
2022 Research and Development Annual Review

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August 2023

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U.S. Department of Transportation
Federal Aviation Administration


Canada

Contents

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The Research and Development Annual Review is a companion document to the National Aviation Research Plan, a report of the Federal Aviation Administration to the United States Congress pursuant to section 44501(c)(3) of title 49 of the U.S. Code. This document is available online at *faa.gov/go/narp*.

Foreword

The FAA continues to provide the world's safest and most efficient aerospace system. In these times of innovation, when new forms of air transportation are constantly being developed, significant challenges persist, including aviation's environmental impacts. These opportunities and obstacles require continued progress on important issues, including combating climate change, protecting the environment, and advancing the agency's safety mission.

The FAA's research and development supports National Airspace System (NAS) modernization by enabling technological, policy, and procedural advancements with a focus on safety and environmental responsibility.

The Annual Review highlights the accomplishments of the research completed during the prior fiscal year, including a description of research results disseminated to the private sector and a description of new technologies developed by the agency. The Annual Review is the companion document to the FAA's National Aviation Research Plan, which describes planned research activities over the next five years.

In FY 2022, the FAA conducted research on a variety of topics, including enhanced air traffic and airspace management; new technologies for aerospace vehicles, airports, and spaceports; infrastructure improvements for the NAS; improved human performance for unmanned aircraft systems remote pilots, cabin crew, maintenance personnel, air traffic controllers; and improved system-wide analysis methods for the NAS.

Performance Results

Overview

The FAA uses research and development (R&D) to support policymaking, planning, regulation, certification, standards development, and National Airspace System (NAS) modernization. The FAA R&D portfolio supports day-to-day operations in the NAS and balances near-, mid-, and long-term aviation needs.

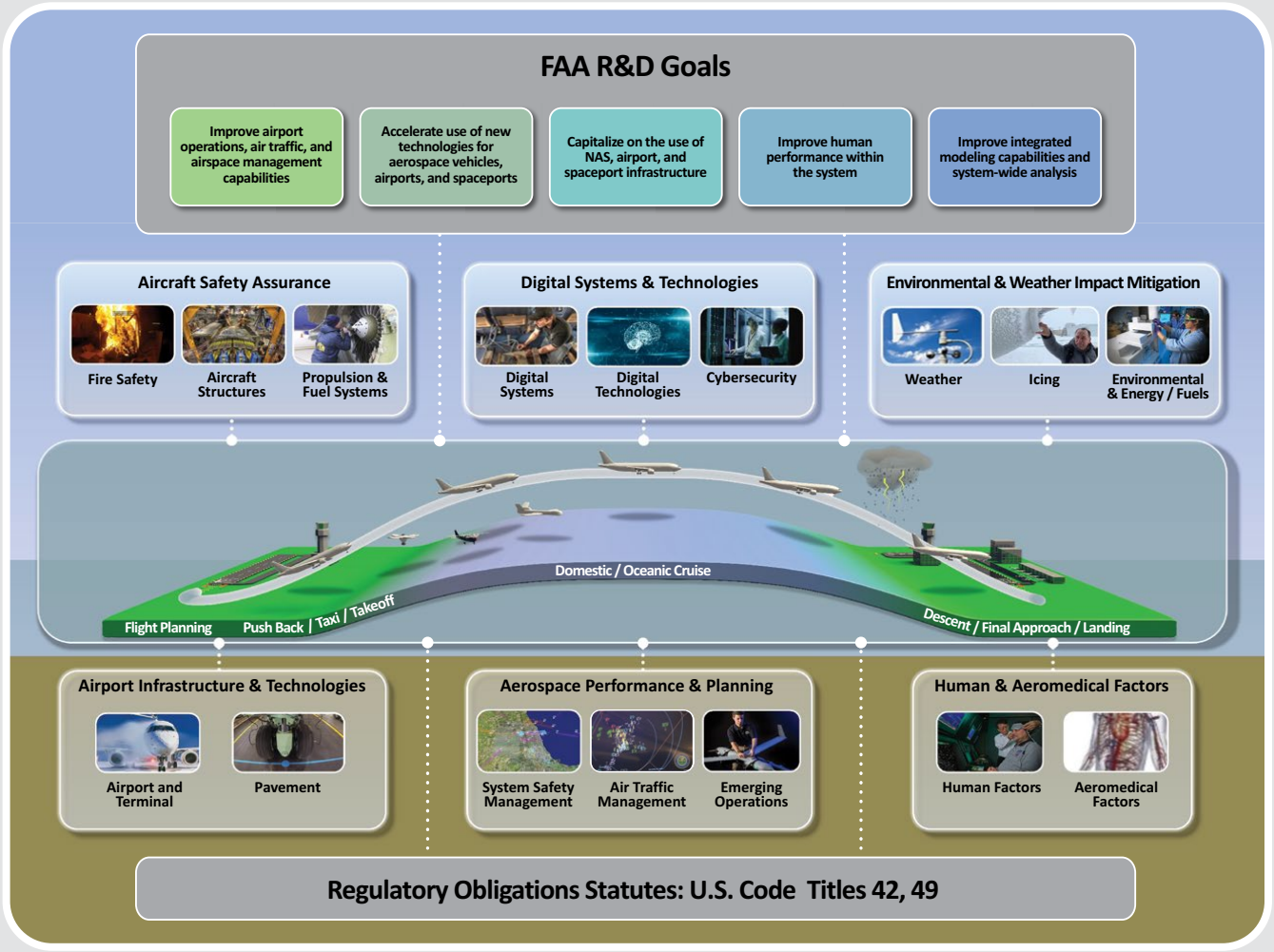
The FAA's R&D goals focus on researching and identifying solutions for:

- **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**

The FAA's R&D activities span multiple research domains which are 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**

The following sections provide in-depth descriptions of the R&D goals, highlight FY 2022 research accomplishments, feature research results disseminated to the private sector, and offer an overview of new technologies developed by the FAA.



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.

Goal 1:

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

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 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.

Goal 1 Research Activity Status

Surface Tactical Flow Research Activities

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Aerospace Performance and Planning	Research mobile technologies in support of the Air Traffic Demonstration 2 (ATD-2) Phase 3 Field Demonstrations	Report on the applicability of mobile technologies to NASA's ATD-2 integrated arrival, departure, and surface metering capability	Completed	Page 11
Aerospace Performance and Planning	Research mobile technologies in support of strategic demand applications	Technical transfer of results to industry	Completed	Page 11

Closely Spaced Parallel Runway Research Activity

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Aerospace Performance and Planning	Support the FAA's Air Traffic Organization in publication of a document change proposal for the Air Traffic Control Handbook	Reduction of current separation standards for closely spaced parallel runway operations	Completed	Page 14

Goal 1 Success Stories

Increasing Airport Efficiency

NASA's Airspace Technology Demonstration 2 program, or ATD-2, is developing technologies in coordination with the FAA that predict airport traffic conditions and determine the best time for departing flights to push back from the gate. Metering, or controlling the release of aircraft from an airport, helps air traffic controllers manage airport congestion.

Shifting some of the departure wait time away from the taxiway prevents long departure queues, saves fuel, reduces emissions, and creates more flexibility for air carriers and passengers. Precisely scheduling takeoffs to help aircraft better integrate into the overhead stream of air traffic increases overall NAS efficiency.

This type of coordination requires integrating numerous data streams from the FAA and airlines and transforming the information so it can be easily shared across various systems. Researchers completed the ATD-2 Phase 3 field demonstration and submitted a final report in 2022 on the applicability of using mobile technologies for integrated arrival, departure, and surface metering.

Updated Standards for Dependent Departures

The FAA updated standards for dependent (staggered) departures from closely spaced parallel runways less than 2,500 feet apart. The changes are based on the agency's research to maximize the use of parallel, converging, and intersecting runways to improve overall capacity at the busiest airports, increase aircraft throughput, and reduce airport delays during all weather conditions.

Studies involved a wide variety of technologies and procedural improvements to improve capacity and efficiency in the NAS. The FAA used the research results to enhance surveillance update rates and display processing times, allowing the agency to update the standards.

Evaluating the Safety of Vaccine Transport

In May 2022, the FAA completed a test of a custom-engineered aircraft lowering device. The tool will allow researchers to use a Boeing B-727 freighter as a testbed for evaluating hazards associated with transporting COVID-19 vaccines containing large amounts of dry ice.

As dry ice warms, it changes from solid carbon dioxide to a gas, which can be hazardous to human health at certain concentrations. The concern addressed by the testing is whether the mass of carbon dioxide gas, which is heavier than air and settles in lower areas of the aircraft, will move forward upon nose-down rotation of the plane, possibly creating a hazardous condition in the flight deck.

The lowering device built by the FAA uses a hydraulic-style automotive lift coupled to a steel cradle lined with heavy-duty rollers to allow the aircraft to slide freely when the lift is raised and lowered. Once the lift is fully lowered, the plane sits at approximately three degrees pitch down, which mirrors the typical aircraft pitch during a routine descent. This capability allows the project's next phase to commence, where researchers will release measured quantities of carbon dioxide gas in various parts of the cargo compartments.

Visibility Information Derived from Weather Cameras will Increase Aviation Safety

Since 2016, the FAA has been developing and testing a new capability that derives meteorological visibility estimates from the *FAA Weather Camera (WeatherCams)* network. This technology, called Visibility Estimation through Image Analytics (VEIA), compares the visible edges of permanent landscape features to clear day images.

