NASA Aeronautics Research

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Aeronautics Research Mission Directorate
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Strategy, Organization, and Vision

NASA Aeronautics – Vision for Aviation in the 21st Century

ARMD continues to evolve and execute the Aeronautics Strategy *https://www.nasa.gov/aeroresearch/strategy*

6 Strategic Thrusts

- Safe, Efficient Growth in Global Operations
- Safe, Quiet, and Affordable Vertical Lift Air Vehicles
- Innovation in Commercial Supersonic Aircraft
- In-Time System-Wide Safety Assurance
- Ultra-Efficient Subsonic Transports
- Assured Autonomy for Aviation Transformation

U.S. leadership for a new era of flight

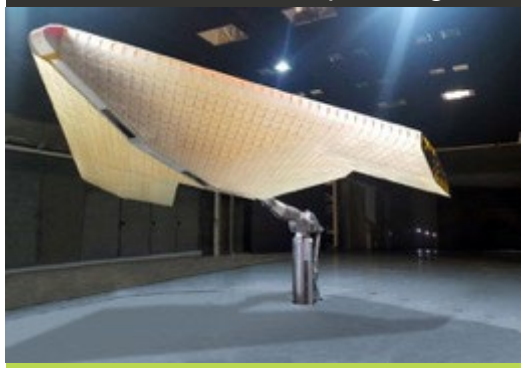
ARMD PROGRAMS

Airspace Operations and Safety Program

Advanced Air Vehicles Program

Integrated Aviation Systems Program

Transformative Aeronautics Concepts Program



Aerosciences Evaluation and Test Capabilities Portfolio

Four Transformations for Sustainability, Greater Mobility, and Economic Growth

FY 2023 President's Budget Request

Aeronautics FY 2023 Budget Request

$ Millions	FY 2022 Request 1/	FY 2022 Enacted 2/	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027
Aeronautics	**$914.8**	**$880.7**	**$971.5**	**$990.9**	**$1,010.7**	**$1,030.9**	**$1,051.5**
Airspace Operations and Safety	147.4	94.5	156.2	159.0	164.2	183.6	196.8
Advanced Air Vehicles	243.7	248.5	253.2	269.5	287.2	270.5	235.9
Integrated Aviation Systems	258.6	281.1	288.9	287.1	284.0	296.4	322.3
Transformative Aeronautics Concepts	148.0	139.6	155.9	158.0	158.0	163.0	176.6
Aerosciences Evaluation and Test Capabilities	117.0	117.0	117.3	117.3	117.3	117.3	119.9

1/ - Full-year appropriations for FY 2022 were not enacted at the time this budget was prepared. Therefore, the FY 2022 column reflects the FY 2022 President's Budget Request.
2/ - FY 2022 Enacted reflects amounts specified in H.R. 2471, Consolidated Appropriations Act, 2022 at the Account level.

- Supports a robust Sustainable Flight National Partnership to enable highly efficient next generation aircraft and ensure U.S. leadership in aviation
  - Demonstrate the first-ever high-power hybrid electric propulsion for large transport aircraft
  - Accelerate development of a full-scale sustainable flight demonstrator X-plane to validate integrated systems and their benefits
  - Advance small turbine cores that will increase engine thermal efficiency and reduce fuel burn
  - Improve the rate of composite manufacturing by 4 to 6 times faster than current production rates
  - Develop technologies needed to increase use of sustainable aviation fuels
  - Develop a robust model-based systems analysis and engineering framework at the aircraft system level
  - Develop the next evolution of air traffic management to safely increase operational efficiency which reduces fuel burn and emissions
- Conducts the first flight of the X-59 Low Boom Flight Demonstrator in early CY 2023 (under review). These flight tests will provide data to the global aviation community to reassess the ban on supersonic flight over land and implement noise regulations acceptable to local communities
- Supports Advanced Air Mobility to ensure U.S. leadership in an emerging aviation market that studies have projected to generate an annual market value of $115 billion by 2035
- Increases funding to develop revolutionary, beyond next-generation zero-emissions aircraft concepts and technologies through the highly successful University Leadership Initiative
- Funds a new effort to improve aerial responses to wildfires by leveraging NASA UAS traffic management (UTM) technologies

FY 2023 Budget Request - Changes

ARMD's FY 2023 budget request reflects four major changes relative to the FY 2022 request

