the-art research facilities in two locations:

- **The William J. Hughes Technical Center is located in Atlantic City, NJ**
- **The Civil Aerospace Medical Institute and the Flight Research and Analysis Group are located at the Mike Monroney Aeronautical Center in Oklahoma City, OK**
- **Each location provides unique research, development, and test and evaluation platforms necessary to facilitate upgrades, improvements, and operational sustainment**

The laboratories serve as a resource for government-industry partnerships. Collaboration internally and across federal agencies, academia, the U.S. military, and the aviation industry is important for sharing research and information, developing policy, and promoting best practices globally.

William J. Hughes Technical Center

Civil Aerospace Medical Institute

1.2 How the FAA's Research Shapes the Future

FAA research focuses on a core safety mission and prioritizes integrating advanced technologies into the NAS while minimizing environmental impacts. Many changes are expected in the NAS, brought about by emerging technologies, new vehicle types, and the evolution of information.

As the world becomes ever more digitally interconnected, there is exponential growth in data availability, computing power, and storage capacity.

Understanding, adopting, and using data science tools such as analytics, artificial intelligence (AI), and machine learning (ML) will allow FAA researchers to analyze and learn from these rich data sources and create insight through problem solving and analysis.

Sample research outcomes related to AI and ML include:

- **Development of standards or best practices for leveraging these technologies in FAA operations and the broader aerospace system**
- **Development of predictive models of various conditions (such as weather) based on rich data sets**
- **Examination of reports and analysis of textual data**

The agency proactively structures its ongoing research to mitigate information systems vulnerabilities and emphasizes the application of AI and ML technologies to create new algorithms, tools, and techniques to further the adoption of safety-enhancing technologies into the NAS.

Mission

The FAA's continuing mission is to provide the safest and most efficient aerospace system in the world.

Vision

The agency's vision is to reach the next level of safety and efficiency and demonstrate global leadership by safely integrating new users and technologies into the aviation system while being accountable to the American public and aviation stakeholders. The FAA's major roles include:

- ***Regulating civil aviation to promote safety***
- ***Encouraging and developing civil aeronautics, including new aviation technology***
- ***Developing and operating a system of air traffic control and navigation for both civil and military aircraft***
- ***Researching and developing the National Airspace System and civil aeronautics***
- ***Developing and carrying out programs to control aircraft noise and other environmental effects of civil aviation***
- ***Regulating U.S. commercial space transportation***

Use of Artificial Intelligence and Machine Learning for Weather Safety

A thunderstorm can cause flight delays by reducing the capacity of air traffic resources.

If a pilot asks to deviate from a planned route to avoid bad weather, an air traffic controller must guide the pilot while safely separating all nearby aircraft.

Predicting delays means first accurately predicting pilot behaviors in convective weather.

In collaboration with NASA, the FAA developed the Convective Weather Avoidance Model, which uses artificial intelligence and machine learning to analyze pilot behavior and flight paths around thunderstorms.

This data becomes a historical record when correlated with detailed weather observations and aircraft trajectories showing if a pilot flew through a storm or changed course to avoid bad weather.

When blended with weather models, the resulting information can begin to predict aircraft deviations and throughput.

Predictions of convective weather impacts allow proactive traffic flow management, increasing the effective use of available airspace and reducing overall air traffic delay.

2.0 FAA Research and Development

The FAA consistently strives to improve the planning, programming, and budgeting of the agency's research and development (R&D) portfolio; increase the return on taxpayer investment; enhance productivity; ensure the relevance, quality, and performance of the R&D portfolio; and develop a comprehensive view of the R&D required to support a vibrant aerospace sector.

The FAA balances R&D investments between those that are strategic and those that are mission-oriented. Strategic investments include understanding and enabling emerging technologies and new business models, as well as addressing the changing needs of system users. Mission-oriented investments include agency priorities and continued FAA safety and efficiency enhancements.

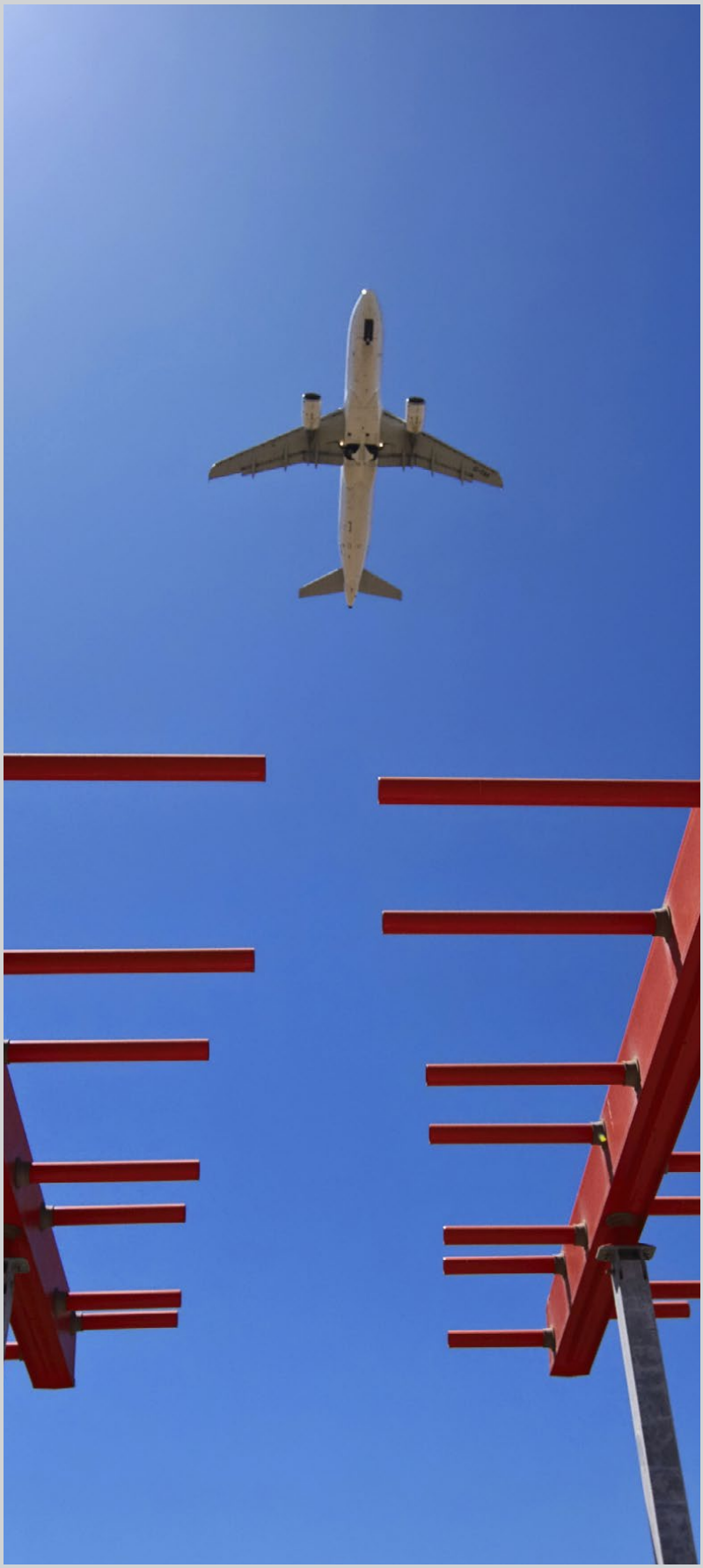
R&D Executive Board

The FAA accomplishes this by leveraging internal senior management guidance and external advice and recommendations. The agency's R&D Executive Board (REB) provides an oversight approach to managing the R&D portfolio development process. The REB frequently meets throughout the year to discuss and coordinate a well-balanced portfolio and make funding recommendations.

Research, Engineering, and Development Advisory Committee

External stakeholder input to the FAA's R&D portfolio development is primarily received through the congressionally-mandated Research, Engineering, and Development Advisory Committee (REDAC). The committee provides advice and recommendations to the FAA Administrator on the needs, objectives, plans, approaches, content, and accomplishments of the aviation research program.

REDAC members include professionals from the aviation and space industries, Federally Funded Research and Development Centers, and academia who are best positioned to identify aviation drivers, issues, requirements, and influencing technologies and understand the level of research investment the aerospace industry is making or is willing to make. Section 3.3 provides additional information about the *REDAC*.



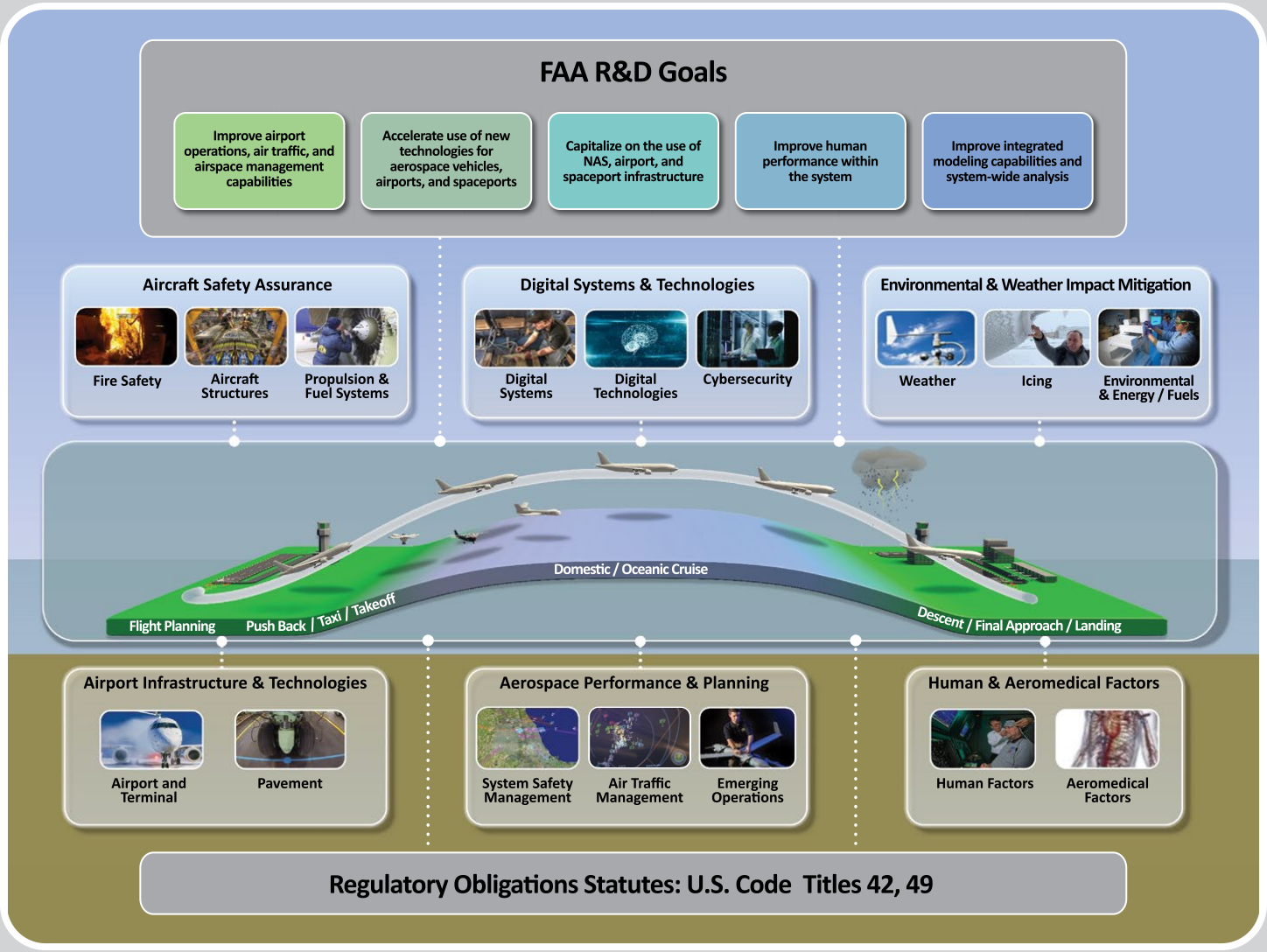
2.1 FAA R&D Framework

The FAA has developed research goals that support its multiple regulatory and operational mission areas, including National Airspace System (NAS) modernization, policymaking, regulation, certification, and standards development. FAA research focuses on identifying solutions for:

- **Accelerating the use of new technologies**
- **Capitalizing on infrastructure use**
- **Improving human performance**
- **Improving integrated modeling and system-wide analysis**
- **Improving operations and management capabilities**

FAA R&D goals address aviation and space research needs, including air and space vehicles, airports and airport systems, spaceports, human operators, air traffic systems, air traffic information, and the customers they serve — the flying public. The goals span multiple research domains, a grouping of programs with a common focus area or body of knowledge. The research domains are:

- **Aircraft Safety Assurance**
- **Digital Systems and Technologies**
- **Environmental and Weather Impact Mitigation**
- **Airport Infrastructure and Technologies**
- **Aerospace Performance and Planning**
- **Human and Aeromedical Factors**



This abstract graphic represents FAA research and development domain areas. White dotted lines indicate areas of impact before, during, and after flight. These connections are notional and not intended to be comprehensive.

2.2 Department of Transportation Innovation Principles

The FAA invests in high-priority research and development activities that are critical to the NAS and align with the following overarching innovation principles of the agency's parent organization, the Department of Transportation (DOT).

Serve Our Policy Priorities

Creating high-quality jobs, achieving racial equity, increasing opportunity for all Americans, and tackling the climate crisis should drive innovation. Innovations should reduce deaths and serious injuries on our nation's transportation network while committing to the highest safety standards across technologies.

Help America Win the 21st Century

The DOT must play a meaningful role in future-proofing infrastructure, enabling adaptability and resilience, and helping communities and public sector partners to bring legacy systems into the digital age.

Support Workers

The DOT will empower workers and expand access to skills, training, and the choice of a union. They will have a seat at the table in shaping innovation.

Allow for Experimentation and Learn from Failure

The DOT is committed to supporting public sector experimentation, sharing insights, and embracing open data and transparency while protecting privacy. That means elevating lessons learned from both successful deployments and those that fall short.

Provide Opportunities to Collaborate

The DOT will embrace public-private partnerships that share risk, foster purpose-driven innovation, and protect the interests of the public, workers, and communities. The DOT must encourage an outcomes-based approach that is technology neutral.

Be Flexible and Adapt as Technology Changes

The DOT should identify opportunities for interoperability among innovations and foster cross-modal integration. In addition, DOT's posture must also remain nimble, with a commitment to supporting technologies that further policy goals.

Positioning, Navigation, and Timing Resilience

In transportation, positioning, navigation, and timing (PNT) refer to capabilities that provide the following services with a high level of precision:

- **Location (positioning)**
- **Ability to move to a new location along a path (navigation)**
- **Knowledge of the current time (timing)**

GPS is the most recognizable global provider of PNT service, but any system, network, or capability that can calculate one or more of these components is considered a PNT service. PNT use within aviation has expanded dramatically over the past few decades, becoming a largely invisible utility supporting numerous technologies, systems, and services. These technologies include:

- **Global Navigation Satellite Systems – satellite constellations that provide PNT services on a global or regional basis**
- **Wide Area Augmentation System – a navigation system that dramatically increases GPS accuracy, integrity, and availability, increasing safe access to airports in lower-visibility conditions**

The aviation industry relies heavily on PNT technologies to support the transition of the National Airspace System to Performance Based Navigation — an advanced satellite-enabled form of air navigation that improves air traffic flow efficiency to and from airports through precise and repeatable flight paths.

The ability to accurately receive PNT information during flight is critical to the safe operation of the aircraft. Intentional or unintentional disruptions to these services present a significant safety hazard. Ongoing research conducted by the FAA and its partners seeks to ensure the continued resilience of these systems through the use of advanced antenna technologies, GPS authentication, and complementary avionics for cyber safety.

Aircraft Accessibility

Travelers who use wheelchairs experience burdens that can make air travel inconvenient, uncomfortable, and potentially unsafe. Examples include mishandled or lost wheelchairs and scooters and issues with transfers to and from aircraft seats.

In support of the Department of Transportation's *Bill of Rights for Airline Passengers with Disabilities* and in accordance with the Air Carrier Access Act, the FAA is evaluating the occupant safety and crashworthiness aspects of installing wheelchairs on commercial aircraft. This research will examine the feasibility of adding wheelchair securement systems on passenger aircraft.

Researchers will also explore possible physical and psychological evacuation issues introduced by these systems. The FAA will use research results for future rulemaking about passengers safely staying in their personal wheelchairs aboard commercial aircraft.

2.3 Research Priorities by R&D Goal

Information highlighted in the following sections represents significant FAA R&D work in each goal area. Although some of the featured research is considered long term, extending beyond 2028, the current National Aviation Research Plan (NARP) focuses on a five-year window beginning in 2024.

Timelines below the research descriptions feature select tasks from that research, the timeframe in which the tasks are scheduled to occur, and the expected results of that work. Research drivers, outcomes, and partners are represented in the area around the timeline.

The highlighted research includes only a sample of specific activities and is not intended to represent or characterize the full breadth of the FAA's research portfolio. The timelines represent work currently planned but are subject to change as the agency's needs, resources, and research priorities evolve.

2.3.1 Goal 1

Improve airport operations, air traffic, and air space management capabilities

Key programs and initiatives:

Efficient airport operations and enhanced air traffic and airspace management capabilities are vital to maintaining the world's most complex airspace system. Research under this goal supports airport and spaceport systems and operations, air traffic management (ATM) in the air and on airport surfaces, integrated weather information, aerospace vehicle operations, and noise and emissions 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 provide improved services to increase capacity, efficiency, system flexibility, and safety. In addition, this work will continue to integrate unmanned aircraft systems (UAS) and space vehicles into the NAS, ensuring safe airport and spaceport access.

To achieve this goal, the FAA will:

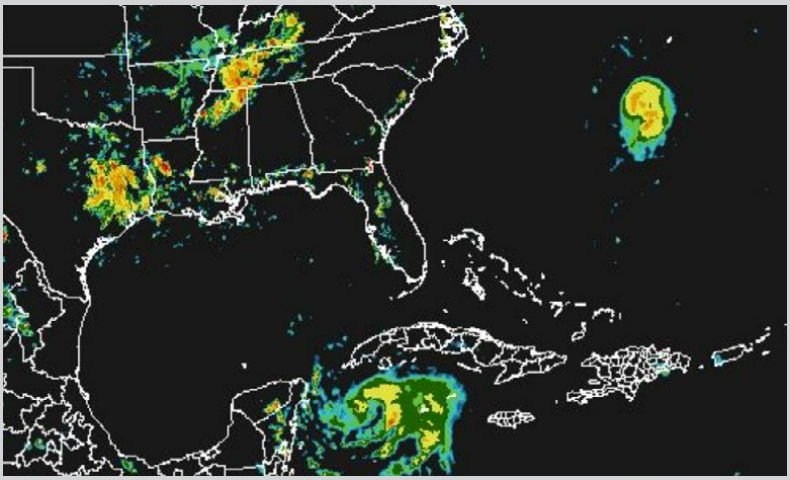
- **Use artificial intelligence (AI) for more accurate and tailored weather forecasting**
- **Implement new capabilities to improve operations on the airport surface**
- **Evaluate the use of AI and machine learning (ML) to improve traffic flow management operations by addressing system-wide demand and capacity imbalances**
- **Use wake turbulence recategorization to increase capacity during poor weather conditions**
- **Explore concepts to increase airport capacity through reduced separation standards, expand applications of dependent and independent operations, and enable operations in lower-visibility conditions**
- **Improve air traffic flow efficiency to and from airports by expanding the use of certain satellite-enabled navigation routes and procedures**
- **Develop and implement new support tools, technologies, standards, and guidance to improve ATM efficiency and effectiveness**
- **Conduct tests, evaluations, and demonstrations to advance and refine new weather information capabilities**
- **Evaluate diverse support structures used in rotorcraft fuel system drop testing to standardize certification**

Weather Program

Using Artificial Intelligence for Weather Hazard Mitigation

The FAA's Weather Program is researching AI to proactively support the growing number and types of NAS users. Researchers anticipate that weather information will need to be tailorable and information-focused to effectively and efficiently support data-driven decisions.

The weather program will use various software applications to provide AI assistance with weather model biases and to feed decision-support tools that analyze the anticipated actions of the users, including pilots, controllers, and dispatchers, to support a more efficient and safer NAS.