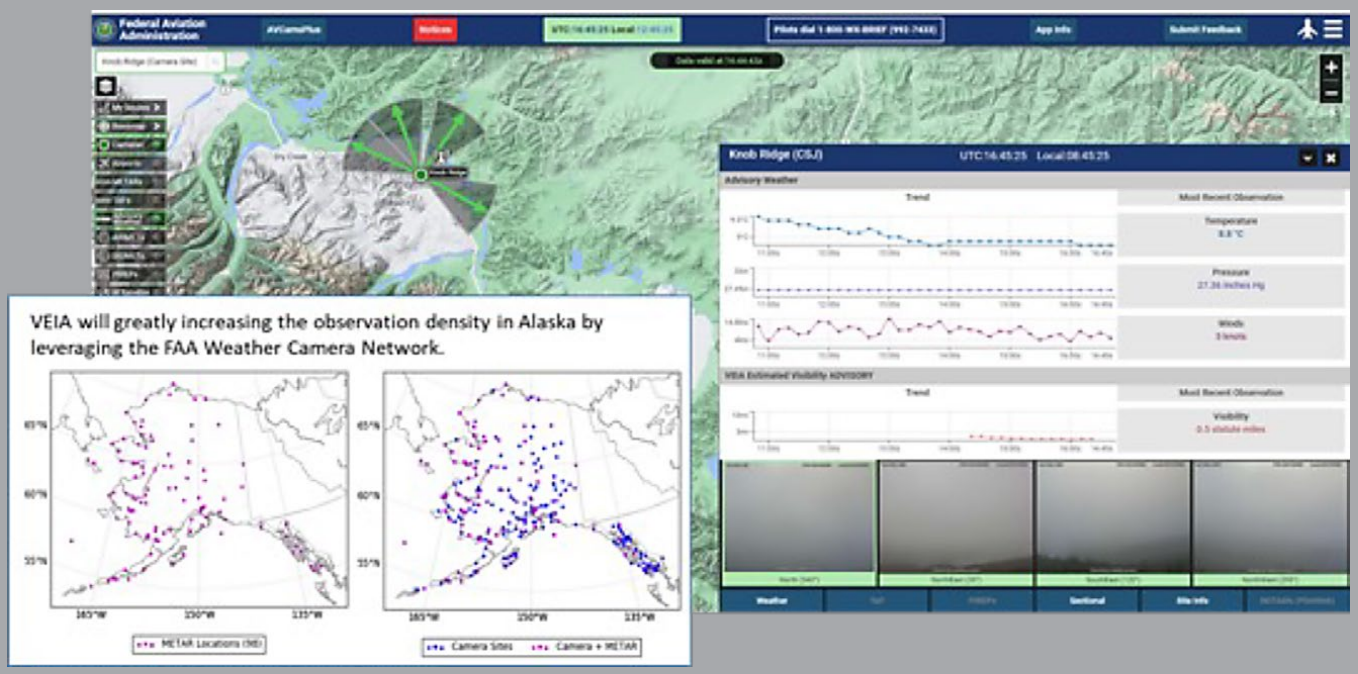
In FY 2022, the FAA completed testing and evaluation of VEIA to prove its meteorological accuracy, value added to aviation users, and safety in an operational environment. Researchers found that VEIA visibility information would increase safety for all aviation users by providing visibility estimates to support decision-making in locations without routine aviation weather reports known as *METARs*.

In the final part of the evaluation, the FAA convened a safety risk management panel in October of 2022, consisting of experts from across the FAA, the National Oceanic and Atmospheric Administration, the National Transportation Safety Board, and academia. The committee reviewed user testing and meteorological accuracy results of VEIA and determined that the technology can be safely implemented. The FAA plans to deploy VEIA visibility estimates on the WeatherCams website in spring of 2023.

Digital Taxi Capabilities

The FAA conducted a successful proof-of-concept activity highlighting digital taxi capabilities and demonstrating progress in communicating pilot and air traffic control (ATC) intent. The event showcased the Intelligent Taxi Guidance Platform prototype through simulated scenarios at the agency's Florida NextGen Test Bed in Daytona Beach, FL.

The interactive session included a prototype overview, a look at the application architecture, a capabilities demonstration, and an assessment of future activities. During the activity, the Intelligent Taxi Guidance Platform interacted with a third-party electronic flight bag application and successfully exchanged taxi-related messages in a simulated environment.



Example of VEIA visibility estimates on the FAA Weather Camera test website from the Knob Ridge region in Alaska. The embedded graphic shows the Alaskan METAR observation density (left panel) compared to the camera density (right panel).

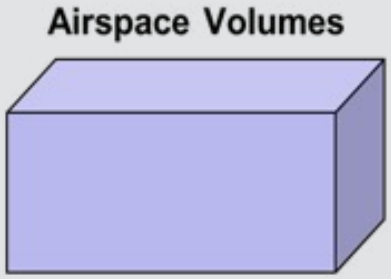
Dynamic Airspace Proof of Concept

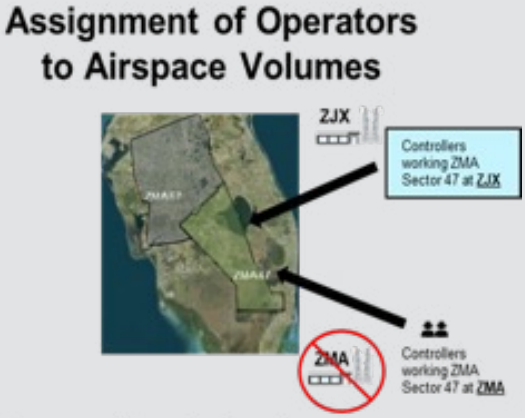
Efficient air traffic and air space management capabilities are vital to maintaining the world's most complex airspace system. Dynamic Airspace (DA) is a new operational concept that proposes a shift from the current structured static airspace to airspace capable of adapting to user demand while adjusting to changing weather, traffic congestion, and complexity patterns, as well as a highly diverse aircraft fleet.

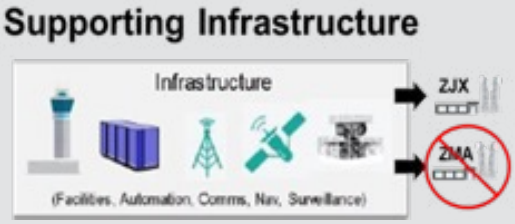
DA will facilitate the remapping of NAS infrastructure elements to support the flexible and timely temporary transfer of airspace to and from different air traffic facilities to ensure maximum throughput in all conditions while maintaining safe operations. The FAA conducted a proof-of-concept demonstration at the Florida NextGen Test Bed.

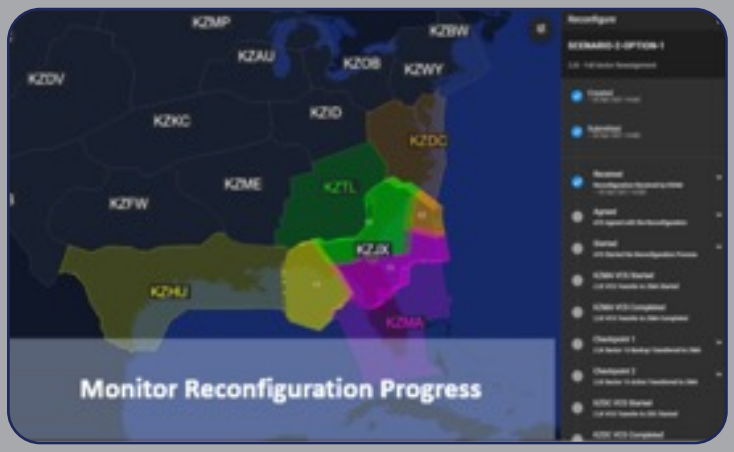
The exercise showcased the capabilities of the Dynamic Airspace Reconfiguration Tool (DART), which offers air traffic managers better visibility and control of regional airspace and provides monitoring and communication abilities between various ATC operations.

Researchers installed DART and the internet protocol Voice Communication System at the test bed location. Using these tools, researchers simulated and demonstrated two dynamic airspace scenarios in which participants resolved unexpected demand and capacity imbalances by reallocating airspace between neighboring high-altitude ATC centers.









Researching Thermal Runaway in Lithium-Ion Batteries

The FAA's fire safety lab is a leading government facility with the expertise and equipment to research and evaluate the state of charge in lithium-ion batteries — a battery's charge level compared to the total battery capacity. Researchers used this expertise to investigate the cause of a battery fire at an air freight carrier to help prevent this from happening again.

In February of 2022, a package containing 140 lithium-ion batteries caught fire on a conveyor belt at a UPS facility in Louisville, KY. Investigators determined the cause as thermal runaway, a chemical reaction within a battery cell that results in a dramatic, uncontrolled increase in temperature and pressure. Lithium-ion batteries have become a common power source for computers and smart devices, but they present a unique fire threat when transported onboard aircraft due to thermal runaway risk.

The package that caught fire was one of five shipped by air from Hong Kong. When the incident occurred, the parcels were being transferred for air shipment to Montreal, Canada. UPS sent one of the remaining packages to the FAA's William J. Hughes Technical Center for researchers to investigate the fire's cause and study the risks posed by batteries at different states of charge.

Investigating the State of Charge

FAA researchers used specialized analysis equipment to determine that the batteries in the package had a substantially higher state of charge than the allowable 30 percent. Batteries exceeding this limit pose a significant fire threat due to thermal runaway. Researchers found the average state of charge of all the batteries in the package was approximately 70 percent.

During the analysis, the research team learned that two types of battery cells were packaged together in unsealed plastic sleeves. The researchers hypothesized that the cells slipped out of the sleeves during handling and the battery terminals made contact, causing the cells to short circuit and enter thermal runaway.

Thermal Runaway Testing

The research team conducted thermal runaway testing to analyze the fire threat of the batteries at various states of charge. The results were consistent with previous FAA studies showing that batteries with high states of charge experienced a more violent reaction during thermal runaway, resulting in considerable burn damage in the surrounding packaging and destruction of the cells.

Researchers conducted five thermal runaway tests on batteries at a state of charge of 70 percent. The batteries exhibited thermal runaway in four of five tests and propagated to adjacent cells. During another round of testing, researchers placed a spark igniter near the stack of batteries undergoing thermal runaway. The gases released during the test caught fire, suggesting a potential spark could have helped ignite the original package.