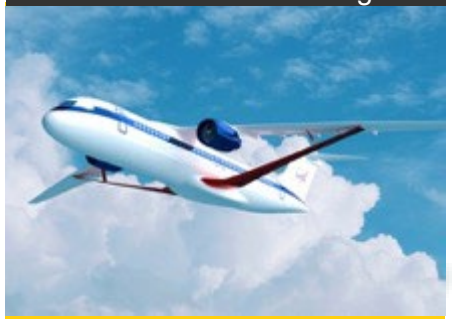
- Increase to the Sustainable Flight Demonstrator project to ensure the project will deliver results to industry in time to meet their needs for critical technologies in the next generation single-aisle aircraft for introduction in early 2030s.
- Increase to the University Leadership Initiative to expand the development of beyond next-generation zero-emissions aircraft concepts and technologies.
- Initiate a new project, Advanced Capabilities for Emergency Response Operations, aimed at improving aerial responses to wildfires and other natural disasters. The project will leverage NASA developed UAS traffic management capabilities, along with other NASA science and technology capabilities, to develop an interagency concept of operations with other federal, state, and local agencies.
- Transfer the Advanced Air Mobility (AAM) project from the Integrated Aviation Systems Program to the Airspace Operations and Safety Program in its entirety. This realignment will maximize the synergies between the AAM project and AOSP's current projects, ATM Exploration, System Wide Safety, and Advanced Capabilities for Emergency Response Operations.

Sustainable Flight National Partnership

NASA – U.S. Industry Partnership to Enable Transformational 2030's Commercial Vehicles