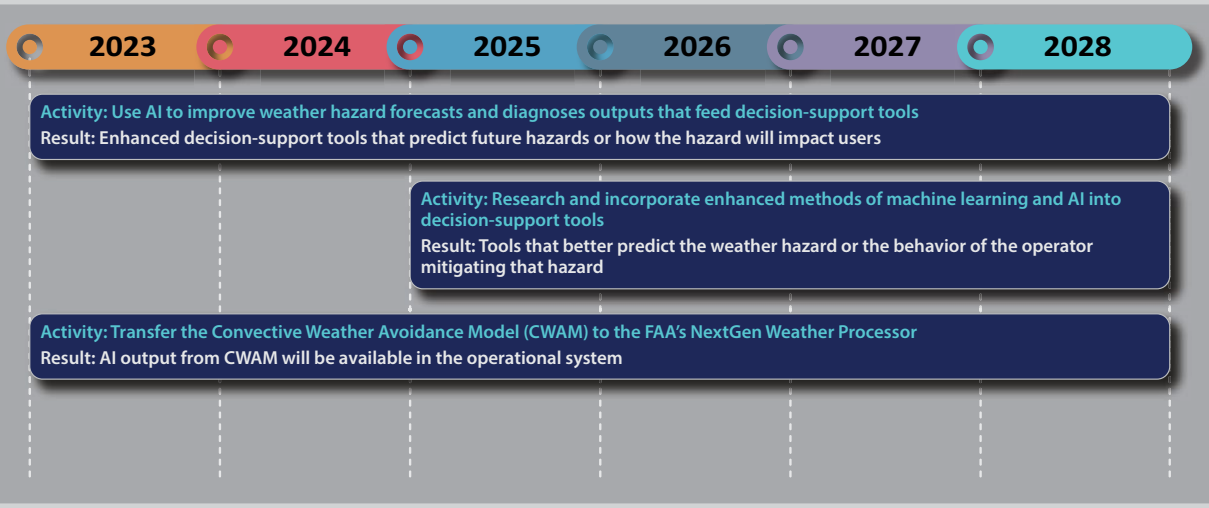
Using Artificial Intelligence for Weather Hazard Mitigation

Driver

Research how to best use artificial intelligence (AI) with an emphasis on providing a more accurate weather forecast or making the forecast tailorable to specific users based on the weather hazard

Outcome

Improve the accuracy of weather hazard information by incorporating AI into model development research and decision-support tools



Partners

Airline operations centers, National Laboratories, National Oceanic and Atmospheric Administration, National Weather Service, Academic institutions, Commercial weather providers and research companies

NextGen - Traffic Flow Management Portfolio

Air traffic managers use Traffic Flow Management procedures and capabilities to control overall traffic flow across the country and alleviate disruptions to ensure safety, efficiency, and equity in air traffic services.

Surface Tactical Flow

At most airports, aircraft departures are managed in the order they push back from the gate. This can overload runways and cause long taxi and hold times on the airport surface.

Holding aircraft longer at the gate allows air traffic controllers to shift some of the departure wait time away from the taxiway and prevent long departure queues. This saves fuel, reduces emissions, and gives air carriers and passengers more flexibility before pushback.

Precisely scheduling takeoffs to help aircraft better integrate into the overhead stream of air traffic increases NAS efficiency. Coordinating schedules between airport operators, air traffic controllers, and flight operators provides air traffic managers with tools to make better decisions about how to reduce congestion.

Current research will focus on implementing new capabilities for pilots and controllers to improve surface operations.

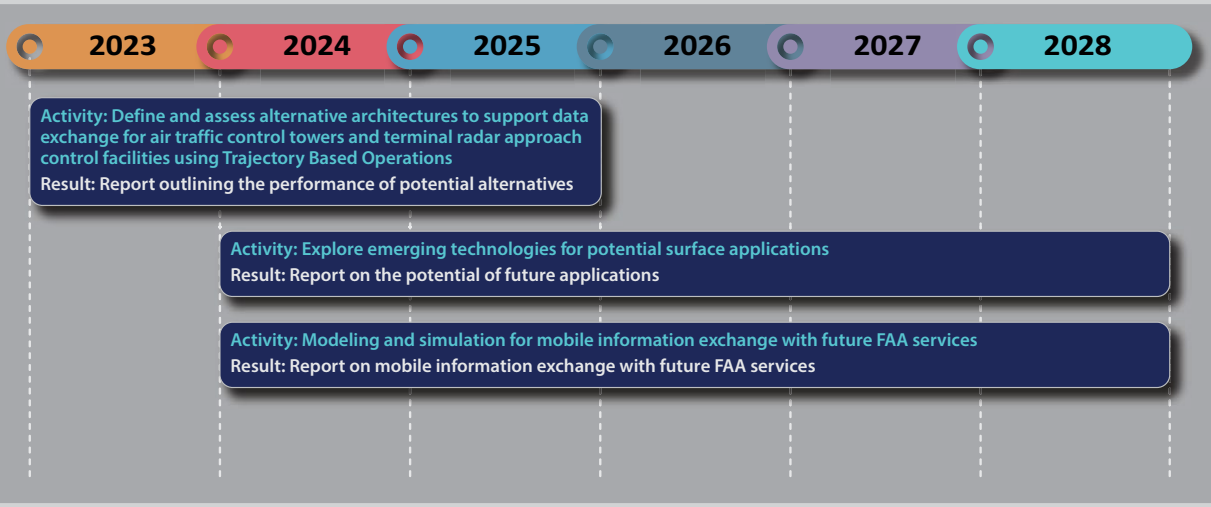
Benefits will include:

- **Enhanced situational awareness**
- **Increased arrivals and departures**
- **Improved use of airspace and ground assets by integrating surface and airspace operations**
- **Decreased environmental impact through reduced taxi time and fuel usage**

Surface Tactical Flow

DRIVER
Implement new capabilities for pilots and controllers to improve operations on the airport surface

OUTCOME
Improved safety, efficiency, and flexibility at airports across the National Airspace System



PARTNERS
NASA, MITRE

Strategic Flow Management Application

Air traffic managers often strategically reroute large numbers of aircraft to reduce congestion in a particular region of airspace due to constraints that diminish capacity. Reducing bottlenecks in one area of the country often increases delays in other parts of the NAS. Current research will identify ways to decrease the use of these large strategic reroutes.

The Strategic Flow Management Application (SFMA) uses AI and ML to help balance NAS-wide demand and capacity. SFMA includes automated, flight-specific route options that consider operator preferences, resources, potential weather impacts, and metering times — the timeframe in which an aircraft is instructed to arrive at a particular location.

This bolsters the ability of air traffic managers to prevent congestion, reduce unnecessary flying time, and improve the sequencing of aircraft to their destination while minimizing the impacts on overall NAS efficiency.

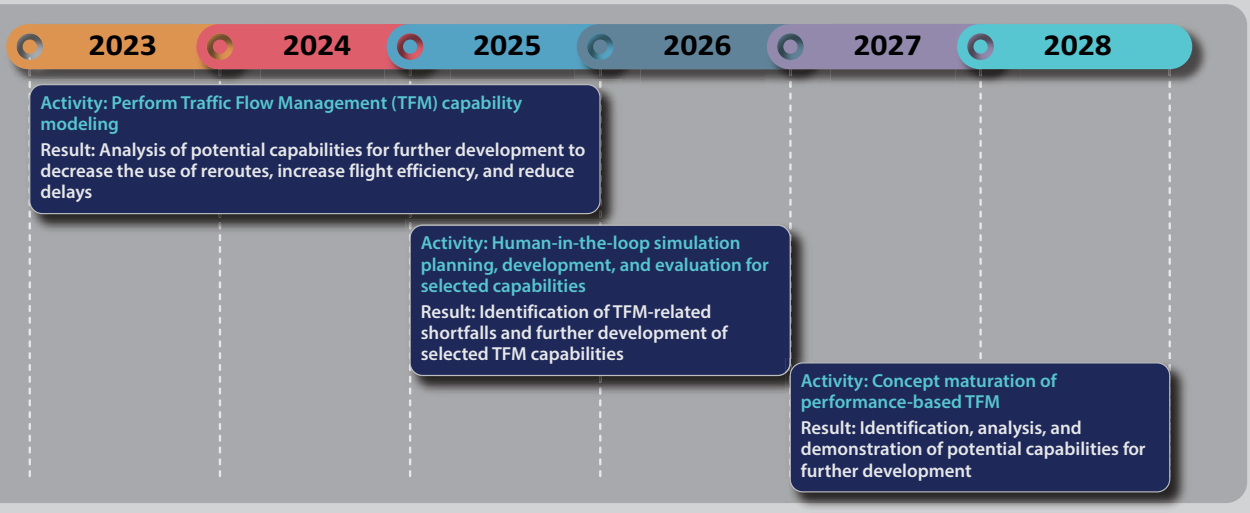
Strategic Flow Management Application

Driver

Develop new traffic flow management techniques and applications to reduce reroutes, delays, and environmental impacts by increasing flight efficiency

Outcome

Results will be used for further research and the development of investment analysis documentation for proposed Traffic Flow Management System enhancements



Partners

NASA

NextGen - Separation Management Portfolio

Separation Management improvements provide air traffic controllers with tools and procedures to safely reduce the required separation between aircraft that have various types of navigation equipment and wake turbulence performance capabilities. Allowing aircraft to safely take off and land closer to each other can translate into improved NAS reliability and predictability, fewer delays, and less fuel burn.

Wake Turbulence Recategorization

Wake turbulence, rotating vortices that form behind an airplane's wings as it flies through the air, can be hazardous to nearby aircraft.

The bigger the aircraft, the bigger the wake. Air traffic controllers must space out aircraft so the wake from one plane does not impact others behind it. By recategorizing wake standards, the FAA has safely decreased the required separation between certain aircraft.

Current research will focus on using Wake Recategorization to increase capacity when poor weather or other conditions require instrument flight rules (IFR) procedures.

The FAA will use research results to develop standards, processes, and decision-support tools for air traffic controllers, allowing them to increase takeoffs and landings at crowded airports.

This would result in fewer flight delays and cancellations — and reduced inflight operating costs — while ensuring the safety of the aircraft, crew, passengers, and cargo.

Wake Turbulence Recategorization

- **Driver**
  Improve airport capacity by safely reducing required wake turbulence separation during instrument meteorological conditions

- **Outcome**
  Controller automation tools that increase throughput at busy airports while minimizing wake safety risk

- **Partners**
  Air carriers, Air Line Pilots Association, International Civil Aviation Organization, Eurocontrol

NextGen - Separation Management Portfolio (continued)

Closely Spaced Parallel Runway Operations

Airports are typically most efficient when the weather is clear and calm. In these conditions, aircraft can take off and land at a steady pace using visual flight rules (VFR) separation standards.

This is not true when visibility deteriorates due to poor weather, which requires more restrictive IFR procedures.

Improving closely spaced parallel runway operations (CSPO) — side-by-side runways spaced less than 4,300 feet apart laterally — has allowed the FAA to develop procedures and tools to increase airport arrivals and departures in all weather conditions.

When VFR approaches are not possible due to low visibility, arrivals and departures at busy airports can still be significantly increased using simultaneous independent and dependent CSPO.

The program uses modern surveillance technology that more accurately displays an aircraft's position to reduce the separation standards required for these operations.

Research in this area will result in updates to advisory circulars by the FAA's Office of Airports and changes to the Air Traffic Control (ATC) Handbook through a document change proposal.

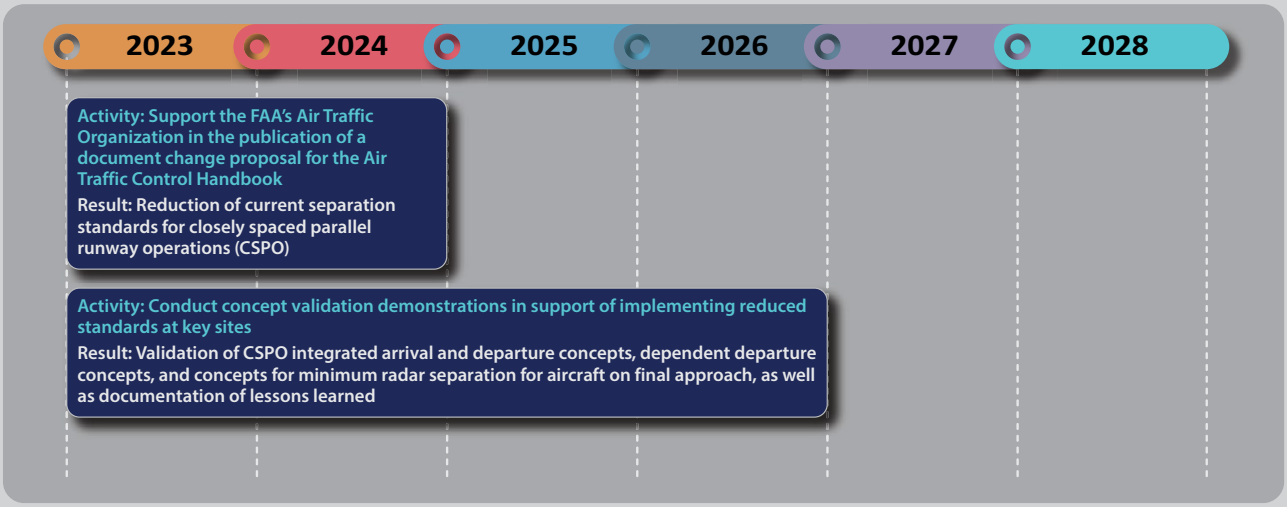
Current research continues to explore ways to increase takeoffs and landings by:

- **Safely reducing aircraft separation standards**
- **Expanding applications for dependent operations, which are staggered aircraft arrivals and departures on parallel runways**
- **Increasing the use of independent operations, which occur when two aircraft arrive or depart side by side**
- **Enabling operations in lower-visibility conditions**

Closely Spaced Parallel Runway Operations

DRIVER
Enable operations in lower-visibility conditions, as well as independent operations on closely spaced parallel runways

OUTCOME
Increase capacity through reduced separation standards



PARTNERS
National Air Traffic Controllers Association

NextGen - Separation Management Portfolio (continued)

Integrated National Airspace System Design and Procedure Planning

The FAA has established a network of thousands of precisely defined, satellite-enabled Performance Based Navigation (PBN) routes and procedures throughout the country to improve air traffic flow to and from airports through all phases of flight.

Current research builds upon the success of PBN procedures at select airports, specifically Established on Required Navigation Performance (EoR) and Multiple Airport Route Separation (MARS).

The EoR concept increases the use of instrument approach procedures that allow planes to turn to align with the runway sooner, reducing passenger time, track miles flown, fuel burn, aircraft emissions, and overall noise footprint while maintaining safety and capacity.

While EoR is used at one airport, MARS extends the EoR concept to multiple airports in close proximity, increasing throughput for both approaches and departures and reducing congestion in the surrounding airspace. Both concepts improve the repeatability and predictability of operations.

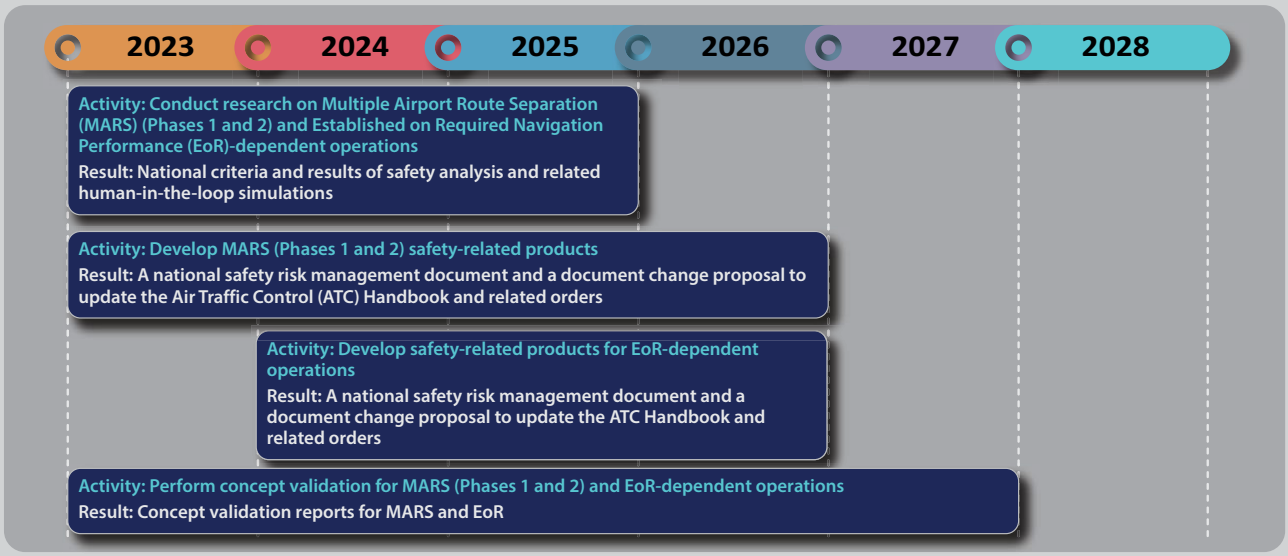
Initially driven by aviation industry priorities through the FAA's NextGen Advisory Committee to enhance air travel through the Northeast Corridor, the new goal of the MARS research is to create national standards.

This would allow more airports across the country to benefit from the concept. Safety analysis results will drive changes to the ATC Handbook and other criteria, which will be updated with new separation standards as positive results are known.

Integrated National Airspace System Design and Procedure Planning

- **Driver**
  Build upon the accuracy of Performance Based Navigation procedures to improve efficiency, access, and flexibility

- **Outcome**
  Research results and safety analysis criteria to inform changes to the ATC Handbook



- **Partners**
  NextGen Advisory Committee, National Air Traffic Controllers Association, Operators, Local airport representatives

NextGen - NAS Infrastructure Portfolio

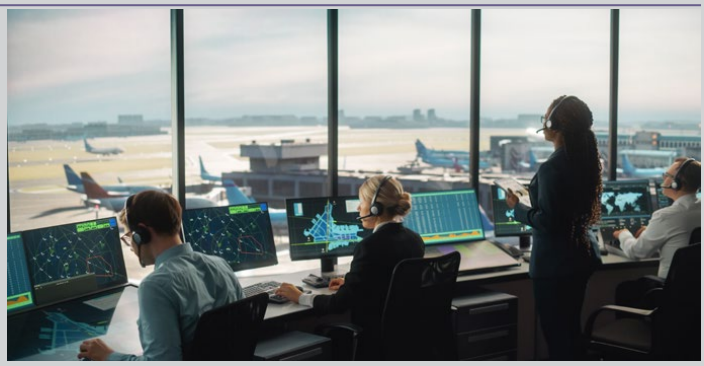
As technology evolves over time, the FAA researches, develops, and implements new support tools, technologies, standards, and guidance to improve ATM efficiency and effectiveness.

New Air Traffic Management Requirements

While ATC involves safely guiding aircraft to and from specific airports, ATM looks at air traffic from a nationwide perspective to balance air traffic demand with system capacity. The New ATM Requirements project studies ways to integrate new and emerging technologies to enhance tools for strategically managing aircraft.

One area of focus is creating and validating standards for the use of internet protocol (IP) networks to transmit air-to-ground and ground-based ATM data using the Internet Protocol Suite. These improvements will enable the following:

- **Future NextGen operations, including Trajectory Based Operations**
- **Increased security measures to protect the safety of critical applications**
- **Improved interoperability with other systems**
- **Additional support for current systems, such as Data Communications, System Wide Information Management, and weather and aeronautical data transmission**



New Air Traffic Management Requirements

DRIVER
Identify opportunities to improve strategic air traffic management through the development of new decision-support tools

OUTCOME
Increase airspace capacity through future standards tools, guidance, and applications

2023

Activity: Complete development of Internet Protocol Suite (IPS) standards, including performance standards validation
Result: Finalized versions of IPS RTCA Minimum Aviation System Performance Standards; IPS standards and recommended practices for the International Civil Aviation Organization with an accompanying technical manual, and Airlines Electronic Engineering Committee IPS form, fit, and function standards

Activity: Conduct large-scale demonstrations using the Boeing Eco-Demonstrator with IPS avionics and corresponding IPS ground gateway
Result: Verification that IPS data transmission meets performance requirements in an operational air traffic control environment and documentation to support a successful investment analysis readiness decision

2024

2025

Activity: Develop enhanced services applications, requirements documentation, and a security and safety assessment for the IPS Gateway
Result: Program documentation, including analysis reports and specifications to support the successful transmission of air-to-ground enhanced services using IPS

Activity: Conduct safety risk management analysis for using artificial intelligence (AI) to support air traffic controller functions
Result: Requirements for the potential use of AI to support controller functions

2026

PARTNERS
Airframe manufacturers, Avionics vendors, Air traffic service providers, Eurocontrol, Single European Sky Air Traffic Management Research

NextGen - NAS Infrastructure Portfolio (continued)

Weather for Forecast Improvements

Inclement weather, including thunderstorms, snowstorms, wind shear, icing, and fog, can create potentially hazardous conditions and often results in reroutes, flight delays, and cancellations. Accurate weather forecasts help air traffic managers, operators, and pilots better plan for poor weather, increasing safety and reducing delays.