The FAA's Unique Expertise

Without the FAA's aviation expertise and advanced research facilities, the risk of future lithium-ion battery thermal runaway events would remain unchecked. The FAA is uniquely charged with providing objective data, analysis, and regulations for the transportation of lithium-ion batteries in the United States and a key leader in global aviation fire safety.

Photograph of fire on UPS conveyor belt (L) and post-fire remnants (R)

Goal 2:

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

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 the new industries, improve aircraft performance, and drive policy.

Goal 2 Research Activity Status

Supersonic Aircraft Research Activity

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Environmental and Weather Impact Mitigation	Assess global environmental effects from aircraft technologies for modeled scenarios to 2050	Technology-level and flight-level analyses, assessment of original equipment manufacturer mission specifications, and projection of local environmental effects at national and international airports	Completed	Page 24

Unmanned Aircraft Systems Detection at Airports Research Activities

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Aerospace Performance and Planning	Develop preliminary counter-unmanned aircraft systems (UAS) performance standards	Report on preliminary counter-UAS performance standards	Completed	Page 27
Aerospace Performance and Planning	Install and test UAS detection and mitigation technologies at four additional U.S. airports	Validation of performance characteristics identified during initial testing at Atlantic City International Airport	Completed	Page 27

Unmanned Aircraft Systems Disaster Preparedness and Response Research Activity

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Aerospace Performance and Planning	Conduct outreach with fire departments and emergency service agencies	Document UAS use cases, best practices, and risks of using drones during emergencies, and disaster preparedness and response activities	Completed	Page 28

Goal 2 Success Stories

Environmental Noise Standards for Supersonic Aircraft

The FAA is examining the impacts of reintroducing supersonic flight, including understanding aircraft engine parameters and improving the prediction of supersonic aircraft noise. As part of its research, the FAA reported environmental findings at the Twelfth Meeting of the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) in February 2022. As a result, the committee agreed to develop landing and takeoff noise standards for supersonic airplanes during its next work cycle.

CAEP is a technical committee that assists the ICAO Council in formulating new policies and adopting new standards and recommended practices related to aircraft noise and emissions and, more generally, aviation environmental impact.

UAS Detection and Mitigation Research

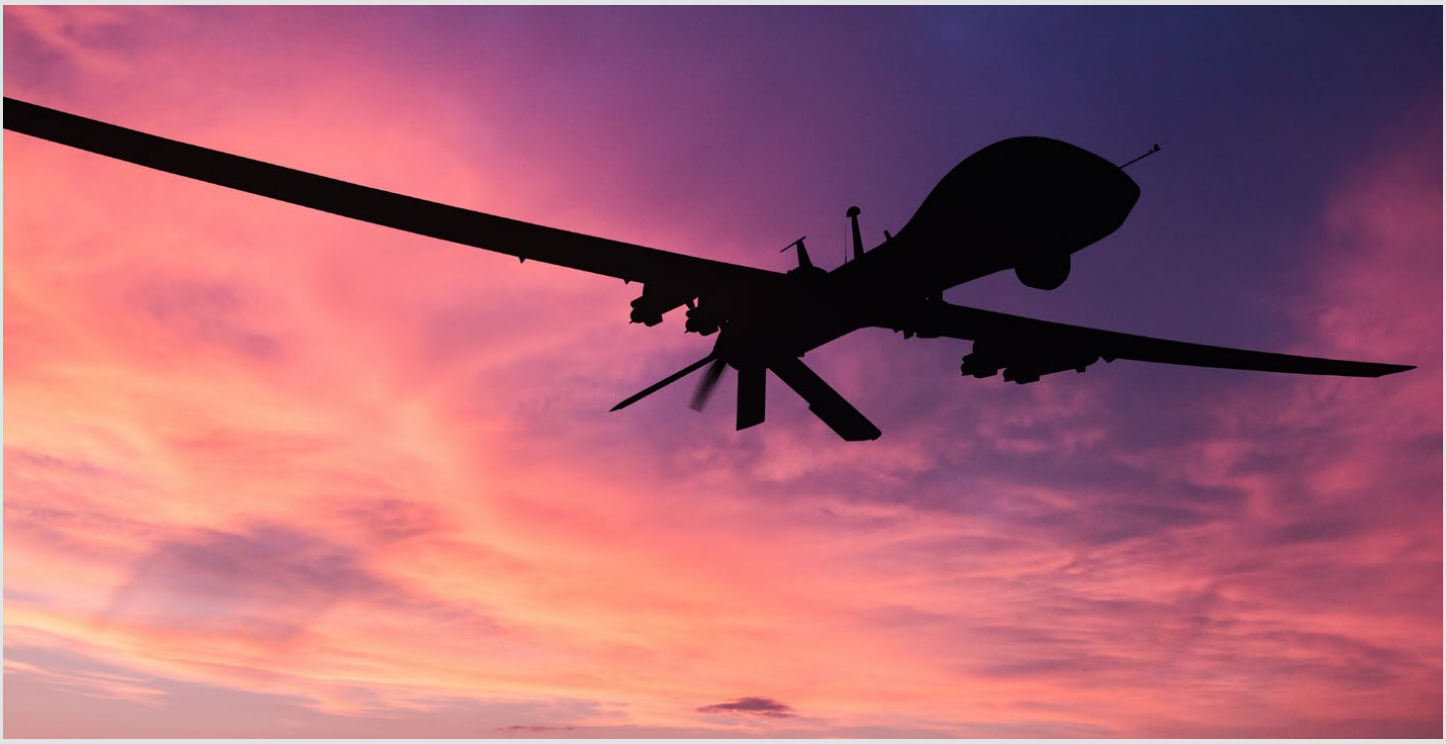
UAS, or drones, are rapidly growing in number across the United States. This surge increases safety and security concerns, especially near airports. The FAA selected five host airports to evaluate technologies and systems that could detect and remove potential safety risks posed by drones: Atlantic City International (ACY) in New Jersey, Syracuse Hancock International (SYR) in New York, Rickenbacker International (LCK) in Ohio, Huntsville International (HSV) in Alabama, and Seattle-Tacoma International (SEA) in the state of Washington.

Two vendors completed testing at ACY in 2022. Researchers conducted calibration and quality testing with the vendors to ensure the system was operational and performed as required. The evaluation included flying UAS vehicles around the airport in approximately 160 unique test scenarios. Researchers relocated the first technology to LCK and the second to SYR to evaluate them in new environments. Three additional detection vendors installed their technologies at ACY to begin testing. Upon completion, the FAA will move the technologies to HSV and SEA for further evaluation. The team expects to assess at least 10 technologies before the program ends.

Researchers have conducted over 2,500 UAS flights in support of this program. Through this research, the FAA will identify regulations and standards necessary to safely detect unauthorized drone activity at the nation's airports in a way that does not adversely impact the safe and efficient operation of the NAS as directed by Congress in the FAA Reauthorization Act of 2018, section 383.

UAS Disaster Preparedness and Response

Drones can be powerful tools during emergencies and for disaster preparedness and response, improving operations and saving lives. FAA researchers are studying ways to help facilitate coordination between local, state, and federal government agencies and increase the use of these tools during such events.



In 2022, researchers completed the first phase of work. The team compiled use cases and developed concepts of operation and operational risk assessments for human-made and natural disasters and emergencies such as wildfires, hurricanes, tornadoes, and flooding.

Researchers will use the results in an upcoming program focused on extensive flight testing and demonstration events. The FAA will use the information gathered to create future requirements, technical standards, and regulations to ensure proper coordination between government agencies and airports during emergencies, as directed by Congress in the omnibus budgets of 2018 and 2019.

Helicopter Noise Abatement Training

The FAA created operational noise training for seven helicopter models as part of a flight test campaign that helps pilots reduce aircraft noise. Based on analyses of acoustic data, the online training modules are designed to help pilots anticipate the directional noise generated by the helicopters under different operating conditions. Pilots can use this information to adjust their flight path, airspeed, approach descent, and deceleration rate to optimize flight patterns and reduce noise.

New Developments in Fuels and Noise Technologies

The FAA completed the first full year of research and development under the third phase of the Continuous Lower Energy, Emissions, and Noise (CLEEN) program. CLEEN is the agency's primary environmental effort to promote the development of new aircraft and engine technologies, accomplished through a cost-sharing approach with industry partners.

Program goals include reducing fuel burn, emissions, and engine noise from aircraft and evaluating sustainable alternatives to traditional jet fuels. The FAA initiated Phase III of CLEEN in 2021 with an expected duration of five years.

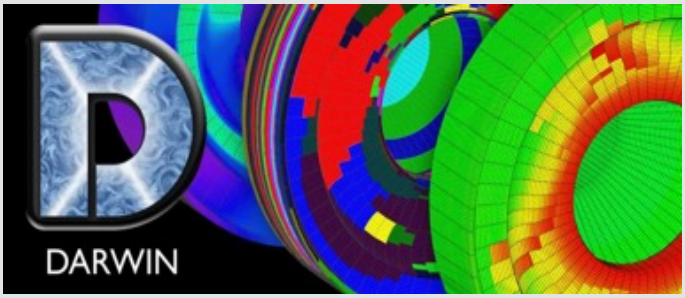
In the program's first year, eight industry partners completed conceptual and preliminary design activities on many aircraft and engine technology projects. These technical design reviews represent significant steps in maturing the CLEEN Phase III technologies. Completing this work sets the stage for prototype fabrication and ground and flight testing in the program's later years.

Results are expected to:

- **Mature the technologies**
- **Reduce technical risks**
- **Demonstrate emissions, noise, and fuel burn benefits**
- **Prepare technologies for introduction into future aircraft and engine designs, leading to NAS environmental benefits**

DARWIN® 10.0 Turbine Engine Design Software Release

Through funding provided by an FAA aviation research grant, the Southwest Research Institute developed and released version 10 of the turbine engine design code known as *DARWIN®*, or Design Assessment of Reliability with Inspection software.