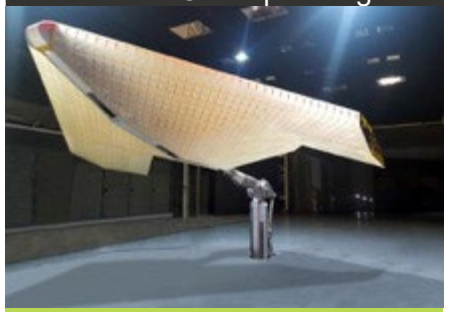
Airspace Operations and Safety Program

Advanced Air Vehicles Program



Integrated Aviation Systems Program

Transformative Aeronautics Concepts Program



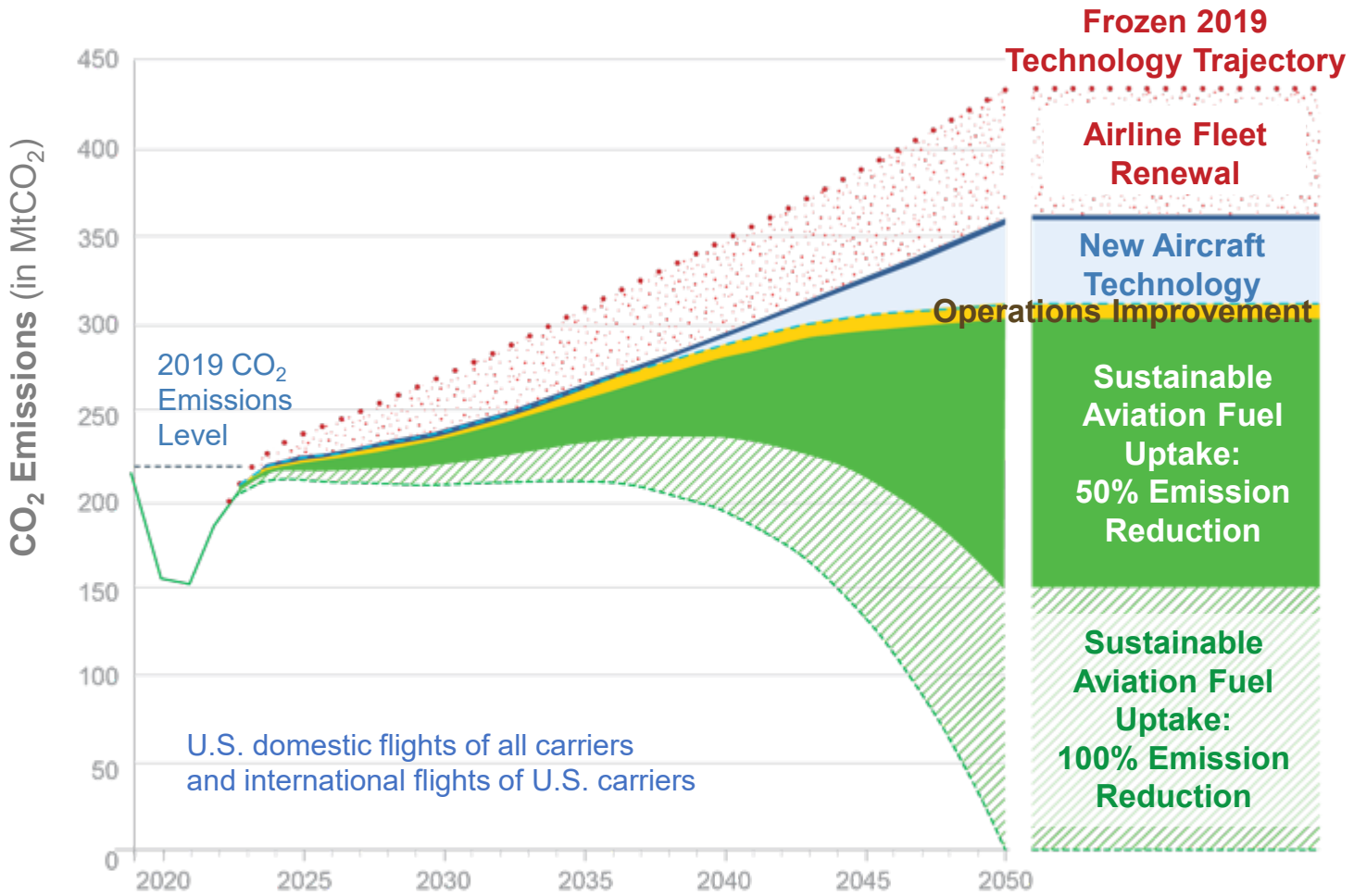
Aerosciences Evaluation and Test Capabilities Portfolio

U.S. Aviation Climate Action Plan

Global Context for Sustainable Aviation

U.S. aviation goal is to achieve
net-zero greenhouse gas emissions by 2050.

U.S. Aviation Climate Action Plan is aligned with
- U.S. economy-wide goal
- International Civil Aviation Organization
- Air Transport Action Group



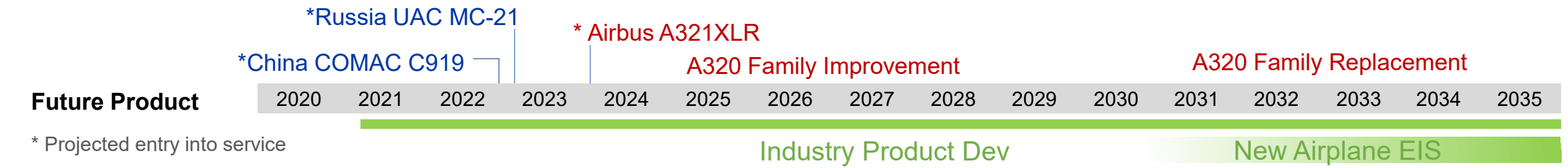
The U.S. is working with the global community to achieve net-zero greenhouse gas emissions by 2050 using a common basket of measures.

Single-Aisle Transport Airplane Competition

COMAC C919
Image Credit: Weimeng

UAC MC-21
Image Credit: Denis Fedorko


Airbus A321



* Projected entry into service

Extensive European funding for commercial aviation technology, including COVID-mitigation efforts –

- Horizon Europe (Clean Aviation **$4.6b**, Clean Hydrogen **$2.2b**, Made in Europe **$2.2b**)
- Next Generation EU Recovery fund fostering hydrogen economy, sustainable fuels
- Country level aviation R&D – Germany, France, UK **($800m** plus)

Policy issues:

- Emissions/efficiency could become market access barrier (countries contemplating fuel efficiency/ emissions restrictions for future entry into EU airspace)
- Energy infrastructure will significantly impact ability to adopt alternative energy sources for aviation (Hydrogen, alternative fuels)