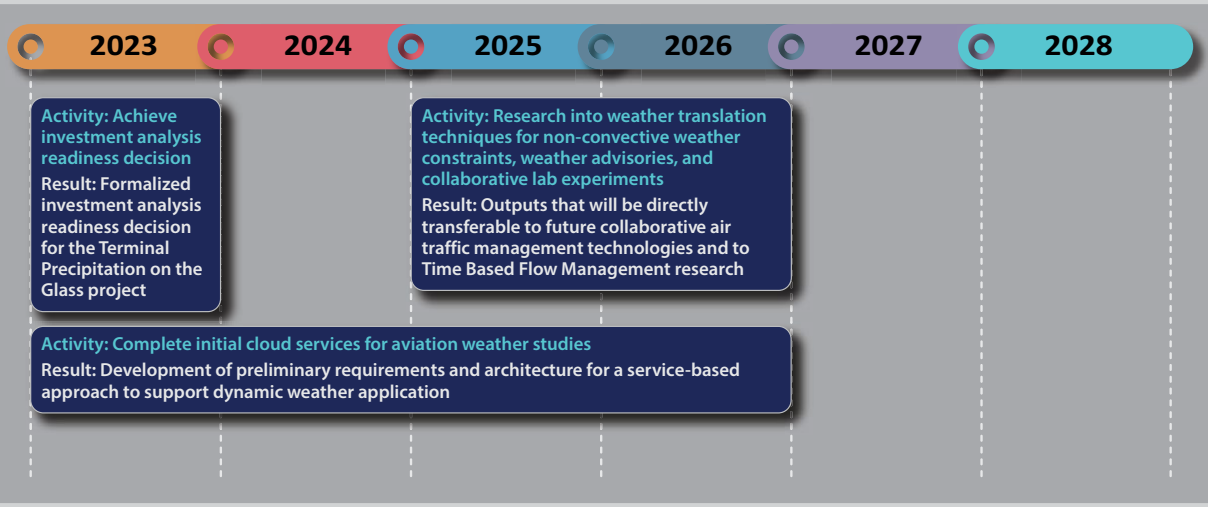
The Weather for Forecast Improvements project will study current tools available for obtaining aviation-related weather information and identify future needs for weather forecast information.

The goal is to provide more accurate information to the flight deck, enabling flight crews to make more informed decisions. The program will conduct tests, evaluations, and demonstrations to develop new weather products and ensure they are ready for safe implementation in the NAS.

Weather for Forecast Improvements

- **Driver**
  Improve forecast predictions and how weather information is disseminated in the National Airspace System

- **Outcome**
  Development of weather prediction services and recommendations on how to improve the use of weather information



- **Partners**
  National Weather Service

Continued Airworthiness

Certifying aviation parts and ensuring aircraft are airworthy is critical to the FAA's safety mission.

Effects of Different Platform Materials on Rotorcraft Testing

Preventing or delaying fuel-induced fires can provide critical time for passengers to exit a helicopter following a crash. Current FAA rotorcraft design requirements increase the level of safety in the event of a survivable crash by decreasing the likelihood or delaying the onset of a post-crash fire.

These requirements minimize crash-induced fuel tank leaks and contact with potential fuel ignition sources during and after a crash. This increases the time occupants have available to exit the aircraft before a post-crash fire becomes critical.

For a manufacturer to demonstrate full compliance with FAA requirements, a complete fuel tank structure filled with water to 80 percent capacity is dropped 50 feet in a controlled experiment. There must be no leakage after the drop. Breakaway fittings or flexible lines are required to prevent spillage from interconnecting tanks where motion created upon impact may create a hazard.

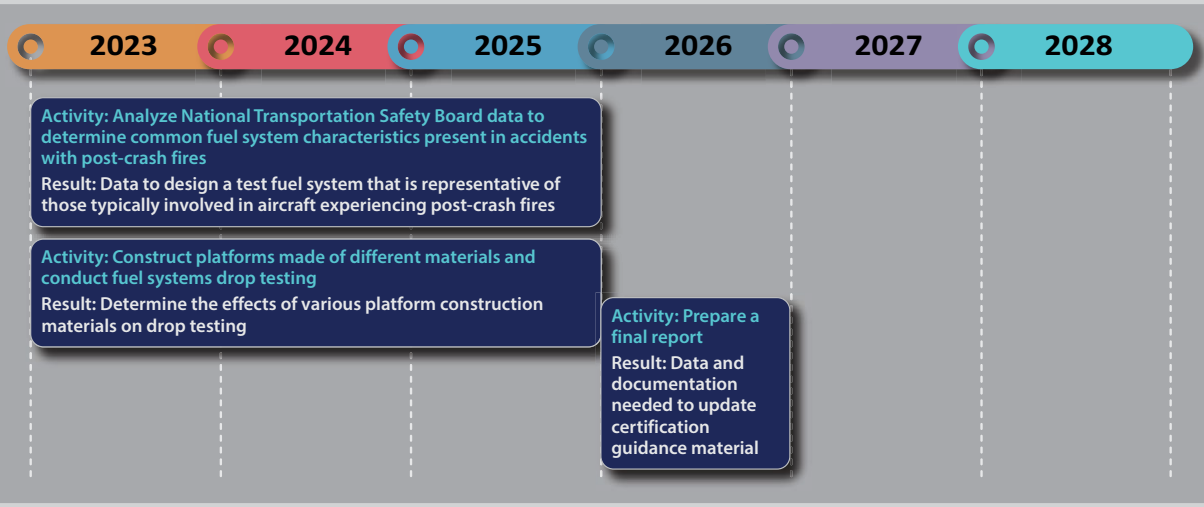
Researchers will study the effects of using different supporting structure materials used for rotorcraft fuel system drop testing as directed by Congress in the FAA Reauthorization Act of 2018, section 317.

The FAA will use the results to update guidance and standardize certification approaches across the rotorcraft industry to ensure the fuel system qualification process is representative of real aircraft conditions.

Effects of Different Platform Materials on Rotorcraft Testing

- **Driver**
  Research the effects of different supporting structure materials used in rotorcraft fuel system drop testing to ensure fuel system qualifications are representative of real aircraft conditions

- **Outcome**
  Update FAA guidance to standardize certification approaches across the rotorcraft industry



- **Partners**
  To be determined

Evaluating Air Transportation Concepts in a Simulated Environment

Robust aviation research and development (R&D) programs require specialized facilities that provide flexible and realistic environments to conduct research and perform human-in-the-loop simulations to evaluate advanced air traffic concepts.

Specialized Laboratories

The FAA's William J. Hughes Technical Center (WJHTC) in Atlantic City, NJ, and the Mike Monroney Aeronautical Center (MMAC) in Oklahoma City, OK, provide such environments where the agency's scientists and engineers can evaluate current and future air transportation system concepts and technologies to enhance the safety and efficiency of air travel for the American public.

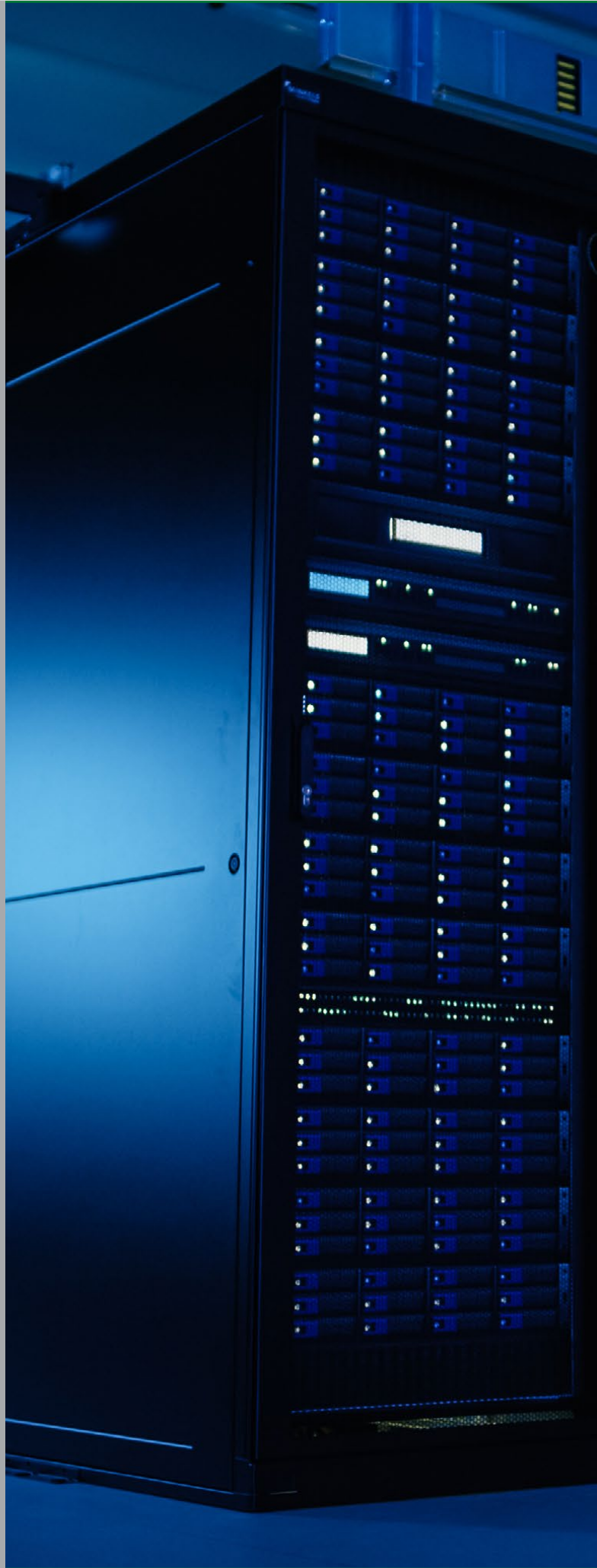
Performing research early during the concept development phase generates cost savings, is safer, and allows the study of extremes that would not otherwise be possible once deployed.

WJHTC R&D laboratories are fully integrated with other FAA and partner capabilities, including MMAC, and provide researchers with highly realistic environments, including the ability to emulate and evaluate field conditions.

Realistic Simulations

The laboratories include the following facilities:

- The Cockpit Simulation Facility at WJHTC operates multiple flight deck simulators representing the most common aircraft types in their respective classes, from commercial aircraft to general aviation planes and helicopters. The facility also maintains a graphics-based flight deck which is reconfigurable to any aircraft type. Researchers use human-in-the-loop simulations to evaluate air-to-ground interfaces, procedures, and processes from the operator's standpoint.



- The Target Generation Facility at WJHTC provides researchers with a dynamic real-time air traffic simulation capability to generate realistic aircraft trajectories and associated digital radar messages for aircraft in a simulated airspace environment. Researchers can use the equipment to create simulated targets in one or more concurrent simulation environments.

- The Research and Development Human Factors Laboratory at WJHTC is a multipurpose facility that includes integrated reconfigurable experiment rooms, each with an operator station (an attached room that serves as the central control point for each experiment.) Another experiment room offers an air traffic control (ATC) tower display. Depending on the specific experiment, researchers can use the rooms separately or together with distributed video, audio, computer, and voice communications.

- The NextGen Prototyping Network at WJHTC provides a highly-performing, scalable, and secure network environment for FAA and non-FAA partners to allow integration and collaboration while protecting critical FAA resources. The network allows the FAA to connect to multiple other facilities, including MMAC; the FAA's Florida NextGen Test Bed in Daytona Beach; NASA; and the Department of Defense (DoD).

- The Laboratory for Innovative and Future Technologies, located on the WJHTC campus at the National Aerospace Research and Technology Park, provides a location for aviation industry, academic, and government partners to work with the FAA to foster innovation and collaboration and promote sustained economic growth for the region and the aerospace industry.

- The Flight Research and Analysis Group located at MMAC operates two full flight simulators — a Boeing 737-800NG and an Airbus A330 with a 320 aero package. These devices provide real-time, realistic, dynamic virtual scenarios to observe and evaluate pilot/controller/aircraft interface and performance data within a defined or generic environment. Additionally, the group develops and conducts data collection through computer models and real-time simulations, including ATC and fast-time simulations.

Facility Upgrades

Researchers are working to enhance simulation and data reduction software to take advantage of new advances in biometric data collection, such as smartwatches and eye tracking. The upgrades will provide less intrusive data collection techniques that decrease the impact on participant performance, as well as improved validity and more accurate data.

The ability to partner and collaborate outside the agency fosters innovation in aviation. A current initiative will provide a network platform to further integrate FAA and partner networks and facilities to support research within the FAA and with other government agencies, the aviation industry, and academic partners. The changes will enhance current networks, add additional connections between WJHTC and the MMAC, and expand and update secure network connections with the DoD for joint cybersecurity activities.

2.3.2 Goal 2

Accelerate the use of new technologies for aerospace vehicles, airports, and spaceports

Key programs and initiatives:

The advancement and introduction of technologies from non-traditional aviation industries are reaching all corners of the NAS. Research under this goal supports applied innovation that identifies and demonstrates new aerospace vehicle, airport, and spaceport technologies; the certifying and licensing of aerospace operators and vehicles; and the study of alternative fuels for general and civil aviation, providing decision makers with essential data and analysis to shape the future of the NAS.

This research yields a safer, more efficient NAS with reduced environmental impacts and keeps pace with continuously changing technology to properly certify operators and operations of new industries, improve aircraft performance, and drive policy.

To achieve this goal, the FAA will:

- **Study potential unleaded and renewable replacement fuels for the existing fleet of general aviation aircraft**
- **Evaluate and demonstrate aircraft and engine technologies that can reduce aircraft noise and emissions while improving fuel efficiency; and conduct testing, analysis, and coordination activities to support the development and deployment of sustainable aviation fuels for gas turbine engines**
- **Examine the environmental impacts of supersonic aircraft and advance technological solutions to support their reintroduction into the nation's aircraft fleet**
- **Analyze airworthiness and safety certification of highly-integrated, complex digital aircraft systems**
- **Identify ways to detect and stop unauthorized drone activity without interfering with flight operations**
- **Research ways to make it easier for emergency responders to incorporate the use of drones during emergencies and to enhance disaster preparedness and response efforts**
- **Develop performance-based standards and test methodologies to ensure the durability, endurance, and reliability of electric engines**
- **Evaluate halon-replacement firefighting agents and update minimum performance standards for their use**
- **Develop vertiport standards and infrastructure to support vertical takeoff and landing aircraft operations**

Alternative Fuels for General Aviation

Alternative Fuels for General Aviation

General aviation supports 1.2 million jobs directly or indirectly and contributes over $247 billion to the U.S. economy, including a $75 billion positive effect on the trade balance (2020, General Aviation Manufacturers Association).

However, this economic benefit is at risk unless the fleet can safely transition to unleaded fuels. Aviation gasoline (avgas) is the only remaining transportation fuel in the United States that contains lead.

Over 220,000 piston-engine general aviation aircraft currently in use rely on this fuel for safe operation. These airplanes and helicopters support essential needs, including medical flights and emergency services.

In some cases, these aircraft are the only available method of travel and are crucial to transporting life-sustaining food and supplies for people living in the most remote areas of the United States, such as parts of Alaska.

The lead additive in avgas creates the very high-octane levels required to prevent detonation (engine knock) in high-power aircraft engines. Operating an aircraft with inadequate fuel octane can result in engine failure and aircraft accidents.

The FAA is working closely with the aviation industry on research that will provide the critical data necessary for the FAA Administrator to authorize an unleaded replacement fuel under section 565 of the FAA Reauthorization Act of 2018.

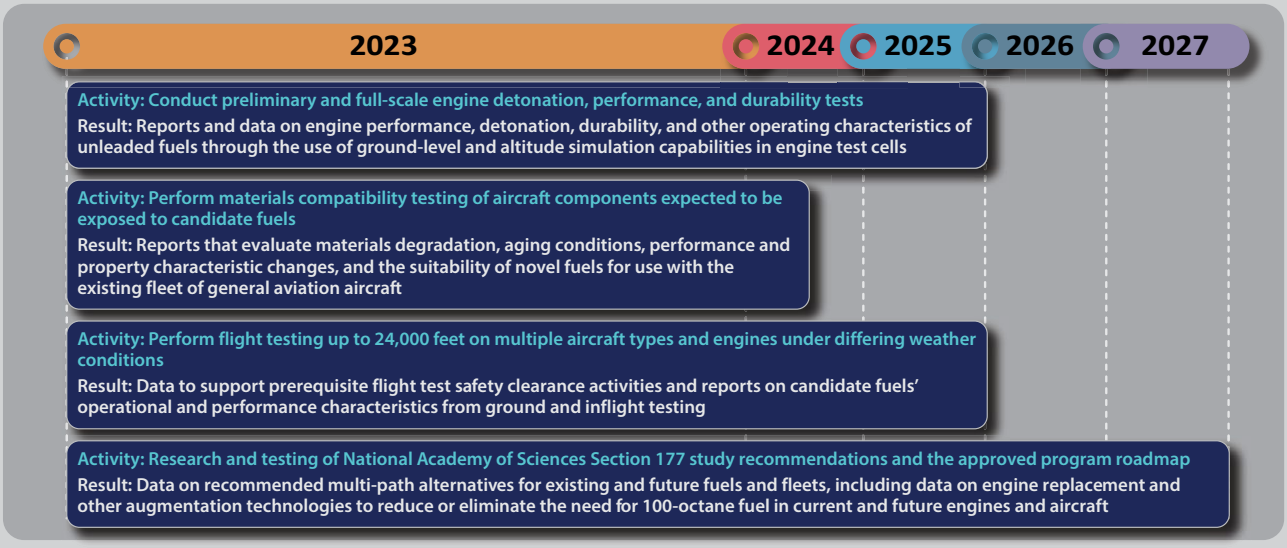
Alternative Fuels for General Aviation

Driver

Facilitate the development and introduction of an unleaded replacement fuel for the general aviation fleet

Outcome

Research results that inform the FAA Administrator's decision to authorize an unleaded aviation gasoline alternative for the general aviation fleet



Partners

Aircraft Owners and Pilots Association, General Aviation Manufacturers Association, National Air Transportation Association

Aircraft Pilot and Aviation Maintenance Workforce Training Programs

More than 800,000 new pilots and 750,000 new aviation technicians will be needed to sustain worldwide aviation over the next two decades.

The FAA's Aviation Workforce Development Grant Program supports eligible projects that help develop a future aircraft pilot and aviation maintenance workforce through education, apprenticeships, scholarships, recruitment, or career transition programs, as directed by Congress in section 625 of the FAA Reauthorization Act of 2018.

The agency has awarded 54 grants totaling $20 million to universities, colleges, high schools, state and local governments, and organizations to educate or train individuals pursuing careers as aircraft pilots or aviation maintenance technicians.

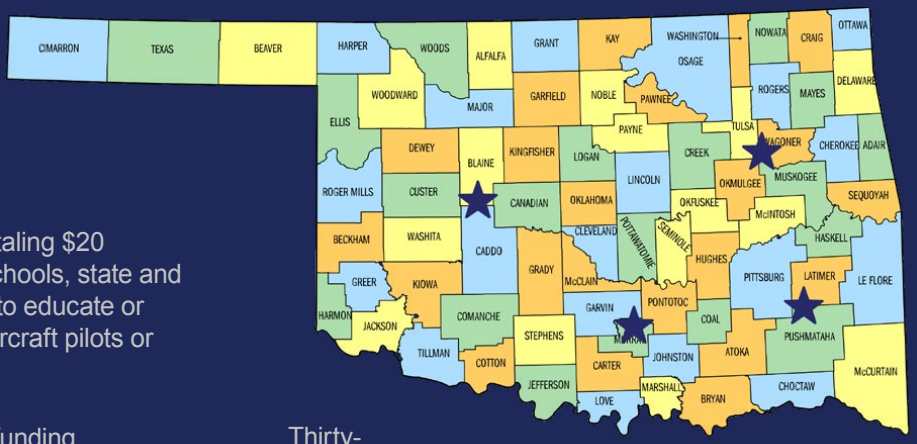
The agency released a third notice of funding opportunities for the grant program in July 2023 and expects to make awards in the second quarter of Fiscal Year 2024.

The grant program supports the administration's principles of rebalancing investments to meet racial equity and economic inclusion goals and Executive Order 13985, "Advancing Racial Equity and Support for Underserved Communities through the Federal Government."

The program is pursuing a comprehensive approach to advancing equity for all, including people who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality.

Program Impact

The Oklahoma Aeronautics Commission (OAC) is creating learning pathways to grow the aircraft pilot industry for years to come. OAC provides students with opportunities to pursue post-secondary aviation programs and careers through an FAA Aircraft Pilot Workforce Development Grant.



Thirty-two educators at 28 high schools across Oklahoma teach aviation content through the program based on Aircraft Owners and Pilots Association (AOPA) curriculum. Ada High School graduate John David Muse is already making progress toward his aviation goals through the program.

"I am very grateful for the opportunity to enroll in aviation coursework while in high school. Because of what I learned, I have been accepted to the Southeastern Oklahoma State University School of Aviation Sciences where I will work to obtain a professional pilot degree," he said.

Muse is among hundreds of Oklahoma students benefitting from the FAA grant program. A total of 341 students (76 female and 265 male) are participating, including 201 from geographically disadvantaged areas.