Engine manufacturers use the software code to design and verify the compliance of life-limited engine parts that need to be replaced regularly due to wear and tear during the life of an aircraft.

When engine parts break due to abnormalities in the metal, fragments can escape the engine case and impact other parts of the aircraft. These uncontained engine failures pose a serious threat to passengers and the continued safe operation of the aircraft.

Released in September of 2022, DARWIN® 10.0 contains improved features, including the ability to conduct FAA certification assessments for rotor axial blade slots, updated titanium anomaly distributions, 3-D visualization improvements, speed and robustness enhancements, and data security features.

The DARWIN® design code is publicly available and licensed to over 20 industrial users, including all major U.S. and European turbine engine manufacturers. Because DARWIN® was developed with federal funds, all federal agencies may use the software for free.

Piston Aviation Fuels Initiative Testing

Hi-octane-leaded aviation fuel is the largest source of airborne lead emissions in the United States. There is no known safe exposure level to lead, and multiple studies document its negative health impacts. The Eliminate Aviation Gasoline Lead Emissions (EAGLE) initiative brings together the FAA, the Environmental Protection Agency, and the aviation industry to transition general aviation to lead-free fuels by the end of 2030.

Operating under the EAGLE umbrella, the Piston Aviation Fuels Initiative (PAFI) collaborates with over 45 industry groups to research, test, and qualify viable, safe, high-octane replacements for leaded aviation gasoline. In addition, PAFI will lead efforts to find sustainable and renewable fuels and fuel components for general aviation.

Continuously learning from research results, the FAA has refined its test methodologies and processes for identifying and screening potential unleaded fuels. Today, the agency has the world's most comprehensive approach to testing and validating fuels to ensure their safe operation in the general aviation fleet of engines and aircraft. This has all been accomplished in collaboration with aviation industry partners to ensure the widest commercial acceptance of tested fuels within the general aviation community.

In 2022, the FAA completed pre-screening performance and detonation testing on the latest Afton/Phillips 66 candidate fuel. This followed formulation refinements based on earlier studies and test results. The FAA used this test data and other test results to verify that the fuel met the performance and detonation requirements for entry into the full-scale PAFI test program. Additional testing for endurance attributes will begin in FY 2023.

A second candidate fuel is in the process of pre-screening performance and detonation testing. Both fuels have been accepted through the materials portion of the screening and

The FAA uses special equipment to research high-octane unleaded fuel replacements for current leaded aviation gasoline.

will need to meet a third criterion during the next fiscal year to proceed to the full-scale testing phase of the program.

Following the completion of full-scale testing, the FAA will issue fleet authorizations for fuels that meet technical and safety requirements in accordance with Section 565 of the FAA Reauthorization Act of 2018. The fuel company will use these and other test results to support their efforts to develop an American Society for Testing and Materials fuel specification.

Emerging Metallic Structures Technology Fuselage Testing

Aircraft manufacturers are increasingly trying to improve performance and reduce fabrication, operations, and maintenance costs by introducing advanced materials into manufacturing and production technologies.

In partnership with Arconic and Embraer, the FAA is investigating safety and structural integrity issues related to emerging metallic structures technology (EMST) applied to the fuselage during manufacturing. Advanced alloys and hybrids are stronger and lighter than metals commonly used to build older aircraft. However, the risks they pose as they age are not as well understood as the systems they replace.

Researchers completed the initial testing and analysis phase in 2022 for an EMST panel constructed with next-generation aluminum-clad alloy reinforced with an aluminum-lithium substructure. The team used the FAA's Full-Scale Aircraft Structural Test Evaluation and Research fixture to conduct testing.

Test results demonstrated improvements in the structural performance using EMST compared to the baseline panel constructed with conventional materials and processes. The next testing phase will study the effects of pressurization on fatigue cracks. The FAA will use the study results from this program to create policies that ensure the safe and efficient implementation of EMST in aircraft products.

Improving Acoustics in Compact Engine Nacelle Architectures

Closing out Phase II of the CLEEN program, the FAA completed work with Boeing in FY 2022 to improve acoustics in compact engine nacelle architectures. A nacelle is the outer casing of an aircraft engine. Boeing designed, fabricated, and integrated acoustically-treated parts into a LEAP-1B engine nacelle.

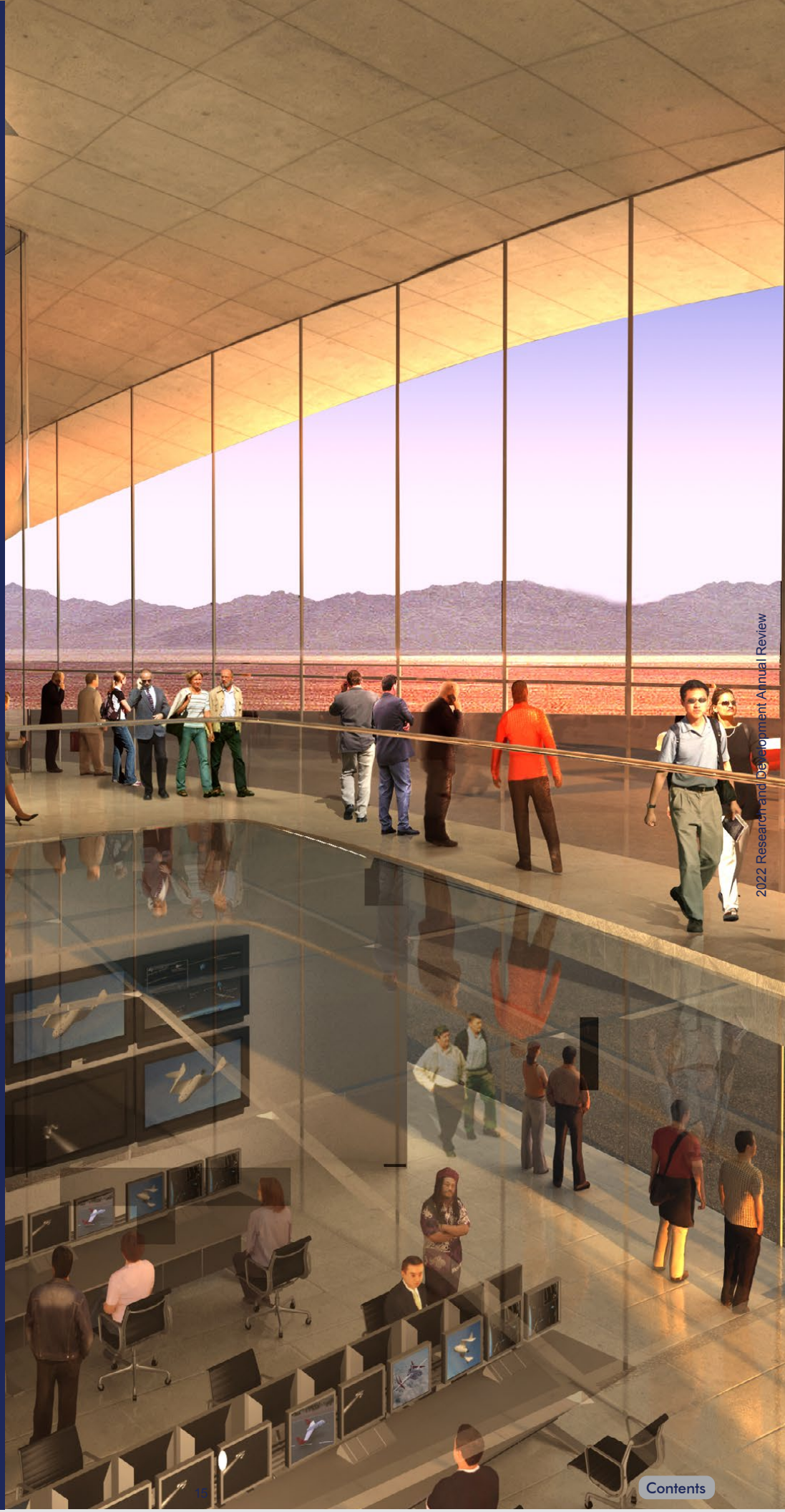
Researchers conducted a noise flyover prototype test in July 2021 using Boeing's 737 MAX 9 aircraft, providing data on the technology benefits for future incorporation into next-generation nacelles. The results exceeded expectations for noise reduction. Now available, Boeing will use this technology in future aircraft designs and products.

Goal 3:

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

A durable, long-life, and resilient infrastructure forms the backbone of an efficient, safe, and secure NAS. Research under this goal includes airport runways, taxiways, air traffic management (ATM), 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 research will lead to a longer-lasting, lower-cost, dependable infrastructure defended against cyber events.



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Goal 3 Research Activity Status

Cybersecurity Data Science Tools Activity

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Digital Systems and Technologies	Vulnerability and risk assessment technology research	New software and technical documentation	Completed	Page 37

Goal 3 Success Stories

Cybersecurity Solutions

The FAA manages ATC operations through a complex network of computer and information systems. Cyber-attacks are a growing concern for the aviation industry, although many new tools are emerging to safeguard networks. The FAA's Cybersecurity Data Science (CSDS) program aims to identify effective and innovative ways to apply artificial intelligence (AI), machine learning, and data science technologies to prevent, detect, and neutralize evolving cybersecurity threats for aircrafts, airlines, and airports.

In FY 2022, the CSDS program researched vulnerability and risk assessment (V&RA) and lateral movement defense technologies (LMD), areas with strong interest from the aviation industry. Using information gathered from these studies, the team created software prototypes for V&RA and LMD. The FAA plans two advanced technology demonstrations for airlines, airports, and aircraft manufacturers. The agency will use information gathered from the demonstrations to evaluate use cases and create cybersecurity guidance.

New Internet Protocol Suite Standards

ATM evaluates air traffic from a nationwide perspective to balance demand with system capacity. The FAA is studying ways to integrate new and emerging technologies to enhance tools for strategically managing aircraft.