High-Speed Commercial Flight

Sustainable transformation of the speed of air travel

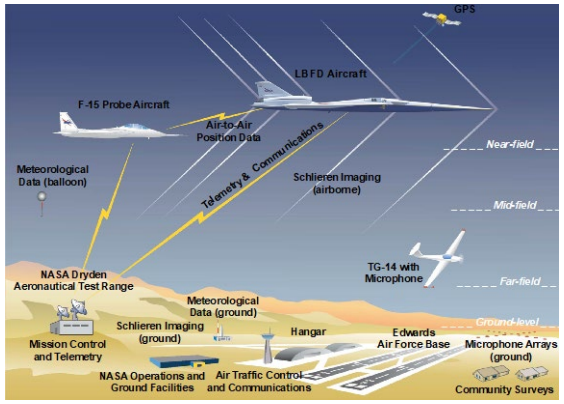
Addressing the unique barriers to sustainable, environmentally responsible high-speed flight

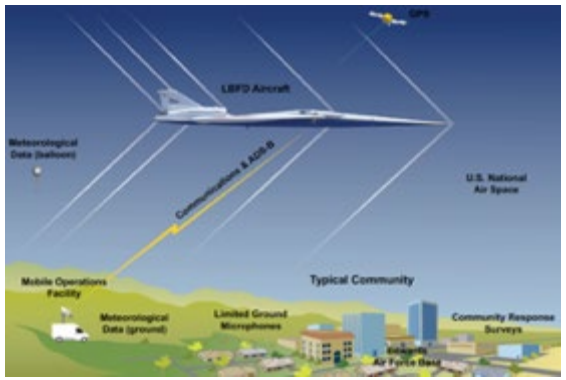
Generate key data to support development of en route certification standards based on acceptable sound levels

Scenes of X-59 Construction

Complete X-59 Build in Late 2022
Achieve First Flight in Early 2023

Low-Boom Flight Demonstration Mission Overview





Phase 1 – Aircraft Development

In progress (FY18-23)

- Design, fabricate a quiet supersonic research aircraft
- Prove performance in test range flights
- Prove safety for flights in normal airspace

Phase 2 – Acoustic Validation

Preparation in progress (FY18-23), Execution FY23-24

- Prove the acoustic characteristics match design targets
- Detailed in-flight and ground measurements in test range

Phase 3 – Community Response Testing

Preparation in progress (FY19-23), Execution FY24-27

- Conduct community tests
  - Select communities
  - Outreach and engagement (including STEM)
  - Obtain regulatory approvals
  - Plan surveys and recruit participants
  - Collect ground measurements

Systematic Approach Leading to Community Testing

Low-Boom Flight Demonstrator Project

Budget Update

Since the FY 2022 budget request, the LBFD project budget was increased to provide additional reserves. The reserves are required to mitigate realized and estimated cost overruns due to ongoing COVID-19 impacts, Lockheed Martin performance issues, and unknown unknowns in FY2022-2024. The project exceeds the original Agency Baseline Commitment cost estimate by 22% and first flight date by 11 months.

$ Millions	FY 2020 & Prior	FY 2021	FY 2022	FY 2023	FY 2024	Total
FY 2022 Budget Request	$433.1	$97.3	$74.6	$36.8	$15.3	$657.1
Additional Reserves			$18.7	$12.1	$9.1	$39.9
FY 2023 - LBFD Project	**$433.1**	**$97.3**	**$93.3**	**$48.9**	**$24.4**	**$697.0**

Note: LBFD Project Lifecycle Cost does not include the costs for community response test development and flight operations.

LBFD Mission - Phase 2 and 3 Status

Acoustic Measurement

- Ground Recording System (GRS) under development by Crystal Instruments, Inc.
  - Initial prototypes undergoing extensive testing
  - Phased delivery of 125+ units to support Phase 2 & 3 measurement
- Progress continues on airborne acoustic measurement systems

Concept for GRS Unit

Community Test Planning & Execution

- Contractor team in place
- Test, exposure, and survey plans in development
- HMMH team refining airfield and community selection process