The OAC and its statewide partners designated four exemplary high schools to serve as Aviation High Schools of Excellence for this program. The schools, located in key areas of the state, support surrounding school districts as they implement the AOPA curriculum and post-secondary pathways to aviation careers.

NextGen - Environmental Research - Aircraft Technologies and Fuels

Assess and Demonstrate Aircraft and Engine Technologies that Can Reduce Aircraft Noise and Emissions while Improving Fuel Efficiency

Through the Continuous Lower Energy, Emissions, and Noise (CLEEN) program, the FAA is working with the aviation industry to develop certifiable aircraft and engine technologies that increase fuel efficiency while reducing noise, emissions, and aircraft operating costs.

CLEEN is a cost-share partnership with aviation manufacturers that helps accelerate environmentally beneficial technologies. These development efforts culminate in full-scale ground and flight test demonstrations, which ultimately support deploying these technologies into the NAS. CLEEN aims to achieve environmental protection that enables sustained aviation growth. The program is implemented in five-year phases, each with specific improvement goals.

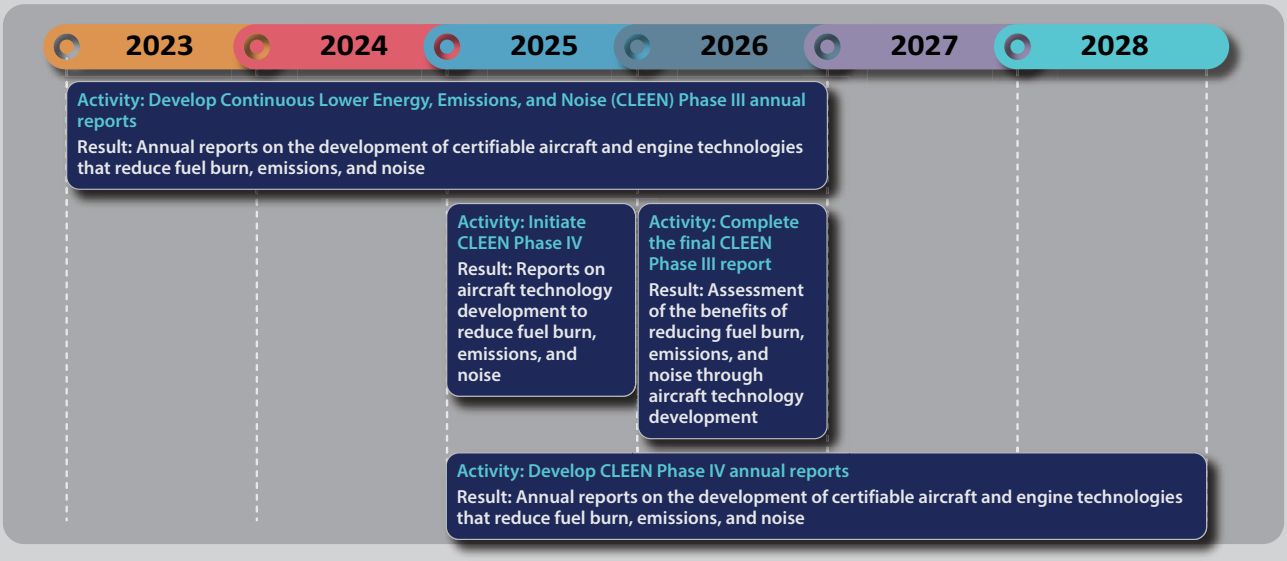
In Phase III of the program, which began in 2021, research focuses on reducing certification noise levels, community noise, nitrous oxide, particulate matter emissions, and fuel burn for subsonic and supersonic aircraft. The FAA will determine goals for Phase IV in the coming year, with an expected program launch in 2024 to 2025, depending upon the available budget.

Researchers in the CLEEN program are also working with the Commercial Aviation Alternative Fuels Initiative and the Center of Excellence for Alternative Jet Fuels and Environment (ASCENT) to obtain critical information on sustainable aviation fuels to ensure they are safe for use. ASCENT researchers are working closely with the FAA to ensure these fuels are adequately credited under international emissions standards.

Assess and Demonstrate Aircraft and Engine Technologies that Can Reduce Aircraft Noise and Emissions while Improving Fuel Efficiency

- **Driver**
  Quiet, clean, and efficient air transportation that removes environmental constraints on aviation growth

- **Outcome**
  New aircraft technologies accelerated into the fleet to reduce fuel burn, emissions, and noise



- **Partners**
  Aircraft manufacturers, Engine manufacturers, NASA, Center of Excellence for Alternative Jet Fuels and Environment

Supersonic Aircraft

By flying faster than the speed of sound, supersonic aircraft may one day allow passengers to spend more time at their destinations and less time traveling there. The DOT and the FAA are taking steps to advance the development of civil supersonic aircraft. This research is critical to accelerating the reintroduction of these high-speed aircraft into the nation's fleet.

Work examines the environmental impacts of supersonic aircraft, such as landing and takeoff noise, emissions, fuel burn, and sonic booms. The FAA will use the research results to develop policies and international standards and support analytical methods development for noise mitigation technologies as directed by Congress in the FAA Reauthorization Act of 2018, section 181.

At present, there are potentially two generations of supersonic airplanes. Generation 1 aircraft would fly supersonically over the oceans but subsonically over land. These aircraft would use technological advances to reduce their environmental impact relative to the Concorde — a supersonic aircraft introduced in the early 1970s that was ultimately retired two decades later.

Generation 1 aircraft would still produce a strong sonic boom when flying beyond Mach 1 (faster than the speed of sound). Generation 2 supersonic airplanes would use advanced airframe technology to mitigate the severity of sonic booms and potentially enable supersonic flight over land.

Supersonic Aircraft

Driver
Examine the impacts of reintroducing supersonic flight, including understanding aircraft engine parameters and improving the prediction of supersonic aircraft noise

Outcome
Support domestic rulemaking and international standards setting

2023

- **Activity: Model and measure the basics of supersonic jet noise**
  Result: Multi-fidelity methods that will enable reliable noise reduction estimates for takeoff and landing jet noise

2024 2025

- **Activity: Conduct clean sheet supersonic engine design and performance analyses**
  Result: Data to inform decision making on fuel burn, emissions, and noise impacts of clean sheet and derivative propulsion systems, providing a roadmap for technology development

2025 2026

- **Activity: Develop landing and takeoff noise standards and recommended practices at ICAO for Generation 1 supersonic airplanes**
  Result: Globally-accepted landing and takeoff noise standards and recommended practices for new Generation 1 supersonic airplanes, which will provide manufacturers with the regulatory certainty needed to complete their designs

2026 2027 2028

- **Activity: Develop low sonic boom standards and recommended practices at ICAO for Generation 2 supersonic airplanes flying in en route airspace**
  Result: Globally-accepted low sonic boom standards and recommended practices for new Generation 2 supersonic airplanes, which will enable potential supersonic flight over land

Partners
International Civil Aviation Organization (ICAO), Airframe and engine manufacturers, Center of Excellence for Alternative Jet Fuels and Environment, NASA

Accelerating the Development of Emerging Technologies

The FAA is an incubator for new and emerging technologies for air and space travel. The agency actively engages with innovators across the country to develop creative solutions for current and future aviation challenges, such as advanced air mobility, unmanned aircraft systems, unmanned traffic management, commercial space, electric propulsion systems, vertical takeoff and landing vehicles, and other new concepts.

Through these partnerships, the FAA can provide a path for entrepreneurs to rapidly mature promising technologies and transfer them to the aviation industry while allowing the agency to leverage these emerging technologies and respond more quickly to operational challenges.

The agency aims to attract talent from all sectors of society, lower the barriers to presenting promising technology to aviation stakeholders, and create a space for meaningful solution demonstration and validation through the use of the FAA's science and technology infrastructure.

The laboratories and staff at the FAA's William J. Hughes Technical Center in Atlantic City, NJ, and Civil Aerospace Medical Institute in Oklahoma City, OK, provide relevant settings for technology demonstrations and readiness evaluations.

By engaging with innovators, the FAA can:

- **Increase agility for rapidly addressing emerging air transportation needs**
- **Align research and development activities with known and forecasted challenges and opportunities in the aviation industry**
- **Address statutory requirements by investing in longer-term research**
- **Influence and shape the air transportation system of the future**

The FAA's objective is to advance selected innovation proposals from initial consideration through maturity and out to academia and industry using technology transfer tools and mechanisms. The agency will emphasize inclusion and equitable access to growth opportunities by extending the program's reach to traditionally underserved communities through outreach and partnership efforts.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Digital System Safety

Complex Digital Systems

Aircraft are increasingly dependent on highly-integrated complex digital avionics and flight control systems, which continue to evolve due to technological innovations and a desire by the aviation industry to reduce costs and lessen the time it takes to get new products to the marketplace.

This makes it difficult for researchers and standards-setting bodies to thoroughly test new technologies under various normal and abnormal operating conditions. If one of these critical systems were to fail, it could result in the loss of the aircraft and a loss of life.

Adding to concerns, the aviation industry is proposing the increased use of AI and ML in critical aviation systems. However, little is known about the validation and verification of AI and ML in a safety-critical environment. Industry is also proposing the use of autonomous (non-piloted) aircraft under conditions where regulations and guidance do not currently exist. These new technologies could introduce unknown risks if not adequately addressed early in the research, development, test, and evaluation cycle.

Research will focus on analyzing airworthiness and safety certification of highly-integrated complex digital aircraft systems, including software and airborne electronic hardware, such as autopilots, flight controls, and engine controls, as well as the use of AI and ML in these products.

The FAA will use the data and results of the research to create policy and guidance for the certification and means of compliance for new aircraft and systems using these technologies.

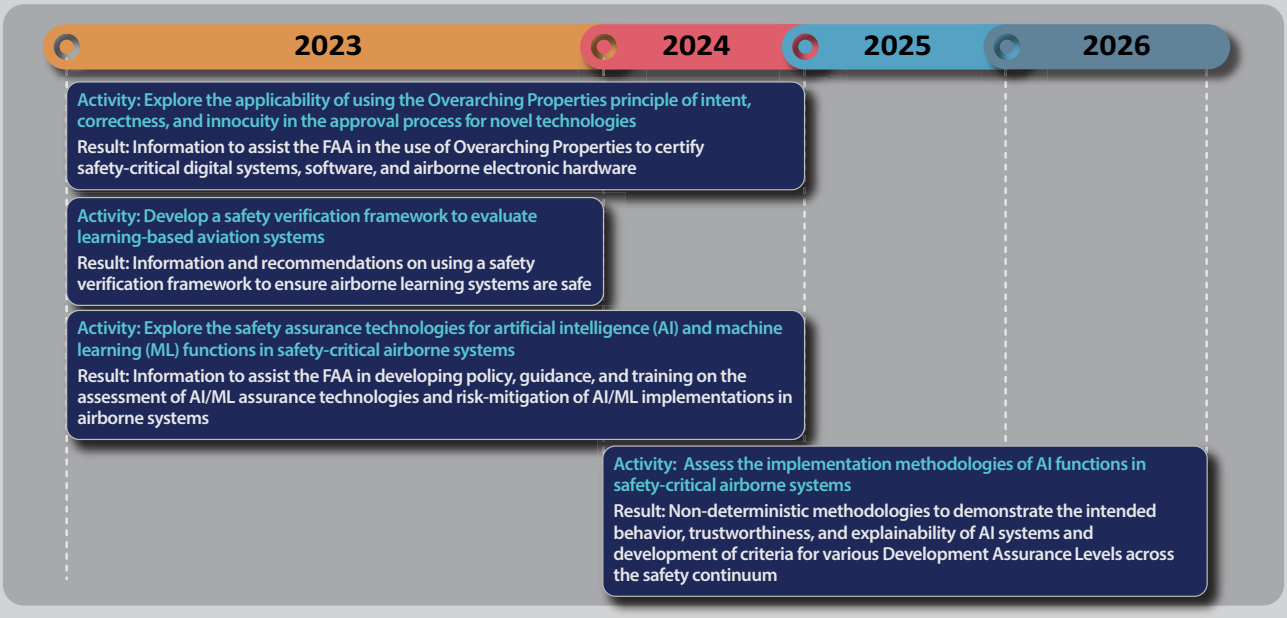
Complex Digital Systems

Driver

Ensure the continued safety of evolving highly-integrated complex digital airborne systems

Outcome

Implementation and safety assurance methodologies to demonstrate an acceptable means of compliance for these evolving systems, certification criteria, and information to train certification engineers



Partners

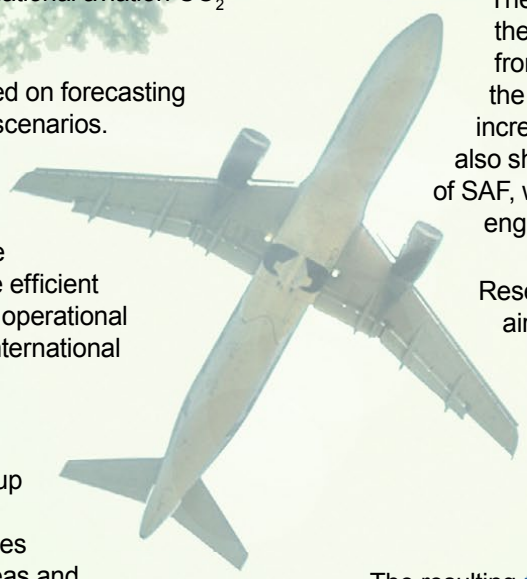
NASA, Department of Defense, Software Engineering Institute, Boeing, GE Research, Airbus, Honeywell, Aerospace Vehicle Systems Institute, University of West Virginia, George Washington University

FAA Spearheads Effort to Reduce Global Aviation Carbon Dioxide Emissions

Carbon dioxide (CO_2) emissions are the primary driver of aviation's climate impacts. While aviation currently accounts for two to three percent of global CO_2 emissions, this share is projected to increase as aviation continues to grow. International aviation and high-altitude flight represent the majority of these emissions.

The FAA played a leading role in efforts by the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) to assess the feasibility of a long-term aspirational goal for international aviation CO_2 emissions.

A CAEP task group worked on forecasting emissions under various scenarios. Researchers focused on how different levels of development and deployment of sustainable aviation fuels (SAF), more efficient aircraft technologies, and operational measures could reduce international aviation CO_2 emissions.



The FAA provided direct leadership in the task group through its conclusion in 2022, with U.S. nominees co-leading many work areas and contributing in the following ways:

- **Providing technical expertise across all areas, examining the potential of fuels, aircraft technology, and operations to reduce CO_2 emissions in the future**
- **Organizing participation by experts from multiple government agencies**
- **Coordinating efforts across the FAA's Environment and Energy Research and Development portfolio and the federal government to deliver a robust analysis based on the best available data**

Research projects under the Center of Excellence for Alternative Jet Fuels and Environment (ASCENT) — led by the Massachusetts Institute of Technology, Washington State University, and the Georgia Institute of Technology — provided analysis critical to the projection of the potential of SAF and more efficient aircraft and engine technologies to reduce CO_2 emissions.

Building upon these efforts, the Department of Transportation's Volpe National Transportation Systems Center integrated the projected benefits of these different solutions to provide global forecasts of CO_2 emissions through 2070 under various scenarios.

The resulting analyses show the scope of the challenge of reducing CO_2 emissions from international aviation, especially as the number of operations is projected to increase in the future. However, the results also show the massive potential and importance of SAF, which can be used in today's aircraft and engines to reduce lifecycle CO_2 emissions.

Research and development of more efficient aircraft and engine designs will be vital to reducing the amount of fuel and energy needed to fly these future operations, while operational efficiencies will be modest as the objectives of capacity and throughput of the airspace are maintained.

The resulting *technical report*, published by the ICAO Council in March 2022, formed the technical basis for discussions on the long-term aspirational goal at the ICAO High-level Meeting, which took place in Montreal in July 2022.

Results from this study were presented at the 41st ICAO Assembly, paving the way for a decision to adopt a goal of net zero CO_2 emissions from international aviation by 2050. This aligns the world's aviation CO_2 goals with those set by the United States under the 2021 U.S. Aviation Climate Action Plan.

Building the Infrastructure to Support Emerging Advanced Air Mobility

Advanced air mobility (AAM) is an emerging transportation system that could change how we travel across a town or city or to and from rural areas of the country. AAM uses developing technologies, such as vertical takeoff and landing (VTOL) aircraft, to transport people or cargo short distances. AAM aircraft could one day be used as air taxis, to transport large cargo, or to help with firefighting, air ambulance, or search and rescue operations.

The agency is working to establish operational rules, AAM pilot training standards, and how to integrate these new vehicles into the National Airspace System. A central part of the FAA's AAM research focuses on the takeoff and landing infrastructure, called vertiports, needed to support this exciting new way of travel.

The FAA coordinates with other federal entities, such as the National Renewable Energy Laboratory and aviation industry partners, to conduct AAM and vertiport research. These efforts help identify AAM-related safety risks and ensure that vertiport design standards make AAM possible in rural, suburban, and urban environments.

The agency is working with NASA on the *AAM National Campaign* to help communities across the country learn about AAM. The FAA and NASA are also testing AAM concepts through this partnership, including automated flight plan communications, beyond-visual-line-of-site, traffic avoidance, trajectory management, and approach to landing and takeoff areas.

The timing is right for more research in this area. The FAA canceled the previous advisory circular (AC) on Vertiport Design (AC 150/5390-3) due to a lack of compatible aircraft. Now that VTOL technology has matured, the agency is developing new guidance.

While a new advisory circular is still in development, the FAA has issued *Engineering Brief No. 105 on Vertiport Design*, which provides interim vertiport design guidance for VTOL operations until more comprehensive, performance-based guidance is developed. Current and future research will provide the groundwork the FAA needs to establish policies and vertiport guidance to ensure the AAM system is safe and effective.

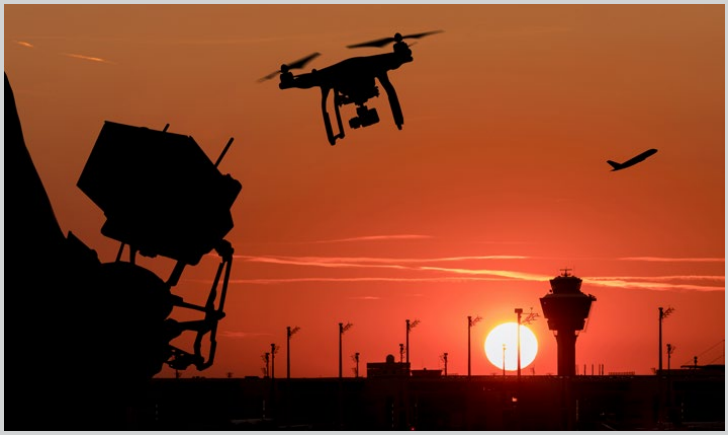
Unmanned Aircraft Systems Research

Unmanned Aircraft Systems Detection and Mitigations at Airports

Detecting unauthorized UAS, or drone, activity at the nation's airports and removing that threat ensures the safety and security of the flying public.

Research will identify regulations and standards necessary for the safe use of counter-UAS technologies that do not adversely impact or interfere with safe airport operations, air navigation, air traffic services, or the safe and efficient operation of the NAS — as directed by Congress in the FAA Reauthorization Act of 2018, section 383.

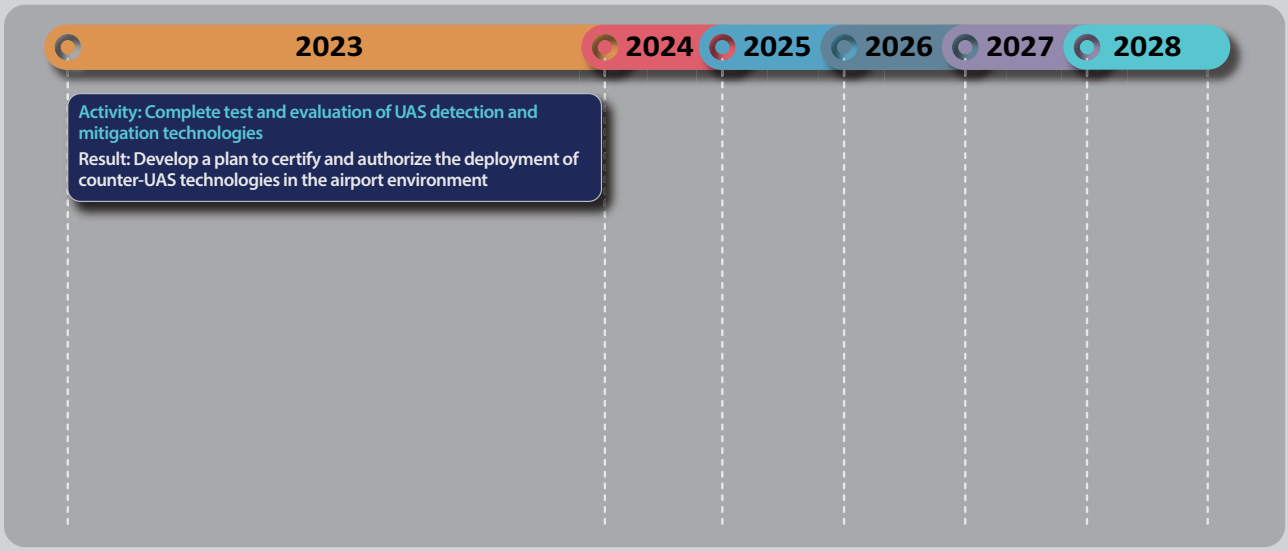
The FAA will test drone detection and mitigation systems at five airports as part of this research.