One area of focus is creating and validating standards for internet protocol networks to transmit air-to-ground and ground-based air traffic management data using the Internet Protocol Suite (IPS). Researchers completed draft versions of the following IPS standards in 2022:

- **RTCA Minimum Aviation System Performance Standards**
- **IPS standards and recommended practices for ICAO with an accompanying technical manual**
- **Airlines Electronic Engineering Committee IPS form, fit, and function standards**

Researchers also created prototype avionics and completed lab and flight testing to gather initial performance measurements and support standards validation.

Final report on Cybersecurity Considerations for Connected Aircraft Applications

The aviation industry is embracing technologies such as cloud-based and client-server architectures and AI to enhance avionics systems to allow future autonomous flights. The traditional flight deck is being supplemented by rapidly expanding applications for Electronic Flight Bags (EFBs), which pilots use to exchange safety and other important information with ground systems and assist flight crews with strategic decision making. However, there is a need for reliably and securely connecting aircraft applications and services to the NAS air traffic management infrastructure, where the EFB can act as a secure bridge to onboard avionics.

The FAA completed a security control assessment for the Flight Deck Collaborative Decision Making system architecture and the Digital Taxi Instructions application using the Connected Aircraft Security Controls (CASC) tool. CASC can be used to select and tailor minimum security controls to comply with government and industry cybersecurity standards, including FAA Order 1370.121A and *National Institute of Standards and Technology Special Publication 800-53.*

The analysis demonstrated the usefulness of the CASC tool and proved its effectiveness in determining security controls for future FAA systems and guiding future tool enhancements.

Using UAS to Enhance Situational Awareness during Aircraft Rescue and Firefighting Response

The FAA conducted research and hands-on exercises to explore how UAS can improve situational awareness and enhance the effectiveness of aircraft rescue and firefighting (ARFF) personnel during an incident response.

Researchers found that drones equipped with thermal and visual cameras significantly benefited incident commanders in various ARFF response scenarios. Upon completion of the testing, the FAA published a report, *Evaluation of UAS for Live Monitoring to Enhance Situational Awareness during an ARFF Response*, providing a research summary, along with platform and payload specifications.

Shared at the ARFF working group annual symposium, the report was downloaded more than 200 times in the two weeks following publication. The FAA will use the research results to set minimum performance specifications and technical/operational considerations for using UAS to aid ARFF response.

Contents

Goal 4:

Improve human performance within the system

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.

Goal 4 Research Activity Status

Infectious Disease Research Activity

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Human and Aeromedical Factors	Conduct a cabin health safety risk assessment	Develop a framework for modeling, simulation, and analysis, and other associated tools	Completed	Page 42

Rotorcraft Safety and Accident Research Activity

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
Aerospace Performance and Planning	Research wire strike avoidance	Identification of sensor and display technologies to detect wire location, and create a prototype design for low-cost and low-weight wire-cutting technologies	Completed	Page 43

Goal 4 Success Stories

Cabin Air Quality Assurance

The FAA is committed to the health and safety of passengers and cabin crew by maintaining strict cabin air standards. In rare instances, certain mechanical issues can cause fumes (from engine oil, hydraulic fluid, or deicing fluid – known as bleed air contaminants) to enter the cabin.

Researchers identified sensors and sensing technology with the potential for detecting one or more of these bleed air contaminants. Working with the FAA, Kansas State University (KSU) completed Phase I of the project and submitted a report to the FAA for review. A follow-on contract for Phase II work was awarded to KSU in consultation with the FAA and U.S. Navy. Preliminary sensor data and bleed air chemical analysis is ongoing, as is planning for the on-wing aircraft tests.

Effects of Airplane Cabin Interiors on Egress

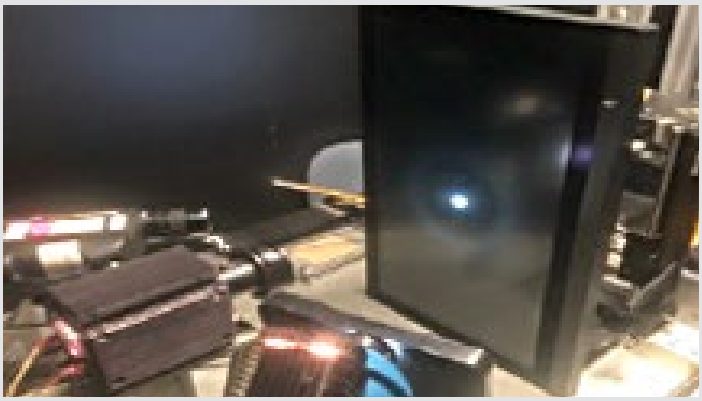
Researchers published a report in 2022 documenting the impact of aircraft seating changes on the time it takes passengers to exit an aircraft. Airlines and airframe manufacturers are proposing varying legroom and seat width to improve customer comfort while maximizing the use of space. However, seating arrangement has a direct impact on evacuation time.

The FAA evaluated the effects of these changes on passenger safety using the Civil Aerospace Medical Institute's Flexible Cabin Simulator. Researchers studied the effects of seating arrangement and the impact of an occupant's size, form, and functional capacity on the time it takes to exit the aircraft.

Data derived from this work will help the agency create regulatory standards and minimum aircraft seat pitch and width requirements, as required under the FAA Reauthorization Act of 2018, section 577.

Touch-Based User Interface Guidance

Touch screens are increasingly appearing on ATC displays and equipment. The FAA has limited guidance and standards for these touch-based interfaces. To address this, the agency initiated a project to establish requirements for ATC systems based on aviation industry benchmarks and other scientific sources.

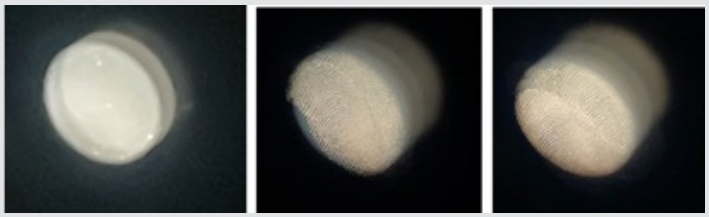


Optical testing apparatus

Working with Honeywell Aerospace, the FAA conducted a literature review of the current touch screen market to identify best usability practices and standards the agency could apply to future ATC system design. Standards addressed in the research included:

- **User interface definition**
- **Readability**
- **Luminance**
- **Reflectance**
- **Touch target size**
- **Touch errors**
- **Heads-down time**
- **Touch gestures**
- **Latency**
- **Fatigue**
- **User interface display position**

Through analysis and integration of the available scientific and technical information, researchers produced a comprehensive final report and briefing describing recommended design requirements for ATC touch screens, known standards for using touch-user interfaces, and design process considerations.



Area of reflection measurement.
Left = 0 fingerprints; Middle – 5 fingerprints; Right = 10 fingerprints

Managing Air Traffic in High-Density Areas

With the projected growth in aviation over the coming decades, air traffic is expected to increase — particularly in areas with multiple, busy airports. In partnership with the Department of Transportation's Volpe National Transportation Systems Center, the FAA examined flight deck human factors perspectives on instrument flight procedures through testing of the agency's Multiple Airport Route Separation (MARS) program.

MARS is an ATC concept that uses pairs of instrument flight procedures to manage congestion and deconflict flights into and out of areas with multiple, high-density airports. Research included work to define airspace complexity, data collection and analysis about flight operations in the New York metropolitan region, an assessment of one of the proposed MARS program arrival applications, and a sampling of pilot behaviors demonstrating resilience in current-day operations. The Volpe report provided several recommendations for instrument flight procedures design, operations, and the MARS program.

Pilot-Controller Voice Response Time Research

The FAA sponsored a series of studies that characterize routine communications in various ATC environments. One study systematically examined the time required for pilots to respond to time-sensitive ATC transmissions. This work, conducted by Volpe for the FAA, continues to be cited by various organizations, including ICAO and NASA.

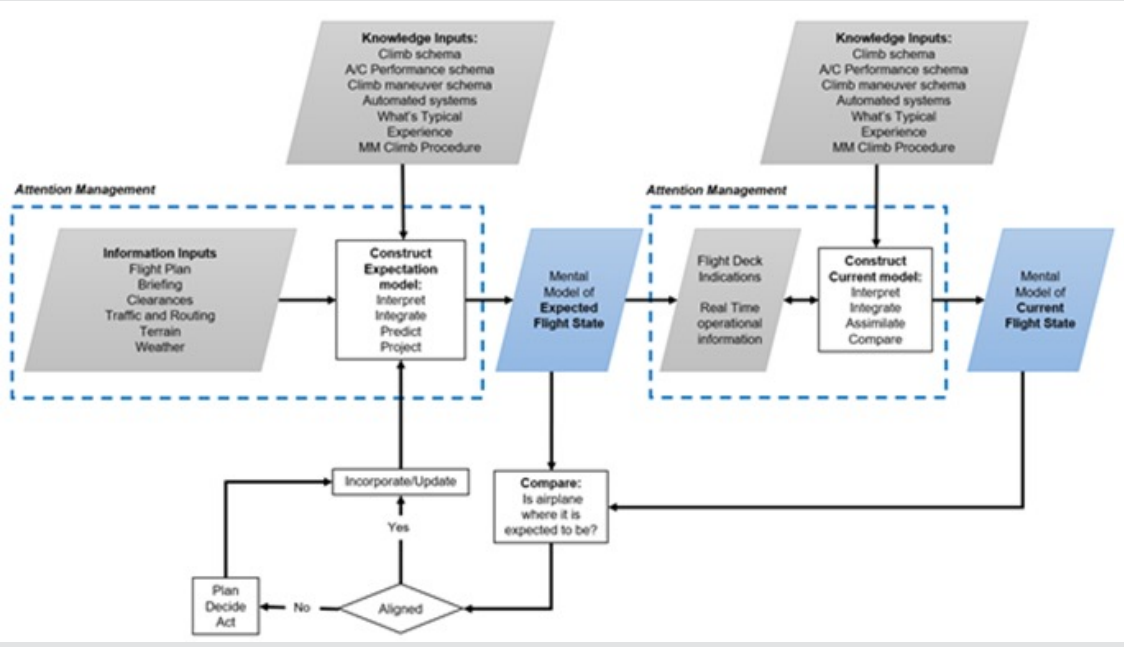
ICAO's Separation and Airspace Safety Panel and the FAA's Controller-Pilot Data Link Communications Working Group used the studies to jointly discuss the applicability of past pilot-controller voice communications research to assumptions in the development of new separation standards. Standards-setting bodies will use the information to decide whether new voice communications technologies require further separation and communication performance standards.

Pilot Cognitive Skills during Air Carrier Operations

Aviation increasingly relies on new communication, navigation, surveillance, and decision-support technologies. However, the impact of these tools on the behavior and performance of pilots is unclear and requires further study.

The FAA led a research effort to establish a baseline of cognitive skills and knowledge required for flight path management (FPM) tasks for transport aircraft. During the studies, pilots verbalized their thought processes as they conducted FPM tasks to provide insight into the cognitive skills applied throughout the flight. Researchers compared expected flight behaviors to actual behaviors. The data gathered from this research will serve as a reference point for future comparison, identify potential risk areas, and test the effectiveness of measures to limit those risks.

Follow-on research will examine the risks associated with the long-term use of information automation systems and pilot cognitive skill development, retention, and proficiency. The FAA will use the resulting data to create guidance for ensuring pilots develop and maintain the appropriate tasks, skills, and proficiencies needed for current and future aircraft systems and operations.



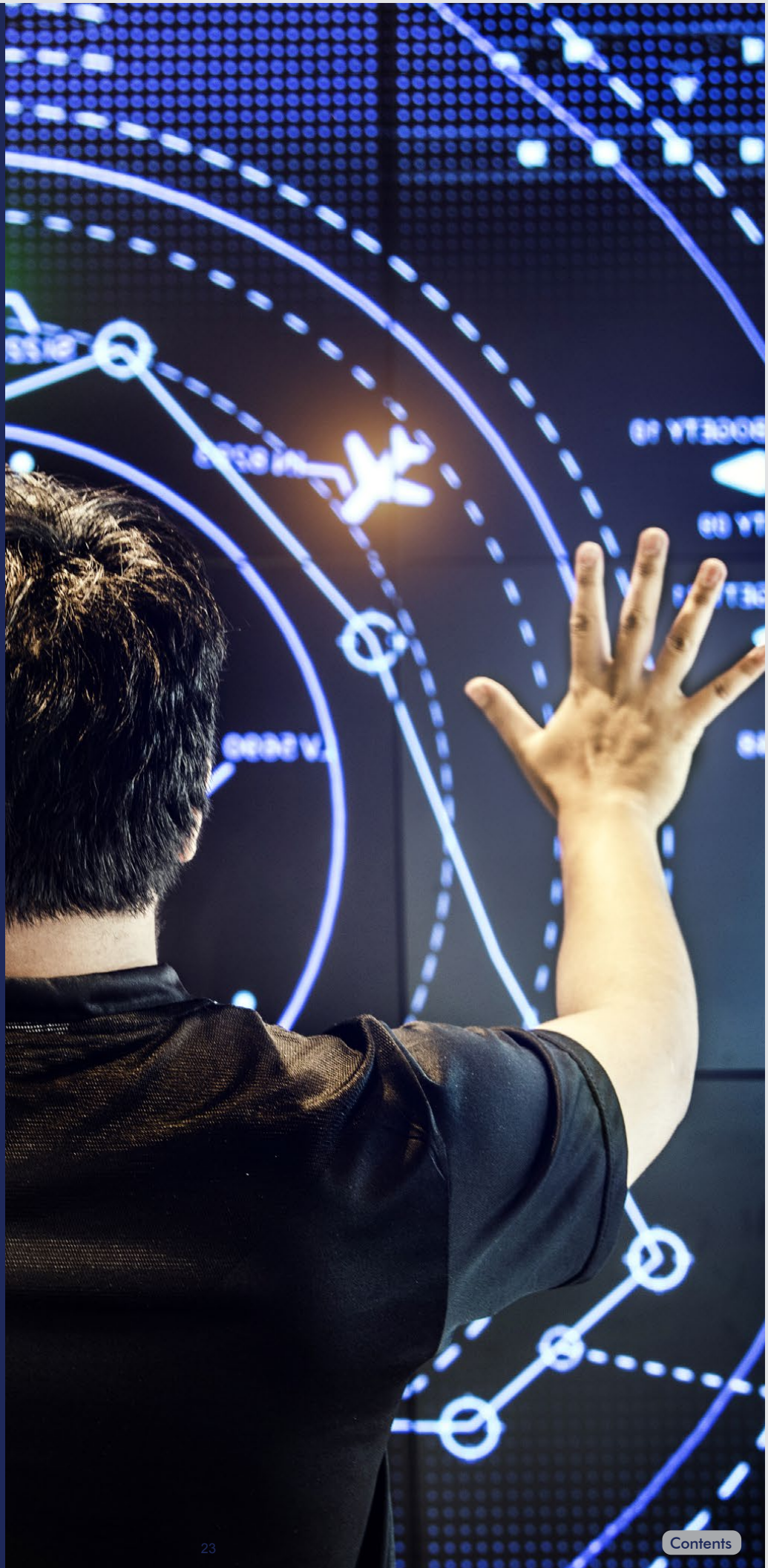
Contents

Goal 5:

Improve integrated modeling capabilities and system-wide analysis

Using technologies such as data sharing, artificial intelligence, and machine learning, 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.



Goal 5 Research Activity Status

Domain	Activity Name	Results	Status	FY 2023–2027 NARP Location
No activities were scheduled for completion in FY 2022				

Goal 5 Success Stories

NASA and FAA Laboratory Integrated Test Environment

NASA Langley's Air Traffic Operations Lab and the FAA's William J. Hughes Technical Center performed the second test of their integrated laboratory simulation capabilities in 2022. This represents a key milestone in the agreement between the two agencies to collaborate on advanced air mobility (AAM) research.

The organizations are working together to advance systems, infrastructure, protocols, and technologies for drones, electric vertical takeoff and landing vehicles, air taxis, and other aircraft operating in low-altitude airspace surrounding population centers.

The integrated laboratory, known as the NASA/FAA Laboratory Integrated Test Environment, is an innovative and unique research capability that serves as a starting point for multi-year research activities to better identify, understand, and validate airspace requirements for urban air mobility and AAM. The lab supports research in concept validation, human and machine systems integration, and other areas.

During testing, researchers used a Sikorsky S-76 simulator to perform medical transport missions in the same Atlantic City, NJ, airspace as a simulated Cessna 172. Additionally, the FAA provided subject matter expertise and experience in vertical flight simulation capabilities and rotorcraft performance to help with AAM route development.

Recent enhancements to the test environment include the addition of two fixed-base simulation capabilities from the FAA's Cockpit Simulation Facility, as well as modifications to NASA's existing capabilities.

Technology Transfer of Weather Tools to the Aviation Industry

The FAA completed a technology transfer package in 2022 for the Global Weather Note algorithm, which provides flight deck notification of impending turbulence or other adverse weather conditions within the next three to 20 minutes. Global Weather Note runs on the ground, projecting each aircraft's position forward in time based on the aircraft's flight plan, speed, and heading. The tool calculates a qualitative categorical turbulence severity (light, moderate, or severe) based on a given weather grid and predefined thresholds along the aircraft's path.

Global Weather Note was recently merged into the FAA's Remote Oceanic Meteorological Information Operational (ROMIO) viewer to provide even more situational awareness information for aircrews and operators. The ROMIO viewer provides near real-time weather information, rapidly updated convective weather information over remote areas and oceanic regions without ground-based radar coverage, and advance warnings to pilots of thunderstorms along their flight routes to enhance safety and efficiency.

FY 2022 Research Agreements

The FAA research and development (R&D) portfolio is a collection of programs spanning multiple research areas. The agency's unsurpassed laboratories and expertise enable cutting-edge research, resulting in technical knowledge and products that enhance the safety, capabilities, and efficiency of the National Airspace System and benefit the American people.

In pursuit of the agency's mission, the FAA maintains partnerships with over 350 stakeholders from other federal agencies, as well as domestic and international partners from academia and the aviation industry. This year the agency executed 78 new agreements.

2022 FAA Agreements	
Center Of Excellence Grants	56
Aviation Research Grants	12
Cooperative R&D Agreements	7
Interagency Agreements	2
International Agreements	1
Total	78

Research Grants

The FAA engages with academic institutions through two primary mechanisms: Centers of Excellence (COE) grants and aviation research grants and cooperative agreements.

Centers of Excellence

COEs enable collaboration and coordination between government, academia, and the aerospace industry to advance aviation technologies and expand FAA research capabilities. Among the unique benefits of this program are the congressionally-required matching contributions, effectively doubling resources, and the opportunity for the next generation of aviation professionals to actively pursue solutions to aviation's biggest challenges. The 63 active COE awards in 2022 represented 24 different academic institutions across five COEs.

2022 Centers of Excellence Grants

CENTERS OF EXCELLENCE	ACTIVE GRANTS	FY 2022 AWARDS (#)	FY 2022 AWARDS ($)
Unmanned Aircraft Systems	28	13	$2,012,573
Alternative Jet Fuels & Environment	11	11	$2,580,230
Advanced Materials	4	2	$700,000
Technical Training & Human Performance	11	3	$219,424
General Aviation	2	9	$491,410
	56	38	$6,003,637

The grants were awarded to:

- Drexel University
- Florida Institute of Technology
- Georgia Tech Research Corporation
- Kansas State University
- Mississippi State University
- New Mexico State University
- Ohio State University
- Pennsylvania State University
- Stanford University
- University of Alaska - Fairbanks
- University of North Dakota
- Wichita State University
- Embry-Riddle Aeronautical University
- Georgia Institute of Technology
- Iowa State University
- Massachusetts Institute of Technology
- Missouri University of Science and Technology
- North Carolina State University
- Oregon State University
- Purdue University
- University of Alabama Huntsville
- University of Dayton
- University of Utah
- University of Vermont

Aviation Research Grants and Cooperative Agreements

Aviation research grants and cooperative agreements focus on innovative research the FAA administrator considers key to the long-term growth of civil aviation and research focused on preventing catastrophic failures. This year the agency awarded 12 new aviation research grants to 10 academic institutions.