Unmanned Aircraft Systems Detection and Mitigations at Airports

Driver
Test and evaluate counter-unmanned aircraft systems (UAS) technologies that can detect and mitigate threats without impacting National Airspace System operations

Outcome
Develop a plan to certify and authorize the deployment of counter-UAS technologies in the airport environment



Partners
Airport operators, Department of Homeland Security, Department of Defense, Department of Justice, Transportation Security Administration

Unmanned Aircraft Systems Research (continued)

Unmanned Aircraft Systems Disaster Preparedness and Emergency Response

The real-time capabilities and versatile functions of drones and their ability to deploy rapidly make them powerful tools during emergencies and for disaster preparedness and response. Drones can improve these operations and help save lives.

Research will focus on creating procedures that help facilitate coordination between local, state, and federal government agencies to ensure proper coordination during disaster and emergency response situations.

Specific emphasis will be given to expanding the role of the FAA's UAS center of excellence in transportation disaster preparedness and emergency response as directed by Congress in the 2018–2022 omnibus budget appropriations.

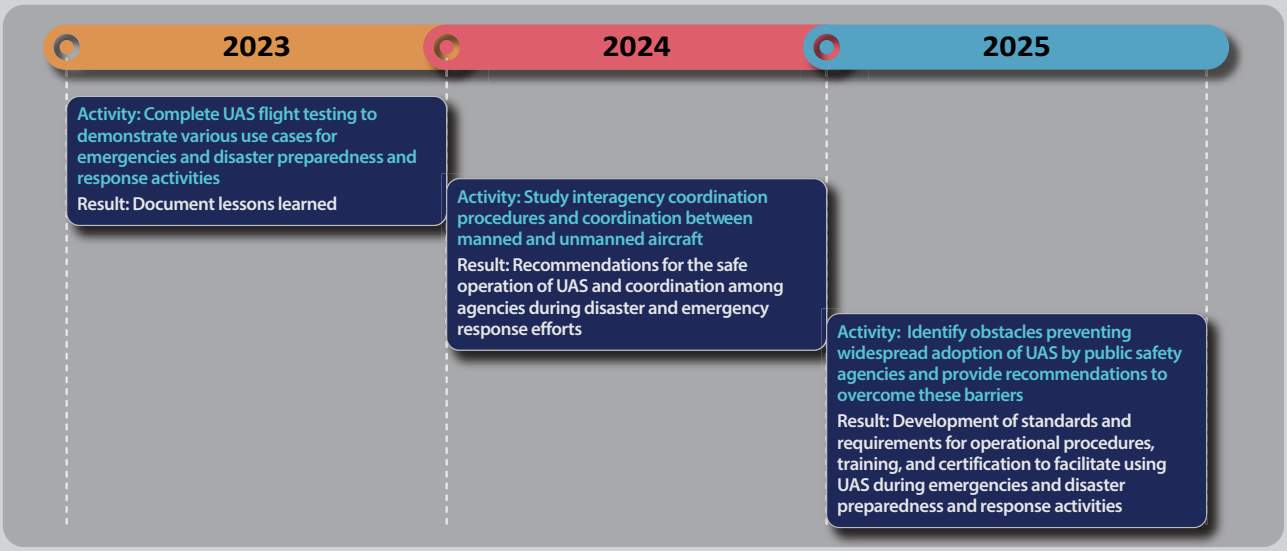
Unmanned Aircraft Systems Disaster Preparedness and Emergency Response

Driver

Increase the use of unmanned aircraft systems (UAS) during emergencies, and for disaster preparedness and response, by removing barriers to adoption and enhancing interagency communication

Outcome

Develop requirements, technical standards, policies, procedures, guidelines, and regulations to enable emergency and disaster preparedness and response operations for UAS



Partners

Alliance for System Safety of Unmanned Aircraft Systems through Research Excellence, Department of Homeland Security, Federal Emergency Management Agency, NASA, Department of Commerce, National Oceanic and Atmospheric Administration, National Institute of Standards and Technology, Department of Agriculture, U.S. Forest Service; State and local governments

Sustainable Aviation Fuel Grand Challenge

Supporting the growing demand for air travel while reducing aviation's impact on the climate is an ongoing challenge. The aviation industry is pursuing a combination of aircraft technologies, operational improvements, carbon offsetting, and sustainable aviation fuels (SAF) to decrease aviation's environmental impact.

SAF offers the best near-term solution to rapidly reduce aviation greenhouse gas emissions. The drop-in replacement for jet fuel is produced from wastes, renewable materials, and gaseous carbon sources that achieve a minimum of a 50 percent reduction in lifecycle greenhouse gas emissions. This means SAF can be used in today's aircraft and engines to reduce aviation's climate impact.

In September 2021, the Secretaries of Transportation, Energy, and Agriculture signed an agreement to launch a government-wide *Sustainable Aviation Fuel Grand Challenge*, committing the agencies to work with stakeholders to reduce costs, enhance sustainability, and expand the production and use of SAF. The goals of the SAF Grand Challenge are to supply at least three billion gallons of SAF per year by 2030 and, by 2050, sufficient SAF to meet 100 percent of aviation fuel demand — projected to be around 35 billion gallons per year.

The FAA is playing a leading role in developing and implementing the SAF Grand Challenge. The agency is working closely with the Department of Transportation's (DOT) Office of the Secretary, the Department of Energy (DOE), the U.S. Department of Agriculture (USDA), the Environmental Protection Agency, and other federal agencies to implement a roadmap of actions to support the achievement of the Grand Challenge goals.

The *SAF Grand Challenge roadmap* creates a coordinated approach for federal actions that de-risk technology, supply chains, and markets and reduce barriers across six action areas spanning the SAF supply chain.

The roadmap emphasizes:

- **Innovation in SAF raw material production**
- **Improvements in technologies for producing SAF**
- **Investment in production infrastructure**
- **Data collection and analysis to support effective SAF policies**
- **Elimination of barriers to distribution and end use of SAF**
- **Engagement with stakeholders to build, support, and communicate progress toward the goal**

The FAA is providing critical support to roadmap activities. The agency's research and development (R&D) efforts fund efficient and cost-effective safety and performance testing and evaluation of new SAFs through the Continuous Lower Energy, Emissions, and Noise program and the Center of Excellence for Alternative Jet Fuels and Environment (ASCENT) ASTM Clearinghouse. FAA-funded ASCENT projects with Washington State University, Massachusetts Institute of Technology, Purdue University, University of Tennessee–Knoxville, and University of Hawaii are evaluating:

- **SAF economics**
- **Environmental impacts**
- **Policy incentives**
- **Infrastructure needs**
- **Supply potential**

These efforts are integrated with FAA funding for the DOT's Volpe National Transportation Systems Center. Together, this work is creating tools to support the build-out of SAF supply chains across the United States and globally.

The SAF Grand Challenge shows that the U.S. government, across multiple agencies, is committed to SAF research, development, and deployment. In combination with DOE and USDA, FAA R&D investments will create an environment where feedstock producers adopt best practices to reduce emissions, regional collaborations come together to maximize economic and social benefits in developing SAF, and fuel producers ultimately choose to produce and sell SAF to aviation end users.

Propulsion and Fuel Systems

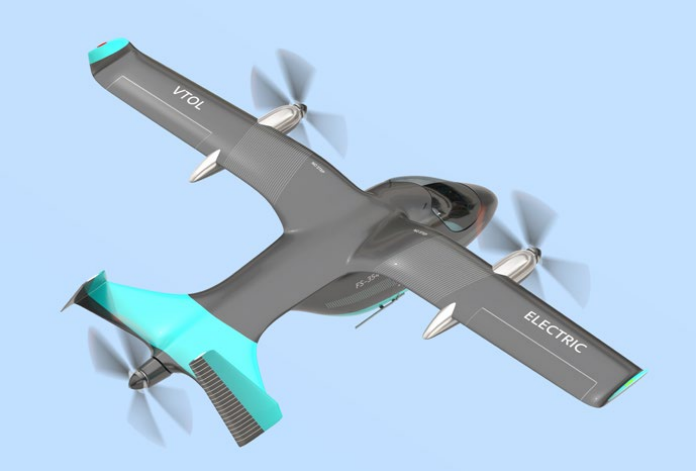
Electric Propulsion Certification Standards

The aviation industry is researching electric propulsion systems to potentially decrease aircraft emissions and reduce dependence on fossil fuels. Companies are pursuing electrically-propelled designs in various aircraft types, including fixed-wing airplanes, large air carriers, and rotorcraft.

New propulsion system designs differ significantly from traditional fossil fuel-powered systems and necessitate new certification rules. Although such guidance exists for electric cars, the standards are not directly applicable due to the difference in operating voltage and environmental conditions experienced during flight.

The FAA is developing performance-based standards and test methodologies to ensure the durability, endurance, and reliability of electric aircraft engines. The research will address the effect of environmental impacts, such as altitude, humidity, and temperature, on electric engines.

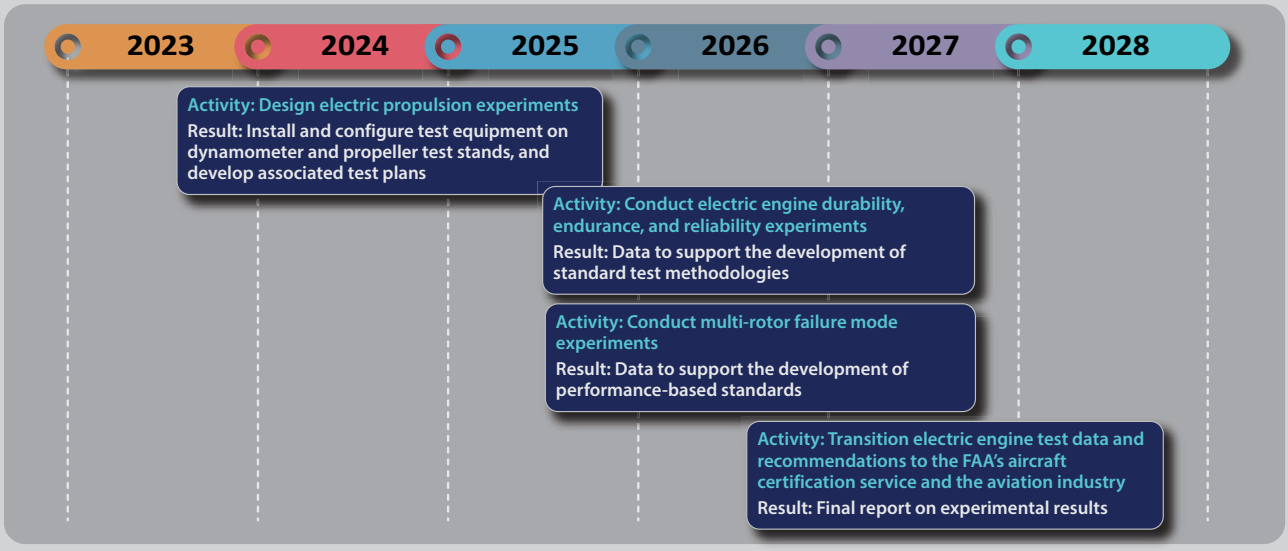
Researchers will also analyze the hazards associated with the failure of one or more electric engines in a multi-engine electric propulsion system.



Electric Propulsion Certification Standards

Driver
Research the impacts of various loads and environmental conditions on electric aircraft engines to ensure safe operations

Outcome
Develop a set of required operating conditions that an electric engine must endure to prove it will be safe throughout its service lifetime



Partners
SAE International, Department of Defense

Fire Research and Safety

Aircraft Halon Replacement

Aircraft halon replacement research focuses on assisting the international aviation community with testing environmentally safe halon-alternative fire suppression agents for use in cargo compartments, engines, auxiliary power units, lavatory trash receptacles, and hand-held fire extinguishers.

The FAA collaborates with aviation industry partners to test firefighting agents with unique characteristics not envisioned when the agency developed minimum performance standard (MPS) test methods for non-halon agents.

Qualification testing of new firefighting agents provides mutual benefits to the participating parties. The aviation industry gains halon-alternative agents that meet Environmental Protection Agency and FAA requirements, and the FAA acquires valuable data to help improve and update MPS test methods.

The FAA will publish a report called "Handbook for Halon Replacement Minimum Performance Standards," which will feature the improved MPS test methods derived from this research. The agency will regularly update the document with evolving fire suppression technologies.

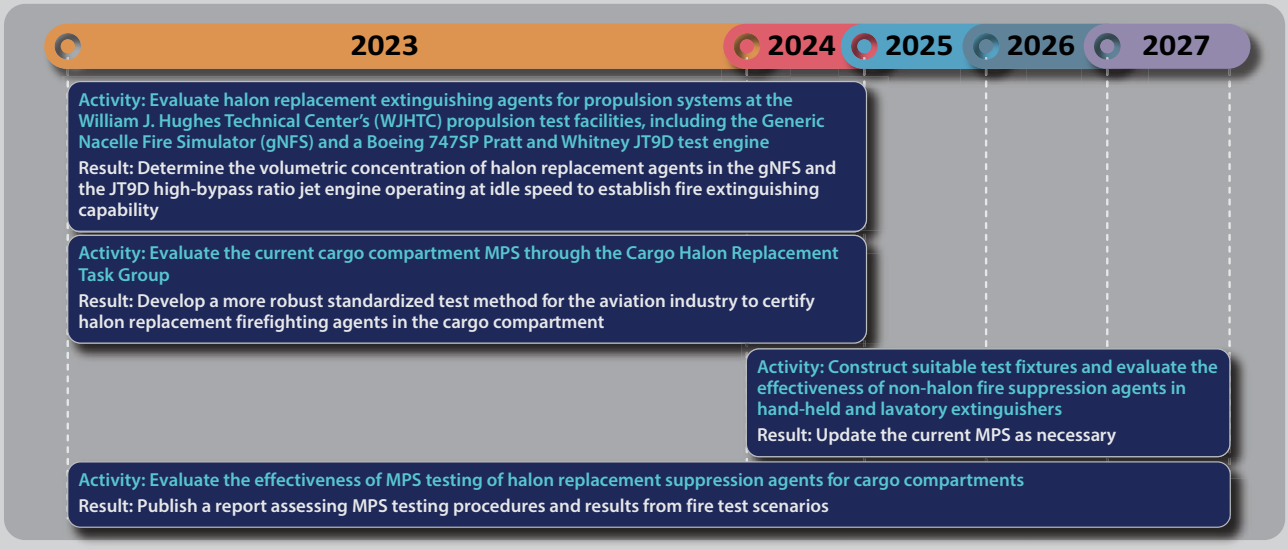
Aircraft Halon Replacement

Driver

Conduct qualification testing for firefighting agents with unique characteristics not envisioned at the time the agency developed minimum performance standard (MPS) test methods for non-halon agents

Outcome

Publish the "Handbook for Halon Replacement Minimum Performance Standards," highlighting improved MPS test methods derived from this research



Partners

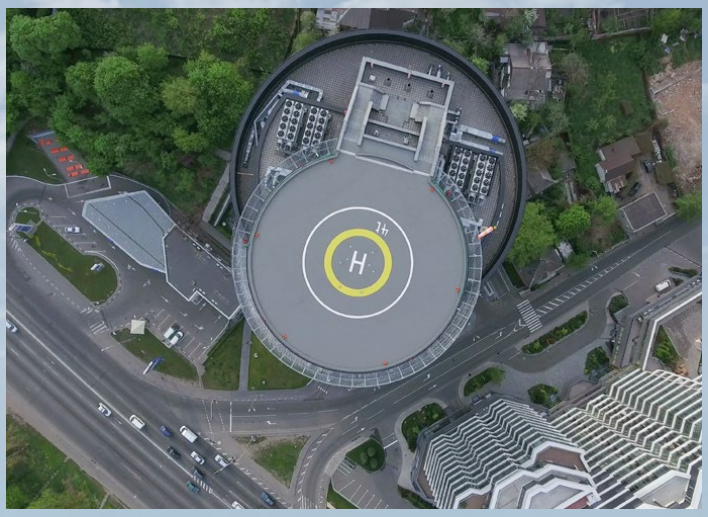
Boeing, Meggitt Safety Systems Inc., Airbus, Collins Aerospace

Airport Technology Research

Vertiport Infrastructure and Design Standards to Support Advanced Air Mobility Systems

Advanced air mobility (AAM) describes a new transportation system that uses emerging technologies, such as vertical takeoff and landing and short takeoff and landing aircraft, to transport people or cargo at lower altitudes and within a shorter range than traditional aircraft. AAM can help increase access to areas underserved by the current aviation industry.

AAM will bring operational challenges to the NAS. New aircraft types will require new kinds of landing pads, charging stations (if powered by electricity), and terminals that can accommodate a large number of aircraft flying frequent, short flights. Therefore, the AAM transportation systems must include well-designed vertiports — specialized vertical aircraft takeoff and landing areas. FAA research provides a framework and data for the development of sound vertiport guidance.



Vertiport Infrastructure and Design Standards to Support Advanced Air Mobility Systems

Driver

Identify advanced air mobility (AAM)-related safety risks and develop new vertiport infrastructure that will meet AAM needs in rural, suburban, and urban environments

Outcome

Vertiport standards that support the design and operation of facilities used by VTOL aircraft with various power sources, considering electric, hydrogen, hybrid, and alternative fuels

2023

- Activity: Conduct an assessment of future vertiport electrical infrastructure
  Result: Improved understanding of required AAM infrastructure needs
- Activity: Conduct an assessment of future vertiport hydrogen infrastructure
  Result: Improved understanding of required AAM infrastructure needs

2024

- Activity: Complete ongoing testing to study downwash and outwash from vertical takeoff and landing (VTOL) aircraft
  Result: Improved understanding of outwash and downwash considerations in vertiport design

2025

- Activity: Develop a test methodology to study integrating automation into vertiports
  Result: Improved understanding of automation integration for vertiports

Partners

National Renewable Energy Laboratory, NASA, Center of Excellence for Alternative Jet Fuels and Environment, European Union Aviation Safety Agency, international regulators

2.3.3 Goal 3

Capitalize on the use of NAS, airport, and spaceport infrastructure

Key programs and initiatives:

A durable, long-life, and resilient infrastructure forms the backbone of an efficient, safe, and secure NAS. Research under this goal includes airport runways, taxiways, air traffic management, and aircraft systems and networks, as well as electrical airport sub-infrastructures and lighting.

Research focuses on increasing the useful life of this infrastructure and decreasing maintenance and repair costs, NAS operations recovery from disruptive events, and cybersecurity research that protects and defends FAA systems from internal and external threats due to rapid advances and sophistication of cyber attacks.

The resulting analysis will lead to a longer-lasting, lower-cost, dependable infrastructure defended against cyber events.

To achieve this goal, the FAA will:

- **Develop new tools to protect the NAS from cyber attacks using AI and ML**
- **Study the feasibility of using geosynthetic materials in airport pavement**


FIRE
FUEL
HYD
CARGO SMOKE
VENTILATION

Information Technology/Cybersecurity

Cybersecurity Data Science with Artificial Intelligence and Machine Learning

The *U.S. National Strategy for Aviation Security* identifies and describes the aviation ecosystem, which includes all aspects of airports, airlines, aircraft, airlift, operators, and aviation management, as well as the interconnection of the world's airspace.

The FAA's Information Cybersecurity research and development program conducts research, analysis, demonstrations, evaluations, and prototype development of cybersecurity data science (CSDS) tools, technologies, and methods to detect, prevent, and mitigate the effects of cyber attacks on elements of the aviation ecosystem.

The program explores CSDS concepts focusing on AI and ML. The research is conducted collaboratively with the aviation industry to address specific stakeholder cybersecurity concerns. Applying CSDS with AI and ML concepts to individual aviation industry challenges — through prototyping, experimentation, and demonstration — will enable greater collaboration and assist the aviation industry with CSDS implementation decisions.

The primary research purpose is to accelerate the aviation industry's timely adoption of novel CSDS and AI/ML technologies to enhance cybersecurity for the airline, airport, and aircraft elements of the national aviation ecosystem to increase safety and resiliency (availability and reliability). Critical research results will include documented guidance for aviation industry stakeholders and standards-setting bodies.

This multi-year collaborative effort will allow the aviation industry to use lessons learned from this research to strengthen their cybersecurity, both individually and collectively, making the broader aviation ecosystem more resilient and safer for the flying public.