2022 Aviation Research Grants

ACADEMIC INSTITUTION	RESEARCH AREA	FY 2022 GRANT ($)
Central Connecticut State University	Non-linear finite element modeling	$75,424
Embry-Riddle Aeronautical University	Pre-flight weather briefing strategies	$186,500
Flight Safety Foundation	Safety concept for air traffic management	$202,621
Massachusetts Institute of Technology	Pilot response to system malfunctions	$488,086
Ohio State University	Human factors engineering for acquisition programs	$299,541
Princeton University	Aircraft ice protection system	$126,214
Rowan University	Data visualization using artificial intelligence/augmented reality	$150,000
	Rotorcraft safety within a cave virtual reality environment	$513,302
Rutgers University	Mitigating fire propagation in commercial airplane cabins	$116,082
Southwest Research Institute	Structural integrity assessment tools for advanced material parts	$200,000
	Probabilistic integrity and risk assessment of turbine engines	$2,250,000
Wichita State University	Emerging metallic structures assessment & research roadmap	$575,000
		$5,182,770

The FAA Provides $4.4 Million for Drone Research

Drones, also known as unmanned aircraft systems (UAS), are the fastest-growing aviation segment in the United States. More than 800,000 recreational and commercial UAS are in the active drone fleet, and that number is expected to increase.

To support this growth, the FAA awarded $4.4 million in drone research, education, and training grants to seven universities in April 2022 — Drexel University, Embry-Riddle Aeronautical University, Mississippi State University, Oregon State University, The Ohio State University, University of Kansas, and University of North Dakota. Research will focus on electromagnetic compatibility with static fields, detect-and-avoid classifications that support beyond-visual-line-of-sight operations, and cybersecurity.

Each year the FAA's center of excellence for UAS research, known as the Alliance for System Safety of UAS through Research Excellence (ASSURE), provides matching grants to educational institutions to advance drone technology and educate future aviation and research professionals.

The awards allow leading research institutions to collaborate with aviation industry and government partners to safely expand the drone market and integrate drones into the nation's airspace. The FY 2022 awards bring the total number of ASSURE grants to 15 and the total amount funded by the FAA to $18.3 million, which the agency's aviation industry partners matched.

Cooperative Research and Development Agreements

The FAA's Technology Transfer program promotes FAA collaborative R&D with other government agencies, industry, and academia and disseminates federally-funded research innovations for the benefit of the American public.

The program executes Cooperative Research and Development Agreements (CRADA). Congress enacted these uniquely beneficial agreements to stimulate collaboration from the nation's cutting-edge federal laboratories and external partners. Benefits include favorable patent opportunities and access to federal laboratories and experts.

2022 Cooperative Research and Development Agreements

	PARTNER	RESEARCH AREA
DOMESTIC	Sikorsky	Conduct rotor blade testing for the FAA in-house test program in the Structures and Materials Laboratory
	Arconic	Research airframe safety and structural integrity
	Columbia Helicopters	Evaluate rotor blade test articles and analyze bonding issues using non-destructive inspection equipment
	AURA*	Research actual latencies and voice quality/speech intelligibility in air to ground (A/G) radio path of current FAA voice communication systems
INTERNATIONAL	Saab	Research field of vision systems technologies on helicopters to improve safety for IFR and VFR helicopter operations in unique operational environments
	Inventive	Research surveillance capabilities and performance of non-rotating, non-cooperative, spectrum efficient sensors
	Supernal	Research high-energy density electrical energy storage systems for aviation propulsion

*Small Business

Stimulating Collaboration through Cooperative Research and Development Agreements

The FAA encourages important cutting-edge research with the aviation industry, academia, and international partners through Cooperative Research and Development Agreements (CRADA). These unique vehicles can be implemented rapidly, similar to other contracts and agreements awarded under the FAA's Acquisition Management System.

Although FAA partners do not receive government funds, they benefit substantially from access to unsurpassed facilities and expertise. In return, the agency can evaluate upcoming advanced technologies and processes to facilitate their certification and safe integration into the National Airspace System.

Interagency Agreements

The FAA entered into two new agreements with federal partners in 2022. The first, with the Air Force Research Laboratory, initiated research to investigate the use of Design Assessment of Reliability with Inspection, or DARWIN, as a tool for predicting and managing cold dwell fatigue in titanium engine rotors. The Naval Air Warfare Center Aircraft Division and FAA researchers are collaborating in a bleed air study to evaluate cabin air quality in the second agreement.

Graphical Turbulence Guidance Product

Turbulence is air movement that generally cannot be seen and often occurs unexpectedly. Many conditions can contribute to turbulence, including atmospheric pressure variations, jet streams, air flow over and around mountains, weather fronts, and thunderstorms. While turbulence is normal and happens often, it can be dangerous when severe.

The FAA's Graphical Turbulence Guidance (GTG) product is a fully-automated tool that provides turbulence forecasts for the aviation community over the contiguous United States, parts of Mexico, Canada, and the western Atlantic and eastern Pacific Oceans.

The current operational version, GTG3, provides gridded forecasts up to 45,000 feet for clear-air and mountain-wave turbulence. These forecasts are updated hourly, provided in hourly increments, and deliver a forecast looking 18 hours ahead.

The next generation, GTG4, will increase product resolution from 13 km to 3 km, providing more spatially detailed forecasts. GTG4 will also add in-depth forecasts of convectively-induced turbulence (such as in and around thunderstorms) to help airlines and traffic flow managers make weather avoidance decisions, increasing safety for the flying public.

The FAA and National Weather Service (NWS) recently held meetings to synchronize the GTG4 development schedule with the 2024 upgrade schedule for the Rapid Refresh Forecast System. This high-resolution weather prediction model will serve as the basis for the GTG4 product.

The successful collaboration between the two agencies allows for uninterrupted public access to the GTG product during a complex two-year transition period, including adapting the new GTG4 software to NWS systems and an FAA safety risk management assessment.

International Agreements

As a key performer in the global aviation community, the FAA maintains collaborative relationships with multiple international partners. This year, the FAA entered into a new international agreement with Nagoya University in Japan to collect atmospheric data in high ice water content conditions in high aerosol environments. This data will support regulatory efforts by the Ice Crystal Icing Aviation Rulemaking Advisory Committee.

FAA researchers hold positions across multiple global harmonization and standards-setting bodies and serve as world-renowned subject matter experts on many topics. Their contributions enable the United States to drive international standards and increase America's economic advantage in aviation.

EUROCONTROL

JCAB
Japan Civil Aviation Bureau

CAAS
Civil Aviation Authority of Singapore

EASA
European Aviation Safety Agency

Transport Canada
Canada

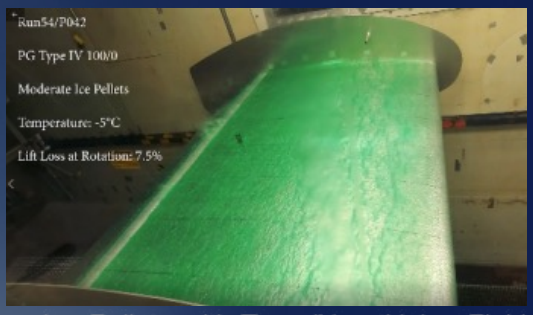
DTU Technical University of Denmark

UK Civil Aviation Authority

ANAC
Agência Nacional de Aviação Civil - Brasil

Aircraft Icing Wind Tunnel Tests

FAA and Transport Canada researchers participated in a joint wind tunnel study, examining how a high-performance aircraft wing coated with anti-icing fluid functioned during takeoff in mixed ice pellet precipitation conditions.



Ice Pellets with Type IV anti-icing Fluid Test (Video Screen Capture)

APS Aviation, Inc. conducted the tests in Ottawa, Canada, at the National Research Council's Icing Wind Tunnel. Researchers installed high-definition cameras in the wind tunnel allowing scientists to actively participate in the testing using a high-definition viewing application on a tablet computer.

Anti-icing fluids are classified by type. The testing aimed to substantiate the current Type IV ice pellet allowance times with new anti-icing fluids, expand the current Type IV ice pellet allowance times for ethylene glycol fluids, and increase the current allowance times, including new temperature bands and new conditions. The FAA and Transport Canada will use test results to make annual updates to N8900 series notices that provide guidance and allowance times for flight operations in icy weather conditions.

Neural Network-Based Runway Landing Guidance for General Aviation

In artificial intelligence (AI) and machine learning, neural networks are designed to perform tasks that are difficult for a computer but easy for a human. But what does this technology mean for aviation?

The FAA conducted a study to determine if AI-based landing assistance can serve as a backup for other navigation systems in case of a GPS outage.

Researchers conducted a flight test using a neural network with a vision-based runway landing guidance system on a fixed-wing aircraft in a use case under the agency's Non-Required Safety Enhancing Equipment policy. The team used a test aircraft developed by Swiss-based company Daedalean, which builds autonomous piloting software systems for civil aviation.

The FAA published a 140-page report in May 2022 summarizing the test results and describing how the agency may use the research for certification and policy development, including determining the reliability, robustness, and real-world capability of such systems.

The FAA and Fulbright Program Partner to Study Human Factors

The U.S. government sponsored an international educational and cultural exchange with the FAA through the *Fulbright Program* to research, study, share ideas, and find solutions to aerospace industry challenges. The Fulbright Program sponsored a three-month rotation at the FAA's Civil Aerospace Medical Institute. Participants conducted human factors research studying the effectiveness of a stress management course presented to FAA Academy trainees.

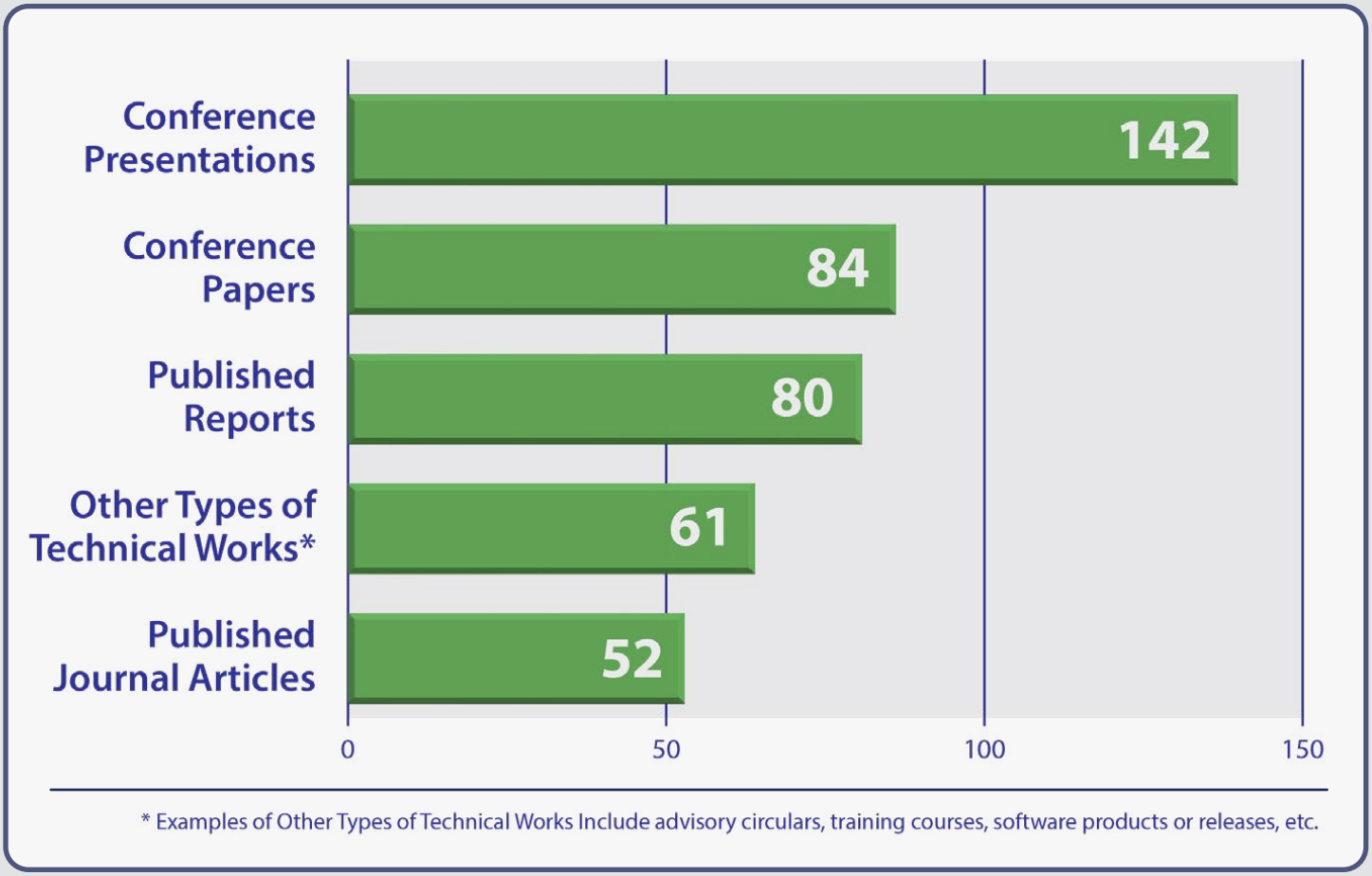
The partnership was a resounding success and paved the way for future international research efforts involving air traffic safety and human factors while supporting the FAA's global leadership initiative to enhance collaboration and harmonization.

Disseminating Research to the Private Sector

The FAA disseminates a broad range of information and products, including formal reports, standards, software, patents, technical knowledge, innovative ideas, and new processes and practices. In 2022, the FAA participated in multiple conferences, distributed technical reports and other products, and published peer-reviewed journal articles. The sustained quality and technical merit of agency products continue to resonate within the research community.

In addition to these formal products, the FAA collaborated with other federal agencies, universities, the aerospace industry, and standards-setting organizations to share expertise and resources to promote national, Department of Transportation, and agency objectives.

2022 FAA Technical Products



FY 2022 FAA Technology Transfers

Biofuels for Aviation

Biofuels are a clean, renewable energy resource with potentially significant environmental benefits for aviation. The FAA completed a project focused on the need for new antioxidants to prevent biofuel from breaking down due to oxidative degradation — a critical requirement in the extreme temperature conditions in aviation.

Researchers developed a method to calculate the service life of biofuel hydrocarbons in the air at any operating temperature. The findings appear in a 2022 article in Thermochimica Acta, a scientific journal featuring original research in general engineering, technology, and inorganic chemistry. The study's method of estimating service life under use conditions will allow researchers to develop better antioxidants for aviation fluids and plastics.

FAA Partners with Industry to Study Structural Bonding Failures

Aircraft manufacturers increasingly use structural bonding as an alternative to costly and heavy rivets to connect aircraft parts, saving construction and fuel costs. However, these bonds can fail, causing serious and sometimes fatal accidents.

In May 2022, the FAA established a three-year CRADA with Sikorsky (a Lockheed Martin Company) to build upon past FAA research into fatal helicopter crashes.

Previous studies identified several points of failure in the main rotor blades related to structural adhesive bonding arising from manufacturing defects or faulty repair processes coupled with operational environment aging effects.

Working with Sikorsky, the FAA will further investigate structural bonding used in main rotor blades and, more broadly, general aviation. Crucial to the success of the agency's test program, Sikorsky will provide the following:

- **Test articles**
- **Loading and usage data**
- **Technical support for rotor blade testing**
- **Test results related to bonding issues in the main rotor blades**

The FAA will use data and recommendations from the research to develop policy guidance for the certification and design of adhesively bonded composite structures. Additionally, the agency plans to develop industry standards and best practices based on the test methods introduced by this project.

Results will be published in the Composite Materials Handbook-17, a consensus-based industry guidance document that provides properties of polymer, metal, and ceramic matrix composite materials, as well as guidance for the design, analysis, material selection, manufacturing, quality control, and repair of products made with these materials.

The FAA is working with Sikorsky through a Cooperative Research and Development Agreement to investigate structural bonding used in rotor blades.

Collaborative Research on Impact Events and Aerospace Materials Using LS-DYNA®

The FAA opened the annual meeting of the LS-DYNA® Aerospace Working Group in March 2022 with a presentation on engine-related impact failure. The FAA's Propulsion and Fuels program presented research examining the impact of jet engine blade fragments on aircraft materials.

Researchers designed lab tests to realistically represent the release and containment of a metallic fan blade. The team performed simulations using advanced material models to accurately capture the complex impact sequence as the blade tip makes contact while bending and rotating before the heavy blade root strikes and perforates the target.

More than 60 representatives from the FAA, NASA, ANSYS, the Boeing Company, General Electric, Pratt & Whitney, Rolls-Royce, Honeywell, Northrup-Grumman, and Sikorsky, along with other representatives from the aviation industry, academia, and government, shared knowledge at the meeting about turbine engine fragment impact modeling.

Such research is vital to improving aircraft safety because when rotating engine parts break apart, and fragments escape the engine case, they can strike other aircraft parts resulting in catastrophic damage. The FAA also presented research testing and modeling impact with materials commonly used in aerospace materials, including Aluminum 2024 and Titanium 6-4 alloys, as well as T800/F3900 carbon fiber reinforced polymer composites.

LS-DYNA® is software used by the aerospace, automotive, and defense industries for simulating and studying impact events, such as fan blade release, engine foreign object ingestion, and bird strikes. Through the LS-DYNA® Aerospace Working Group — a partnership of government, industry, and academia — the FAA works with the aviation industry to improve modeling and dynamic analysis methods used for engine certification and compliance. The working group aims to improve the consistency and reliability of aerospace impact simulations using LS-DYNA® software to gain regulatory agency acceptance of these simulations.

Material Guidelines for Aerospace Vehicle Design

Ensuring aircraft are airworthy and manufacturers comply with safety standards during design and construction are critical to the FAA's safety mission. The agency is actively engaged in the management and continued development of the Metallic Materials Properties Development and Standardization (MMPDS) Handbook. This guidebook is recognized worldwide as the primary authority for metallic materials and fasteners used in aerospace vehicle design.

FAA researchers met with representatives from the aerospace industry and federal government at the *40th MMPDS General Coordination Committee Meeting* held from September 19 to September 23, 2022, in Denver, Colorado. During the event, participants reviewed and agreed to handbook changes, including the addition of new material and fastened system properties, confirmation of published data, changes to guidelines and procedures, and improvements to data analysis methods. The semiannual coordination meetings are an integral part of the MMPDS Handbook development process.

Participation in Professional and Technical Societies

Professional and technical societies bring together experts, knowledge, and technology to share information, create aerospace industry standards, and develop design standards for technology, processes, and systems.

FAA experts provide substantial contributions and guidance in these areas by serving on boards of directors and as chairs, committee and subcommittee members, technical experts, and general members for over 40 separate organizations across nearly 100 focus areas.

Conclusion

FAA research and development fosters the creativity needed to provide safe, efficient, and environmentally-sound solutions beyond today's boundaries and prioritizes integrating advanced technologies into the National Airspace System. To learn more about FAA's planned research activities, view the Annual Review's companion document, the *National Aviation Research Plan*.