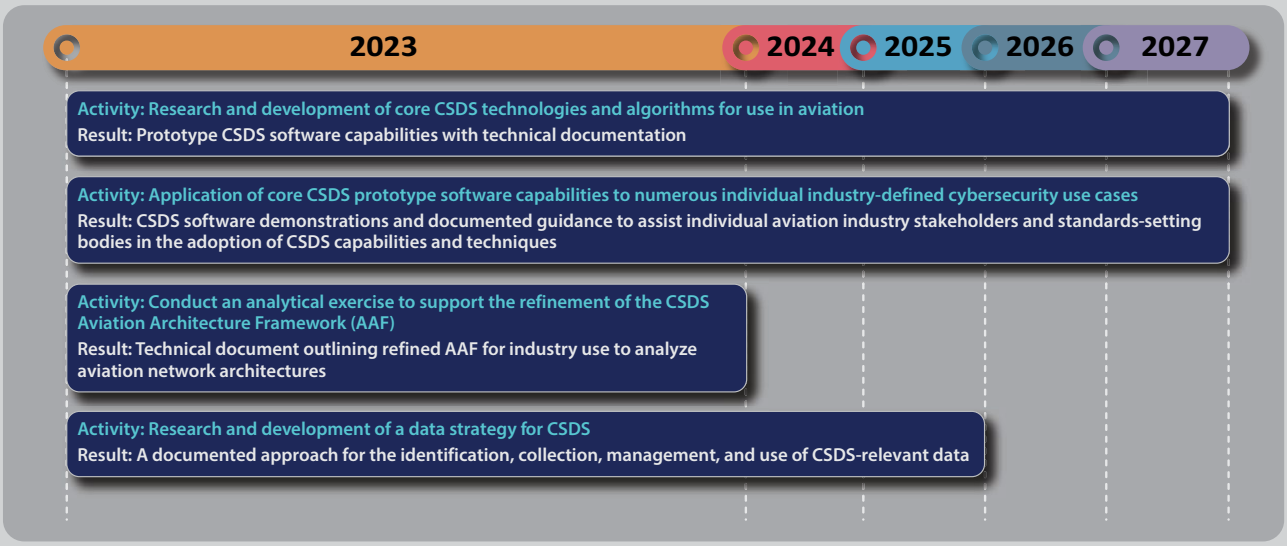
Cybersecurity Data Science with Artificial Intelligence and Machine Learning

Driver

Explore advanced concepts to address the highly complex problem of aviation cybersecurity using cybersecurity data science (CSDS) tools with artificial intelligence (AI) and machine learning (ML)

Outcome

Guidance to foster accelerated aviation industry adoption of novel cybersecurity data science and AI/ML concepts and capabilities to enhance security and resiliency for the airline, airport, and aircraft elements of the aviation ecosystem



Partners

Lincoln Laboratory, Embry-Riddle Aeronautical University, U.S. government agencies, Industry, Airports and aircraft manufacturers, Aerospace Industries Association, Cyber Safety Commercial Aviation Team, Aviation Information Sharing and Analysis Center

Airport Technology Research

Use of Geosynthetics in Airport Pavement Structures

Geosynthetics are materials used to reinforce soil and stone layers of foundations and pavement structures. While geosynthetics show a benefit in highway pavements, they have not been tested under aircraft loads, which are many times greater.

In cooperation with the geosynthetics industry, the FAA is trying to determine the benefits of using geosynthetic materials to reinforce airport pavement layers. The goal is to extend pavement longevity or reduce airport pavement thickness, potentially reducing construction and maintenance costs.

This research supports the FAA Reauthorization Act of 2018, section 525, which states that the FAA should encourage the use of durable, resilient, and sustainable materials and practices, including geosynthetic materials and other innovative technologies.

To meet industry demand, the FAA is conducting full-scale accelerated pavement testing of geosynthetic reinforced pavement structures at the William J. Hughes Technical Center's National Airport Pavement Testing Facility in Atlantic City, NJ.

The research will determine whether pavement life is improved and provide guidance to ensure proper design, construction, and installation of geosynthetic materials within airport pavements through updates to FAA advisory circulars.

Use of Geosynthetics in Airport Pavement Structures

- **Driver**
  Determine if using geosynthetic materials can extend pavement longevity and decrease material construction costs through thinner pavement structure

- **Outcome**
  Quantify the benefits of using geosynthetic materials in airport pavements through improved modeling, and update the FAA's advisory circular related to pavement design and evaluation

2023

Activity: Collect data during testing and after pavement failure
Result: Provide interim recommendations on the use of geosynthetic materials for selected airport pavements

2024

2025

2026

Activity: Collect data during testing and after pavement failure
Result: Provide updated interim recommendations on the use of geosynthetic materials for selected airport pavements

Activity: Perform further test pavement construction and testing of geosynthetic-reinforced pavements based on results from the first round of testing
Result: Updated FAA advisory circular on airport pavement design and evaluation

2027

2028

Activity: Model the use of geosynthetic materials within the pavement structure
Result: Update airport pavement design software and reporting methods

- **Partners**
  Geosynthetic Materials Association, Federal Highway Administration, U.S. Army Corps of Engineers, Academia, Industry

Carbon Removal and Reduction to Support Airport Net-Zero Goals

The administration has prioritized addressing the climate crisis by encouraging a reduction in carbon emissions. In alignment with the Intergovernmental Panel on Climate Change *target of limiting global warming to 1.5 °C*, several industry associations and individual airports have committed to reaching net-zero carbon emissions by 2050.

While previous work has identified numerous carbon reduction strategies, carbon removal approaches and net-zero emission targets have not been widely studied nor adopted at airports.

The objective of this research is to develop a playbook to help airports understand and define how they can reach the net-zero carbon emissions goal by 2050 or earlier. This research will provide foundational knowledge for airports to better understand carbon removal strategies (technology and nature-based) and their potential feasibility in an airport setting.

The guidance will assist airports in selecting and customizing net-zero carbon strategies based on their type, size, and geographic region. The playbook will include a framework for decision making and implementation and will help airports evaluate the tradeoffs and synergies among various carbon reduction and emerging removal strategies.

Such approaches will include, but will not be limited to:

- **Identification of funding opportunities for carbon removal strategies**
- **Summary of current and future utility energy supply mixes in different regions, including the regulatory context for airports to procure their own clean energy from the gas and electricity grid**
- **Combination or sequencing of strategies and technologies for near-term and long-term approaches**
- **Recommendations for how airports could take advantage of recent carbon-related commitments by airlines and other key stakeholders**
- **Description of how on-site utilities or carbon removal technologies could support levels beyond net-zero goals**

The FAA has partnered with the Transportation Research Board through the Airports Cooperative Research Program to perform this research. A panel of industry experts across airport management, consultants, industry association representatives, and the FAA are overseeing the continuing research.

2.3.4 Goal 4

Improve human performance within the system

Key programs and initiatives:

Advanced technologies and capabilities challenge human operators and maintainers, including aircraft and UAS remote pilots, cabin crew, maintenance personnel, air traffic controllers, and others. The impact of design, technology, new concepts of operation, and physiological and psychological stressors can have a profound effect on human performance, which can result in less-than-optimal responses during routine and emergency events.

Research in this goal area seeks to optimize human performance through capability assessments, training, and operational evaluations. Activities address human and medical factors related to an individual's ability to meet flight demands. Optimized human performance 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 air transportation system in the world. Research includes passenger safety in flight and during emergencies.

To achieve this goal, the FAA will:

- **Develop objective metrics assessing cognitive performance risks due to operator fatigue**
- **Lead a safety risk assessment of infectious disease transmission risk onboard passenger aircraft to create a cabin health safety response plan with an associated analytic tool kit**
- **Establish operational standards for the use of advanced vision systems**
- **Study capabilities and crew complements to enable new automatic takeoff and landing operations not covered by existing FAA guidance**
- **Research the causes of helicopter accidents and tools that might help prevent crashes**
- **Evaluate prototypes to develop a path to 14 CFR 60 certification for technologies that simulate interactions between pilots and air traffic control during pilot training**

Aeromedical Research

Diagnosing Operator Performance Impairment from Fatigue

Fatigue from sleep loss or schedule disruption due to jet lag negatively impacts human performance and is a known risk factor for aviation and transportation accidents.

Fatigue prevention measures, such as duty-hour limitations, cannot account for fatiguing conditions such as commute time, lifestyle factors, and rest opportunities outside the workplace. Further, individuals may underestimate their fatigue impairment, leading to inaccurate self-assessments. Development of an objective metric to accurately determine fatigue levels is needed.

This program seeks to develop biologically-based diagnostic tools using biomarkers to objectively identify fatigue levels in individuals. Researchers will apply these tools to provide a reliable means of identifying fatigue in aviation accident investigations.

Accurate fatigue assessment is crucial to understanding the extent of the safety risk and creating the knowledge base for ensuring regulations can appropriately address fatigue risks. Tools developed under this program may also provide improved diagnostics to allow objective real-time measurement of operator fatigue for accident prevention.

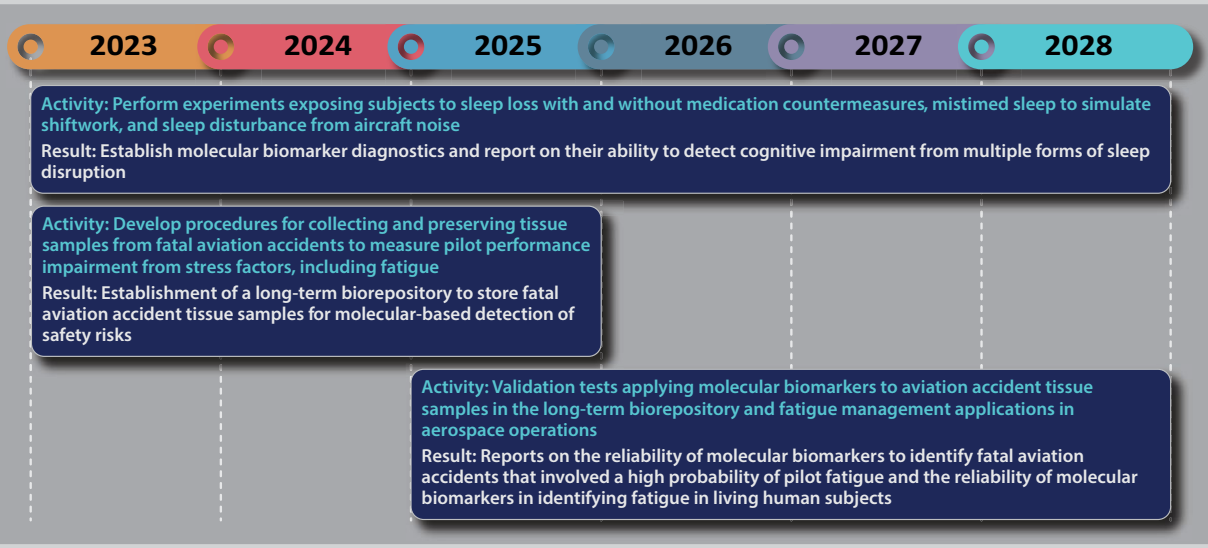
Following stakeholder coordination and adoption by the aviation industry, these tools could be helpful for fatigue risk management strategies and improving current regulations, such as *14 CFR 117* — the federal guidelines governing flight, duty, and rest requirements for flight crews.

The tools could allow new ways to safely expand operations when current duty-hour limitations are too restrictive to meet public demand for services. The research may also be useful in the measurement and management of fatigue risk in novel operations such as commercial space flights.

Diagnosing Operator Performance Impairment from Fatigue

Driver
Develop objective metrics for real-time assessment of cognitive performance risks due to operator fatigue

Outcome
Enable more accurate and sensitive detection of fatigue impairment to assess operational safety risks, and provide diagnostic tools for performance-based safety risk mitigation strategies



Partners
Academic institutions, Department of Defense

Communicable Disease in Air Travel Research

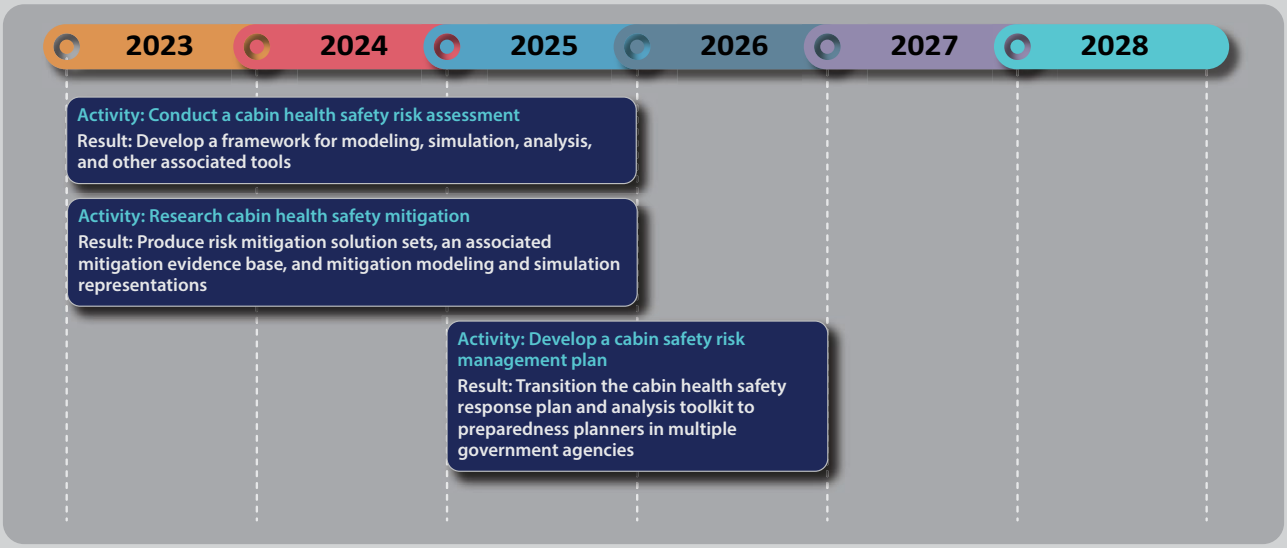
The FAA's Office of Aerospace Medicine is leading a safety risk assessment on communicable disease transmission onboard passenger aircraft. Researchers at the FAA's Civil Aerospace Medical Institute in Oklahoma City, OK, will develop a modeling, simulation, and analysis framework. The output of this research will allow the risk assessment team to estimate the transmission risk quantitatively for diseases requiring contact tracing, such as COVID-19, within transport aircraft cabins.

Researchers will identify risk mitigation strategies, evaluate the associated supporting scientific data, and implement solutions in the modeling and simulation environment to evaluate the effect on disease transmission risk. The FAA will use the knowledge gained from these research activities to create a cabin health safety response plan with an associated analytic tool kit.

Communicable Disease in Air Travel Research

Driver
Understand and minimize the transmission risk for diseases requiring contract tracing within transport aircraft cabins

Outcome
Improved understanding of the communicability of infectious diseases during air travel and development of data-driven, risk-based preparedness plans



Partners
Department of Homeland Security, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, and the National Research Council of Canada

Flight Deck/Maintenance/System Integration Human Factors

Operational Standards for Advanced Vision Systems

Advanced vision systems provide additional visual information to pilots. These tools can enhance safety, may provide an alternative to natural vision, and could allow greater access to airports in low-visibility conditions.

Researchers will study the cognitive and physiological effects pilots experience while using advanced vision systems, sensor-based technologies, and emerging display technologies — and whether these tools provide at least equivalent performance to natural vision.

The FAA will use the results to develop operational requirements, standards, conditions, limitations, mitigations, and authorizations for the expanded use of these systems.

Operational Standards for Advanced Vision Systems

Driver
Examine new ways of using approved and emerging flight deck equipment to improve safety and access during low-visibility operations

Outcome
Evidence-based policy changes to increase throughput and accessibility to airports/runways for low-visibility approach, landing, and takeoff operations

2023 | 2024 | 2025 | 2026 | 2027 | 2028

- **Activity:** Research the expanded use of Synthetic Vision Guidance Systems (SVGS)
  Result: Report on SVGS contributions to pilot performance during low-visibility takeoff operations
- **Activity:** Research the expanded use of single/dual head-up display (HUD) technologies
  Result: Report on the contributions of single/dual HUD technologies and symbology on head-down displays to pilot/crew performance in low-visibility conditions
- **Activity:** Research human factors methods and tools to evaluate new advanced vision systems
  Result: Report on operational evaluation considerations for Enhanced Flight Vision Systems and SVGS
- **Activity:** Research the use of advanced vision systems and new display technologies as alternatives for natural vision
  Result: Report on the contributions of advanced vision systems to pilot performance during low-visibility operations

Partners
Aircraft manufacturers, Avionics manufacturers, Airlines, Business aviation

Single/Dual Pilot Workload During Autonomous Operations

With technological advances, one day, pilots will likely move out of the flight deck and begin monitoring autonomous aircraft from remote locations. For this to be possible, an aircraft would have to be able to take off and land on its own.

Most modern transport category aircraft can automatically land using a tool called autoland, but these approaches require airport infrastructure such as ground-based instrument landing systems for guidance.

Additionally, airlines and operators are currently required to use autoland or some other pilot aid, such as head-up displays and advanced vision systems, when landing in low-visibility conditions.

When it comes to getting off the ground, all aircraft, except UAS, require a pilot to perform the takeoff because the technology does not exist for an airplane or helicopter to take off automatically. Currently, no automatic takeoff guidance or criteria exists, and current autoland guidance pertains specifically to its use to facilitate operations in the lowest visibilities.

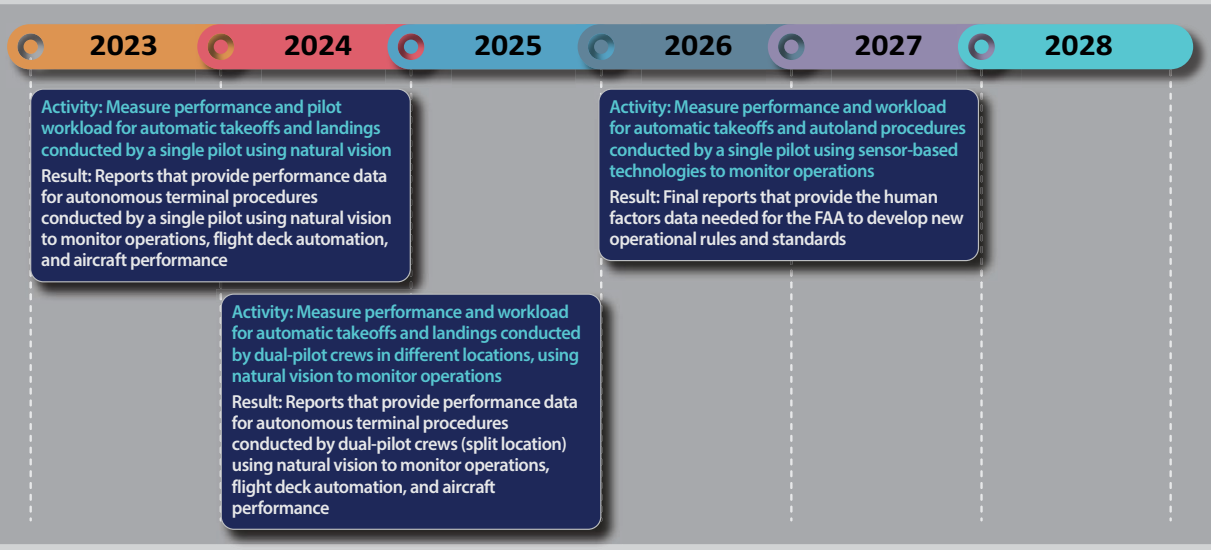
The FAA is conducting human factors research to expand the use of autoland to other types of operations and crew complements. Researchers will also examine whether workloads for single-pilot and optional dual-pilot crews in separate locations are operationally acceptable during future automatic takeoff and autoland operations that are not currently authorized.

The FAA will use research results for future rule changes for operators seeking approvals for fully autonomous operations using equipment and ground infrastructure currently used for Autoland.

Single/Dual Pilot Workload During Autonomous Operations

Driver
Evaluate aircraft capabilities that enable new automatic takeoff and landing operations not covered by existing FAA guidance

Outcome
Create new guidance for automatic takeoff operations and update existing autoland criteria to include single-pilot operations, allowing a pathway for optional dual-pilot crews in separate locations



Partners
NASA, Industry

System Safety Management/Terminal Area Safety

Rotorcraft Safety and Accident Research

A number of high-profile helicopter accidents in recent times involve flight in low-visibility conditions, at low altitudes, and often feature a pilot losing control of the rotorcraft.

Accidents are typically associated with poor weather, spatial disorientation, sustained low-altitude flight in obstacle-rich environments, and a decline of basic skills resulting in a loss of control of the helicopter.

Rotorcraft safety research addresses the top causes of these accidents and incidents. Research topics range from flight data monitoring, aerodynamic models, and noise models to virtual and augmented reality.

Work also involves vision systems and related technologies, such as enhanced, synthetic, and combined vision systems, as well as head-worn and helmet-mounted displays. These tools can provide increased visual information and cues to help pilots reorient themselves at the onset of potential problems.

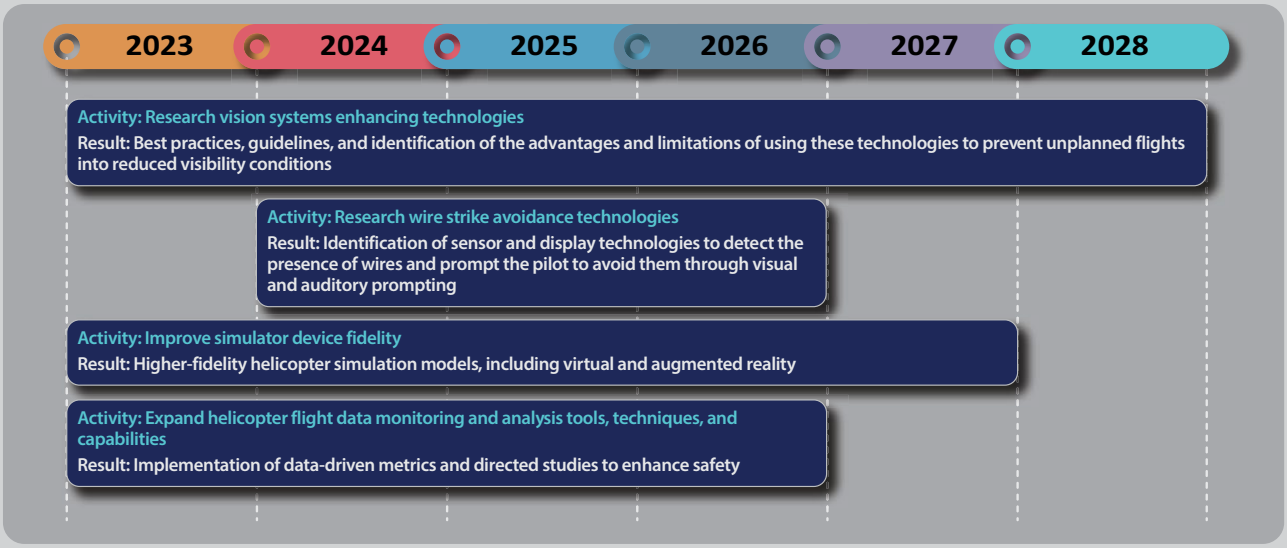
Related rotorcraft safety research work includes:

- **Rotorcraft wire strike detection and mitigation**
- **Higher-fidelity simulation devices and models**
- **Electric vertical takeoff and landing noise modeling**
- **Vertical flight low-level infrastructure, including routes, procedures, vertiport and heliport lighting, markings, sensors, and ground infrastructure**

Rotorcraft Safety and Accident Research

Driver
Increase helicopter safety by promoting and encouraging the adoption of safety-enhancing technologies by the rotorcraft community

Outcome
Reduce the fatal accident rate for rotorcraft and improve safety and operational efficiency through the adoption and utilization of new technologies



Partners
Helicopter safety associations; Manufacturers; European Union Aviation Safety Agency; United Kingdom Civil Aviation Authority; Academia; Partnership to Enhance General Aviation Safety, Accessibility, and Sustainability; Standards-setting committees and working groups

Evaluation of Simulated Air Traffic Control Environments that Utilize Artificial Intelligence

Airline pilots are trained using high-fidelity, Level D full-flight simulators. Although these devices offer a realistic flight experience, they typically do not provide true-to-life air traffic control (ATC) interactions. During training exercises, simulator instructors or other individuals often act as air traffic controllers. These conversations do not accurately reflect real-life exchanges between controllers and pilots, creating gaps in training that can result in miscommunication during actual flight operations.

Simulated ATC technologies are under development that use voice recognition, voice synthesis, and AI to create realistic communications during simulator training. However, the FAA does not currently have a method to certify these new tools for pilot training.

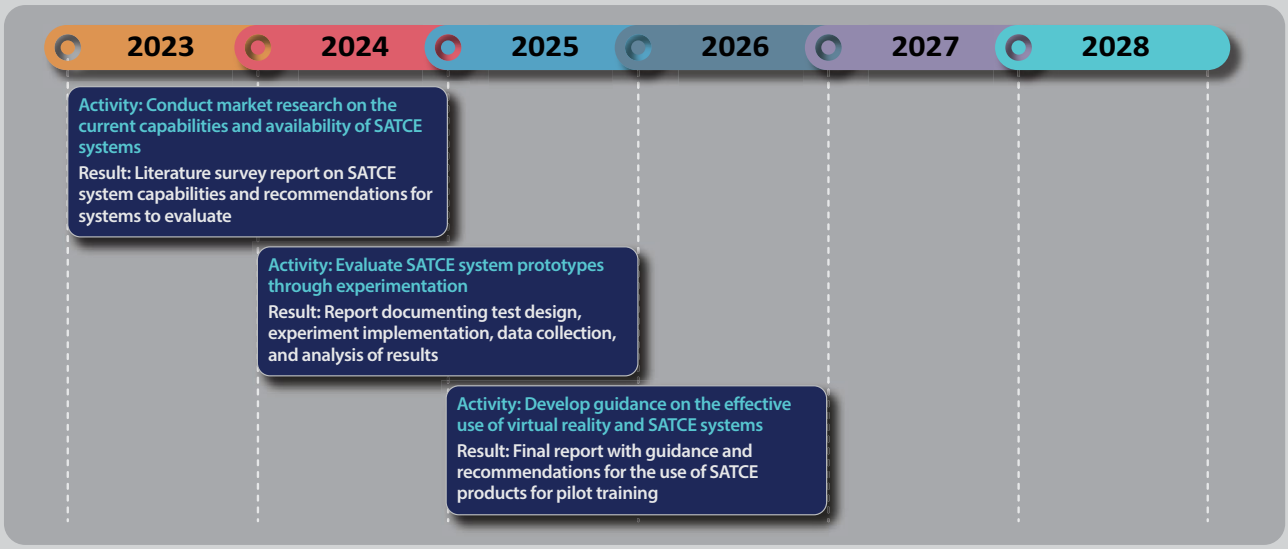
Researchers will evaluate these prototype systems to determine their effectiveness and identify their strengths and limitations.

Using the findings of this research, the FAA can develop a path for certification for simulated ATC environments. The goal is to improve the pilot training experience and reduce the rate of accidents and incidents related to pilot-controller miscommunication.

Evaluation of Simulated Air Traffic Control Environments that Utilize Artificial Intelligence

- **Driver**
  Evaluate simulated air traffic control environments (SATCE) that use artificial intelligence to determine how to certify their use for pilot training

- **Outcome**
  Guidance and recommendations regarding the use of SATCE products for pilot training to reduce operational errors related to pilot-controller communications



- **Partners**
  To be determined

Airliner Cabin Environment

Reports of cabin air contaminants can occur when smoke, odors, and fumes enter an airplane's environmental control system for ventilation, pressurization, and temperature.

This can happen when engine oil leaks or other fluids are ingested into the engine, drawn into the air supply, and distributed throughout the cabin and flight deck.

The FAA is conducting research with Kansas State University and the U.S. Navy to identify and measure contaminant levels after engine ingestion of known chemicals into the air supply. Work includes:

- **Identifying sensor technologies to monitor cabin air quality**
- **Assessing potential health effects on passengers and flight crew**
- **Creating a more objective means for detecting contaminants**
- **Mitigating potential contamination**

The agency expects to provide a final report and recommendations in 2025 for air carriers to monitor airliner cabin air quality as required by the FAA Reauthorization Act of 2018, section 326.

Aircraft Certification, Safety, and Accountability Act

FAA human factors research supports and addresses the content and intent of the Aircraft Certification, Safety, and Accountability Act (ACSAA) passed by Congress in 2020. ACSAA provides recommendations for the agency to better integrate human factors throughout the aircraft design and certification process.

These recommendations are based on recent aviation accidents and technological advances proposed for flight deck equipment design, pilot and maintenance technician training, and flight operations. Current human factors research will focus on the following:

- **Human-system safety**
- **Human-machine interface and interaction**
- **Personnel training and qualification**

The agency will use the results to clarify and expand the use of human factors research when developing regulatory policy and creating processes for flight standards and aircraft certification.

2.3.5 Goal 5

Improve integrated modeling capabilities and system-wide analysis

Key programs and initiatives:

Using technologies such as data sharing, AI, and ML, the FAA has created a number of tools to analyze and model safety, environmental impact, and other data in support of the NAS. 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. Work in this goal area will improve the robustness, adaptability, flexibility, and accuracy of these integrated analytical and computational modeling tools.

Research associated with this goal includes developing a scientific understanding of aerospace systems used to develop NAS improvements; analytical and predictive capabilities used in the capture, parsing, analysis, and sharing of data; and a toolset to evaluate NAS system-wide performance, especially given the introduction of new and emerging technologies. This work will allow the NAS to deliver the highest quality service to the greatest number of stakeholders in a timely, safe, and practical manner.

To achieve this goal, the FAA will:

- **Update existing environmental modeling tools to improve noise measurement and exposure maps, including sound produced by supersonic aircraft**
- **Develop modeling tools and means of compliance methods to ensure the safety of current and newly designed engine propulsion systems**
- **Validate explosive yield models for liquid oxygen-liquid methane rocket propellant to more accurately predict the impacts of explosions**

Environmental Tools/Aviation Environmental Design Tool

Aircraft noise is the primary environmental obstacle to aviation growth. Researchers use the Aviation Environmental Design Tool (AEDT) to model aircraft performance in space and time to estimate fuel use, emissions, noise, and air quality consequences. AEDT is at the core of a comprehensive suite of software tools the agency uses to assess the environmental effects of aviation.

The FAA uses AEDT to facilitate the environmental review of federal actions associated with changes to airports, airspace, and other applicable aviation activities. AEDT is also valuable for domestic and international aviation environmental policy analysis.

The agency sponsors research to improve the accuracy of AEDT and expand its modeling capabilities. Work in the next five years will result in improvements in noise characterization, including farther from the airport for existing aircraft and the ability to model new aerospace vehicles entering the NAS, such as supersonic aircraft.

AEDT's current emissions dispersion model will be updated to better represent and model aircraft-specific emissions. These capabilities will help airports demonstrate compliance with the National Environmental Policy Act and the Environmental Protection Agency's Clean Air Act requirements, streamlining the environmental review process and avoiding delays in airport construction and needed upgrades.

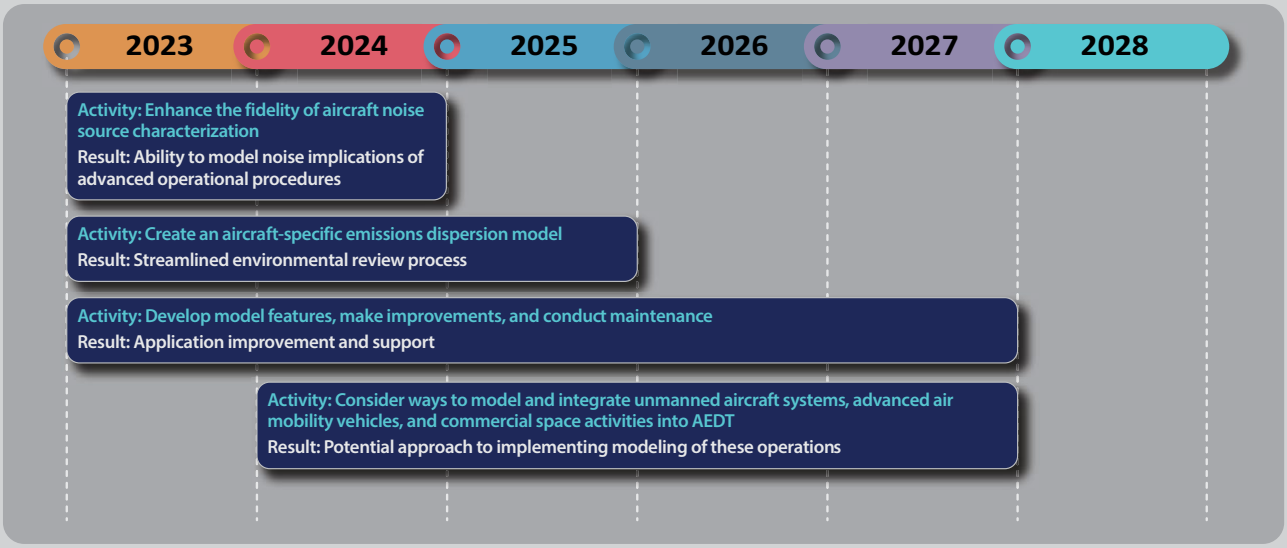
A robust research program through ASCENT supports AEDT development, including several projects to evaluate the potential impacts of noise on sleep and health and the effects of emissions on air quality and climate change.

The resulting knowledge and enhanced modeling capabilities will inform decision making by the FAA and others in the aviation and aerospace industries.

Environmental Tools/Aviation Environmental Design Tool

Driver
Improve the accuracy and fidelity of performance, noise, emissions, and air quality modeling, as well as expand Aviation Environmental Design Tool (AEDT) capabilities for evolving operations

Outcome
Improvements that more accurately represent aviation and aerospace impacts from noise, emissions, and fuel burn, as well as added capabilities to accommodate new aircraft types



Partners
Industry, Center of Excellence for Alternative Jet Fuels and Environment, NASA

Advanced Analysis Methods for Rotor Burst and Blade Release Impacts

Fragments released when fan blades and other high-speed rotating engine components break apart can seriously threaten aircraft safety. Several in-service fan blade fractures in recent years resulted in engine parts striking other areas of the aircraft. One of these accidents led to a passenger fatality.

Manufacturers rely upon computer simulations produced by the LS-DYNA® analysis software to ensure that traditional turbine designs are robust enough to meet FAA certification test requirements for blade containment and debris hazard minimization.

The aviation industry is rapidly pursuing new propulsion concepts such as unducted (open rotor) composite fans and electric propulsion systems. These designs lack containment structures around the largest blades, necessitating shielding to prevent engine fragments from impacting the aircraft. In collaboration with NASA, the Department of Defense, the aviation industry, and academia, FAA researchers are developing modeling tools and means of compliance methods to ensure the safety of these new propulsion systems.

The LS-DYNA® Aerospace Working Group — a partnership of government, the aviation industry, and academia — published modeling guidelines and several material models for widely used aerospace metals and composites.

The improved methodology more accurately predicts damage and penetration, leading to safer shielding designs and vulnerability analysis tools for current and future propulsion systems.

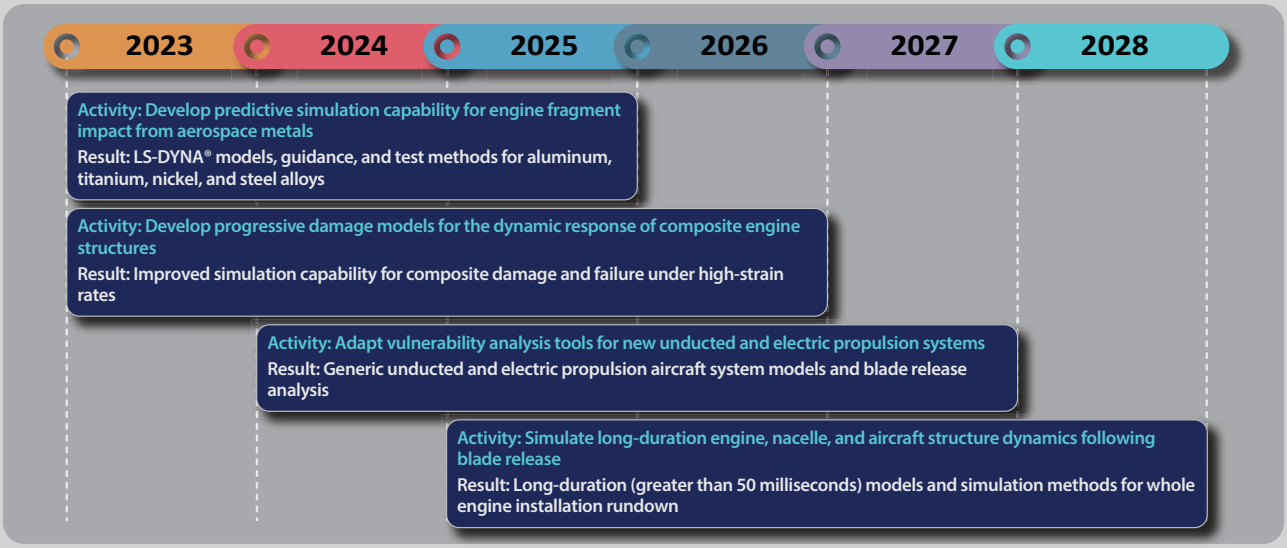
Advanced Analysis Methods for Rotor Burst and Blade Release Impacts

Driver

Reduce the safety hazard from engine blade and rotor separations for traditional turbine engines and new technologies such as unducted (open rotor) fans and electric propulsion systems

Outcome

Improved computational modeling, test methods, and vulnerability analysis for engine fragment impact and shielding



Partners

LS-DYNA®Aerospace Working Group, ANSYS, NASA, Department of Defense, George Mason University, Arizona State University, The Ohio State University, University of Dayton

Commercial Space Transportation Safety

Explosive Yield Research

The FAA is licensing new commercial space launch vehicles powered by a combination of liquid-oxygen and liquid-methane rocket propellant. An accident involving a large launch vehicle full of such fuel at or near a launch site could create a powerful explosion that could break windows a significant distance away during certain weather conditions.

The strength of the explosion, or explosive yield, is driven by several factors, such as total propellant mass in a given propellant combination of liquid oxygen-liquid methane.

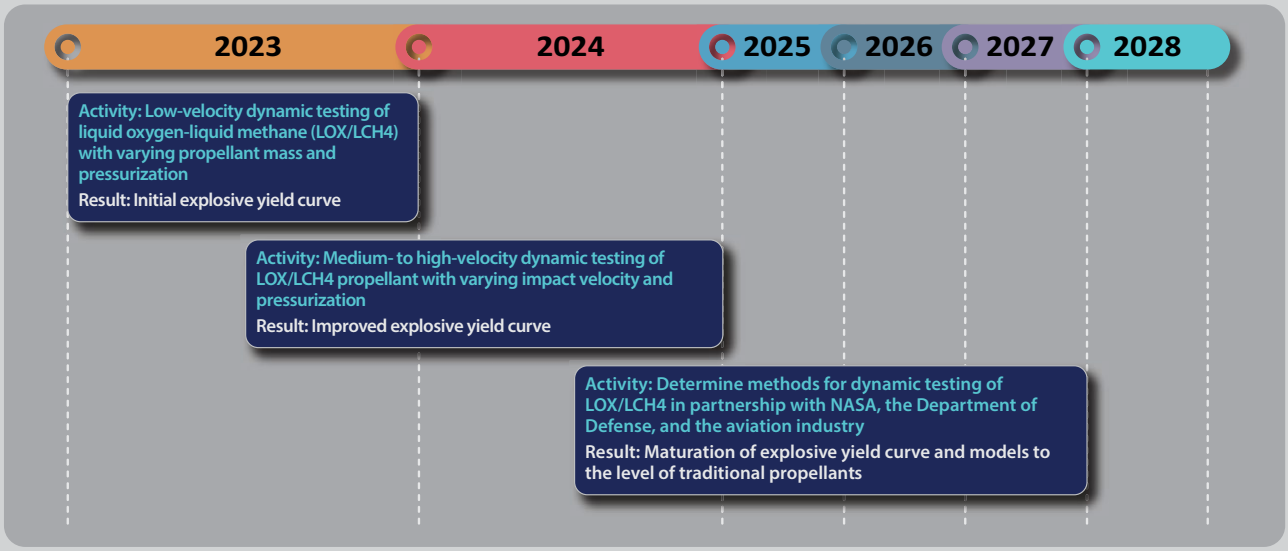
Currently, almost no relevant test data exists to support modeling the strength of liquid oxygen-liquid methane explosions. Researchers intend to validate theory-based explosive yield models developed for liquid oxygen-liquid methane.

The only significant test database exists for Rocket Propellant-1 (a form of kerosene) and liquid hydrogen, both of which have been used for decades. These traditional propellant combinations have significantly different properties than liquid oxygen-liquid methane.

Explosive Yield Research

- **Driver**
  Advance the state-of-the-art modeling of liquid oxygen-liquid methane rocket propellant explosions

- **Outcome**
  Improve the understanding of hazard limits associated with launch site accidents for vehicles containing a combination of liquid oxygen and liquid methane propellants



- **Partners**
  Commercial space transportation industry, NASA, Department of Defense, The Aerospace Corporation


SPACEX

3.0 Partnerships and Collaboration

The FAA collaborates with over 350 stakeholders from academia, the aviation industry, other federal agencies, international entities, and technical societies to drive continuous improvement in the National Airspace System (NAS) and maintain a leadership position in global aviation.

The agency has instituted and participates in various programs and initiatives to maximize the benefit of these relationships, including technology transfer, centers of excellence, aviation research grants, national consortiums, interagency partnerships, and other agreements.

3.1 Technology Transfer

The FAA's Technology Transfer program enables the transfer of research and development technologies among government, industry, and academia and promotes the dissemination of federally-funded research and innovations to the commercial marketplace.

The agency's commitment to technology transfer and innovation is evident in the William J. Hughes Technical Center's Innovation and Technology Advisory Council (ITAC) initiative. The ITAC encourages and supports the maturation of innovative aviation solutions created by the center's highly technical workforce.

Whether bringing the latest technology into FAA labs or advancing innovation out of the agency to the private sector, the Technology Transfer program operates under three pillars of success.

Stimulating Collaboration

The FAA's Technology Transfer program promotes synergy and growth between internal agency research and the aviation community. In coordination with the FAA's legal counsel, the agency allows the exchange of advanced expertise, facilities, and capabilities with the aviation industry, academia, and other federal partners. The program utilizes the full range of available options to bring new technologies to the marketplace and promote economic development.

Encouraging and Protecting Innovation

The Technology Transfer program office, with the assistance of the FAA's legal counsel, manages the agency's patent licensing program. Inventions patented by FAA employees are available for commercial licensing and can result in royalty revenue shared with the inventor and the agency. The FAA has held a small number of active income-generating license agreements.

Promoting Public Benefit

A major focus of the Technology Transfer program is to communicate the innovations and outcomes of FAA research to industry, other federal agencies, and the general public. FAA researchers contribute to technical advancement through various means, not only through traditional technology transfer mechanisms such as collaborative research and development agreements (CRADA) and patent licenses but, more broadly, through technical notes and reports, advisory circulars, regulatory guidance, technical findings, participation in technical society panels, and membership in international advisory organizations and other forums.

Cooperative Research and Development Agreements

The FAA's Technology Transfer program uses Cooperative Research and Development Agreements (CRADA) as a primary mechanism for collaborative research. These agreements offer unique opportunities and benefits for the FAA to work with domestic and international partners from academia and the aviation industry to address complex challenges. Established by the *Stevenson-Wydler Technology Innovation Act of 1980,* CRADAs allow federal labs to negotiate licensing arrangements for patented inventions.

The FAA conducts research through CRADA partnerships in a variety of areas, including:

- **Advanced materials**
- **Airport pavements**
- **Enhanced/synthetic vision systems**
- **Electrical propulsion systems**
- **Fire safety**
- **Predictive impact modeling**
- **Solid-state power control and protective devices**
- **Structural health monitoring**
- **Surface surveillance systems**
- **Unleaded aviation fuel**

The most common path for the FAA to establish a CRADA is for an FAA employee to identify a research opportunity and consult with the Technology Transfer program team. If the research is appropriate for a CRADA and meets the established criteria, the office initiates the development process and manages the agreement through completion.

When the research is better suited to a grant, interagency agreement, or another type of vehicle, the Technology Transfer office coordinates a meeting between the researcher and the FAA organization with the authority to establish the particular type of agreement needed.

Planned Research with the Aviation Industry over the Next Five Years

- **Integrating drones into the National Airspace System (NAS) by collaborating with over 30 industry representatives through the Advanced Aviation Advisory Committee, Integration Partnership Agreement program, Integration Pilot Program, and other unmanned aircraft systems-specific programs**
- **Modernizing the NAS with modern air traffic management methods by defining the minimum aircraft capabilities and equipage necessary for maximizing FAA investments and operational improvements in collaboration with 20 industry partners through the NextGen Advisory Committee**
- **Partnering with 55 industry partners to advance multiple FAA Center of Excellence for Alternative Jet Fuels and Environment initiatives, including dramatically expanding sustainable aviation fuel production, reducing the number of people exposed to significant noise around U.S. airports, and decreasing air quality impacts attributable to aviation**
- **Collaborating with more than 30 industry vehicle developers, infrastructure providers, and airspace managers to safely integrate air taxis, cargo delivery aircraft, and other new vehicle concepts into the NAS through NASA's Advanced Air Mobility National Campaign**

3.2 Partnerships

The FAA works to expand and strengthen cooperation with other federal laboratories and agencies, the aviation industry, and academia to promote technology transfer and joint research.

Industry Partnerships

The FAA recognizes that the aviation industry plays a vital role in helping the FAA maintain and evolve the NAS. Not only does the aviation industry drive innovation, but the agency's industry partners also help the FAA meet the demands of these new technologies.

The FAA develops and maintains strong industry relationships through multiple arrangements, including committees, programs, boards, and campaigns.

An important example of this collaboration is the industry-led research conducted by the FAA's Airport Cooperative Research Program (ACRP). This research responds to aviation needs not addressed by other federal programs and those that individual airports cannot cost-effectively undertake.

ACRP is managed by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine and funded by the FAA through the Airport Improvement Program.

This congressionally-mandated program is a national resource for the airport industry, providing valuable information, guidance, and practical tools to airport owners and operators.

ACRP projects align with FAA research goals and focus on topics identified as critical by airport operators, industry, and users. The research, overseen by industry experts and a designated FAA subject matter expert, provides guidance in the form of handbooks and best practices.

Centers of Excellence

Congress established the Centers of Excellence (COE) program through the Omnibus Budget Reconciliation Act of 1990 Public Law (Pub. L.) 101-508, Title IX – Aviation Safety and Capacity Expansion Act, now codified, in relevant part, at section 44513 of title 49 of the U.S. Code.

The mission of the FAA's COE program is to advance aviation technologies and expand FAA research capabilities while educating the next generation of aviation professionals. The program promotes critical collaboration and coordination between government, academia, and industry.

More specifically, using selection criteria provided under P.L. 101-508, the FAA Administrator and the Secretary of Transportation conducted an open and rigorous competitive process to select COE members throughout the United States.

The selected core and affiliate university members provide congressionally-required matching funding, expertise, and resources to supplement FAA research capabilities and serve the FAA as a primary source of subject-matter expertise for 10 years.

Five COEs are active today.

- **Center of Excellence for Alternative Jet Fuels and Environment**
- **Center of Excellence for General Aviation Safety**
- **The Joint Center of Excellence for Advanced Materials**
- **Center of Excellence for Technical Training and Human Performance**
- **Center of Excellence for Unmanned Aircraft Systems**

The program has designated 13 COEs — including 92 core universities — since the inception of the program and the first grant award in 1993. Several universities served on multiple COE teams. With their non-federal affiliates, COE partners provided more than $345 million in matching contributions to augment FAA research grants.

Centers of Excellence Research Planned over the Next Five Years

- **Urban air mobility noise reduction modeling**
- **Clean sheet supersonic engine design and performance**
- **Safety analysis for general aviation and heated airport pavements**
- **Fatigue behavior of advanced and ceramic matrix composite materials for aircraft design and certification**
- **Improvements to flight inspection antenna modeling and simulations**
- **Transportation disaster preparedness and response**
- **Urban air mobility safety standards, aircraft certification, and impact on market feasibility and growth potentials**

Aviation Research Grants and Cooperative Agreements Planned over the Next Five Years

- Aviation weather
- Airports
- Aircraft safety technology
- Capacity and air traffic control technology
- Communications, navigation, and surveillance
- Human factors and aviation medicine
- Systems science and operations research

Aviation Research Grants and Cooperative Agreements

The FAA targets specific research needs through the aviation research grant program. The agency issues notices of funding opportunity to secure proposals. Congress established this program under the FAA Research, Engineering, and Development Authorization Act of 1990 (P.L. 101-508) and the Aviation Security Improvement Act of 1990 (P.L. 101-604).

The program funds academic and nonprofit research institutions to conduct innovative applied research to enhance technology transfer and integration.

The program oversees aviation research grants and cooperative agreements, encompassing two general categories: research deemed by the FAA Administrator as key to the long-term growth of civil aviation and research focused on preventing catastrophic failures. Grants may range from 12 months to a maximum of 60 months.

Research is conducted under an aviation research grant unless significant FAA engagement will benefit the project. In those cases, the agency uses collaborative agreements. The FAA's involvement ranges from providing research guidance to requiring FAA review and approval of each research phase before the start of subsequent steps.

Interagency Research Planned over the Next 5 Years

- **Improved fire safety standards**
- **Reduced risk of blunt force trauma in rotorcraft crashes**
- **Engine-related impact failures**
- **Vertiport electrical infrastructure**
- **Advanced aircraft structures and materials**
- **Novel flight deck pilot interfaces**
- **Radar algorithms to detect high ice water content conditions**
- **Complex digital airborne systems reliability, safety, risk assessment, and verification**

Federal Interagency Partners

The FAA collaborates with agencies across the federal government to advance the safety and efficiency of the NAS. Both organizations benefit from access to state-of-the-art facilities and technical expertise by combining resources to focus on a shared objective.

This approach significantly advances the rate of scientific discovery and saves taxpayer dollars. Current research areas include fire safety, propulsion, fuel, advanced materials, digital systems, weather, human factors, aeromedical research, and evolving operations.

The FAA maintains ongoing agreements with many government agencies, including:

- **NASA**
- **National Oceanic and Atmospheric Administration**
- **Department of Defense**
- **Department of Agriculture**
- **National Transportation Safety Board**
- **Department of Energy**
- **Smithsonian Institution**
- **Volpe National Transportation Systems Center**

International Partnerships

FAA agreements with international partners are critical to harmonization efforts and ensuring the United States remains a global leader in influencing and driving international standards.

The FAA engages with multiple partners through international agreements and CRADAs.

Key International Research Partners

- **International Civil Aviation Organization**
- **Single European Sky Air Traffic Management Research Joint Undertaking**
- **Transport Canada**
- **National Research Council of Canada**
- **United Kingdom Civil Aviation Authority**
- **Civil Aviation Authority of Singapore**
- **Japan Civil Aviation Bureau**
- **Brazil Air Navigation Service Provider**
- **AirServices Australia**

International Collaboration on Environmental Initiatives

Mitigating aviation's environmental and climate impacts is an important area of international collaboration. The United States is working with international partners through the *2021 U.S. Aviation Climate Action Plan* to influence global standards that maximize environmental benefits, are technically feasible, and are economically reasonable.

Additionally, the United States is implementing the International Civil Aviation Organization's carbon dioxide emission standards for new aircraft, developed collaboratively with the Environmental Protection Agency and the FAA.

International Research Planned over the Next Five Years

- **Developing the International Civil Aviation Organization Global Safety Plan and U.S. National Aviation Safety Plan, which will define a coordinated strategic roadmap for implementing a state safety program and reduce the risk of aviation fatalities**
- **Aiding data-driven collision and fatality risk modeling for the oceanic corridor connecting Canada and the United States with Europe to further mitigate risks and establish and monitor safety performance targets**
- **Developing and fielding a collaborative software platform that will allow air traffic and airline partners in the Americas to share airspace demand and capacity information to enhance efficiency**
- **Supporting the United Kingdom Civil Aviation Authority and Brazilian Space Agency to develop and expand commercial space regulatory procedures**
- **Expanding FAA global training and outreach efforts**

3.3 Advisory Committee

The FAA's research and development (R&D) portfolio is reviewed externally by the Research, Engineering, and Development (RE&D) Advisory Committee (REDAC). The REDAC was established under the Aviation Safety Research Act of 1988 (P.L. 100-591), and its responsibilities were later expanded under the FAA Research, Engineering, and Development Authorization Act of 1990 (P.L. 101-508).

Composed of experts from aviation, aerospace, and related emerging technology-focused corporations, universities, associations, consumers, and government agencies, this group provides advice and recommendations to the FAA Administrator on the needs, objectives, plans, approaches, content, and accomplishments of the aviation research portfolio. By providing valuable feedback from customers and stakeholder groups, the REDAC ensures that FAA research activities are coordinated with other government agencies and the aviation industry.

3.3.1 REDAC Recommendations with the FAA's Response

The REDAC met in the fall of 2021 and spring of 2022 to provide advice to the FAA on the RE&D- and Airport Improvement Program-funded R&D portfolios. The REDAC's recommendations relate to the overall research program, such as roadmaps, program plans, funding, and staffing, and are intended to influence actual research activities within the overall FAA R&D portfolio.

The REDAC's fall 2021/spring 2022 recommendations for the FAA's R&D activities and the agency's responses are detailed and explained in the reports below.

- *FAA Response to REDAC Guidance for the FY 2024 Research and Development Portfolio*
- *FAA Response to REDAC Recommendations for the FY 2024 Research and Development Portfolio*

The Research, Engineering, and Development Advisory Committee provided 29 research-specific recommendations for the FAA's R&D portfolio.

The FAA responded with the following:

29 – Fully concur

0 – Partially concur

0 – Non concur

4.0 FAA Research and Development Funding Profile

The FAA Research and Development (R&D) portfolio supports regulation, certification, and standards development along with National Airspace System (NAS) modernization, policymaking, and planning.

The R&D portfolio addresses the specific needs of FAA sponsoring organizations, including Aviation Safety; the Air Traffic Organization; Airports; NextGen; Policy, International Affairs, and Environment; and Commercial Space. The William J. Hughes Technical Center's R&D Management Division supports the Assistant Administrator for NextGen in managing the FAA R&D portfolio for the agency.

4.1 Budgetary Accounts

FAA R&D is funded through three budgetary accounts[1] — RE&D, F&E, and AIP.

Research, Engineering, and Development

The Research, Engineering, and Development (RE&D) account funds programs that improve the NAS by increasing safety, security, productivity, capacity, and environmental compatibility in order to meet future air traffic demands.

Facilities and Equipment

The Facilities and Equipment (F&E) account funds capital investments relating to air navigation facilities and equipment, aviation safety systems (including acquisition costs, installation, testing, and laboratories), and initial maintenance contracts and training for equipment, facilities, and other construction projects. The F&E account funds R&D in two areas[2]:

- Advanced Technology Development and Prototyping — These programs develop and validate technology and systems that support air traffic services, including requirements for evolving air traffic system architecture and airport safety and capacity improvements.
- Various NextGen Portfolios — These programs have broad applicability across NextGen.

Airport Improvement Program

The Airport Improvement Program (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 research activities to assist in airport development, preservation of critical facilities, economic competitiveness, and environmental sustainability.

[1] *FAA Financial Manual, Vol 2, Chapter 2.3, issued on July 3, 2019 (see also, FAA Order 2400.12).*

[2] *Programs in these areas are typically in concept development/demonstration phases prior to FAA investment decisions.*

4.2 R&D Summary Budget Table

Budgetary Accounts

Table 1, “Planned R&D Budget by Account,” shows FY 2023 Enacted, the FY 2024 President’s Budget Request, and planned funding for FY 2025 through 2028. It also highlights the R&D contract and personnel costs for FY 2024.

Table 1: Planned R&D Budget by Account

Program	Account	2023 Enacted	2024 President's Budget	*2024 Contract Costs ($000)*	*2024 Personnel Costs ($000)*	*2024 Other In-house Costs ($000)*	2025 Estimate ($000)	2026 Estimate ($000)	2027 Estimate ($000)	2028 Estimate ($000) /1
Fire Research and Safety	RE&D	7,136	7,722	*2,792*	*4,849*	*81*	7,600	7,722	8,200	8,300
Propulsion and Fuel Systems	RE&D	3,000	6,374	*3,947*	*2,386*	*41*	6,500	6,880	7,000	7,500
Advanced Materials/Structural Safety	RE&D	14,720	2,526	*1,351*	*1,129*	*46*	3,000	3,526	4,100	4,600
Aircraft Icing	RE&D	2,472	3,960	*2,700*	*1,238*	*22*	3,500	4,000	4,000	4,540
Digital System Safety	RE&D	3,689	7,109	*5,178*	*1,909*	*22*	5,500	7,110	6,000	7,700
Continued Airworthiness	RE&D	8,829	8,425	*4,520*	*3,832*	*73*	9,500	8,925	10,000	9,500
Flight Deck/Maintenance/System Integration Human Factors	RE&D	14,301	15,646	*9,317*	*6,227*	*102*	14,800	15,150	15,300	15,700
System Safety Management/Terminal Area Safety	RE&D	9,252	9,349	*6,406*	*2,879*	*64*	9,800	9,650	10,300	10,200
Air Traffic Control/Technical Operations Human Factors	RE&D	5,911	6,389	*2,481*	*3,823*	*85*	6,000	6,391	6,500	6,900
Aeromedical Research	RE&D	9,000	12,205	*6,995*	*5,094*	*116*	11,600	12,205	12,100	12,700
Weather Program	RE&D	13,786	19,220	*16,678*	*2,491*	*51*	18,850	19,220	19,400	19,700
Unmanned Aircraft Systems Research	RE&D	22,077	21,128	*19,284*	*1,733*	*111*	19,000	21,130	20,500	22,100
Alternative Fuels for General Aviation	RE&D	10,000	11,201	*11,151*		*50*	12,000	11,700	12,500	12,200
Commercial Space Transportation Safety	RE&D	4,708	6,157	*6,157*	-	-	5,350	5,657	6,000	6,200
NextGen - Wake Turbulence	RE&D	3,728	4,680	*3,680*	*915*	*85*	3,750	4,180	4,300	4,700
NextGen - Weather Technology in the Cockpit	RE&D	4,000	-	-	-	-	-	-	-	-
Information/Cyber Security	RE&D	4,769	6,415	*5,635*	*701*	*79*	7,450	7,515	8,000	8,100
Environment and Energy	RE&D	21,000	21,305	*18,176*	*3,022*	*107*	21,200	21,305	22,000	21,800
NextGen - Environmental Research - Aircraft Technologies and Fuels	RE&D	68,000	70,774	*67,769*	*2,995*	*10*	72,000	71,034	73,000	71,810
System Planning and Resource Management	RE&D	4,141	5,097	*3,259*	*1,797*	*41*	5,100	5,200	5,700	5,700
Aviation Workforce Development - Section 625	RE&D	15,000	2,001	*1,269*	*732*	-	13,000	13,000	13,000	13,000
William J. Hughes Technical Center Laboratory Facilities	RE&D	5,481	5,447	*2,566*	*2,841*	*40*	5,500	5,500	6,100	6,050
Aviation Accessibility Research	RE&D	-	2,000	*2,000*	-	-	-	-	-	-
RE&D TOTAL	**RE&D**	**255,000**	**255,130**	***203,311***	***50,593***	***1,226***	**261,000**	**267,000**	**274,000**	**279,000**

/1 The funding levels listed for years 2025 to 2028 are estimates and subject to change.

4.0 FAA R&D Funding Profile

Table 1: Planned R&D Budget by Account (continued)

Program	Account	2023 Enacted	2024 President's Budget	*2024 Contract Costs ($000)*	*2024 Personnel Costs ($000)*	*2024 Other In-house Costs ($000)*	2025 Estimate ($000)	2026 Estimate ($000)	2027 Estimate ($000)	2028 Estimate ($000) /1
										/2
Advanced Technology Development and Prototyping	F&E	24,300	34,440	*34,440*	-	-	36,380	35,190	38,930	35,360
William J. Hughes Technical Center Laboratory Sustainment	F&E	16,900	16,900	*16,900*	-	-	16,900	16,900	16,900	17,000
William J. Hughes Technical Center Infrastructure Sustainment	F&E	15,000	10,000	*10,000*	-	-	10,000	10,000	10,000	10,000
NextGen - Separation Management Portfolio	F&E	17,000	14,400	*14,400*	-	-	14,000	14,000	14,000	13,000
NextGen - Traffic Flow Management Portfolio	F&E	15,000	10,000	*10,000*	-	-	11,000	9,000	9,000	12,000
NextGen - On Demand NAS Portfolio	F&E	8,500	8,500	*8,500*	-	-	11,000	9,000	9,000	11,000
NextGen - NAS Infrastructure Portfolio	F&E	20,850	12,000	*12,000*	-	-	14,000	13,500	15,000	16,000
NextGen Support Portfolio	F&E	5,000	5,000	*5,000*	-	-	8,000	7,000	8,000	7,000
NextGen - Unmanned Aircraft Systems (UAS)	F&E	13,000	14,000	*14,000*	-	-	16,000	16,000	16,000	16,000
NextGen - Enterprise, Concept Development, Human Factors, & Demonstrations Portfolio	F&E	11,000	11,000	*11,000*	-	-	10,000	10,500	10,500	11,500
Center for Advanced Aviation System Development (CAASD)	F&E	57,000	57,000	*57,000*	-	-	47,000	47,000	47,000	47,000
F&E TOTAL	**F&E**	**203,550**	**193,240**	***193,240***	**-**	**-**	**194,280**	**188,090**	**194,330**	**195,860**
Airport Cooperative Research		15,000	15,000	*15,000*			15,000	15,000	15,000	15,000
Airport Technology Research		40,828	41,801	*41,801*			42,500	42,500	42,500	42,500
AIP TOTAL	**AIP**	**55,828**	**56,801**	***56,801***	**-**	**-**	**57,500**	**57,500**	**57,500**	**57,500**
GRAND TOTAL		**$514,378**	**$505,171**	***$453,352***	***$50,593***	***$1,226***	**$512,780**	**$512,590**	**$525,830**	**$532,360**

/1 The funding levels listed for years 2025 to 2028 are estimates and subject to change.
/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.