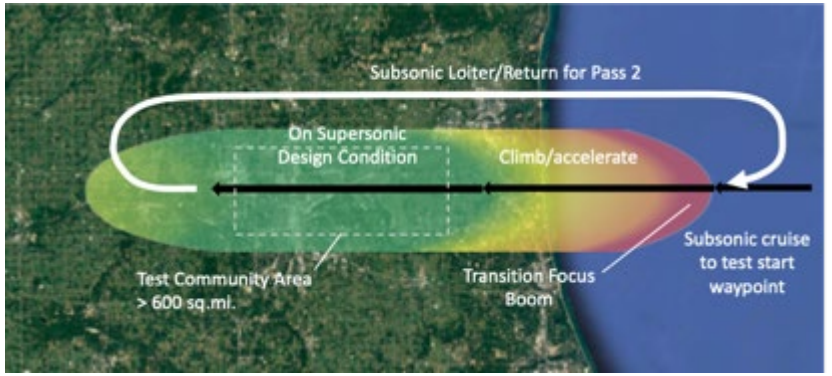
Advanced Airborne Measurement

Prediction Validation

- Continued improvements to increase accuracy and reduce turn around time for both CFD and propagation tools
- Preliminary pre-flight exposure planning and post-flight analysis tool delivered

International Standards Development

- Continued engagement with FAA, International Civil Aviation Organization-Committee on Aviation Environmental Protection (ICAO-CAEP) and the international research community
- Beginning engagement with CAEP on defining phase 2 and 3 data products that could support en route standards development
- International workshops held in December 2021 to gather input and feedback on current plans for community testing

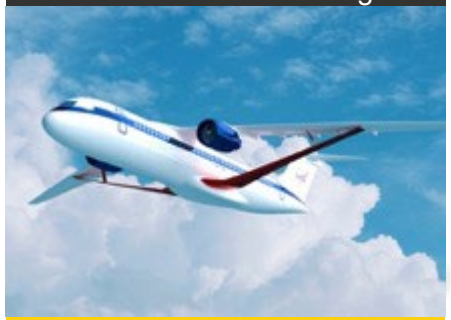


Representative Community Test Mission

Advanced Air Mobility Mission

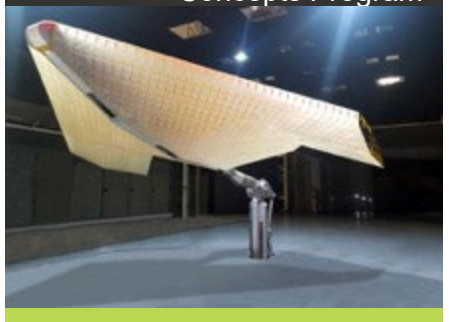
Airspace Operations and Safety Program

Advanced Air Vehicles Program



Integrated Aviation Systems Program

Transformative Aeronautics Concepts Program

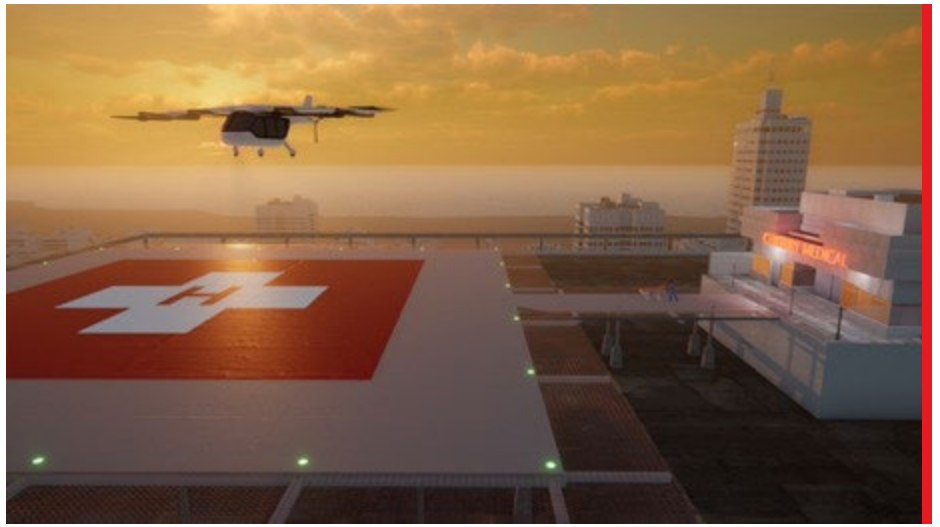


Advanced Air Mobility Mission

Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

Advanced Air Mobility Missions are Emerging

CARGO TRANSPORT



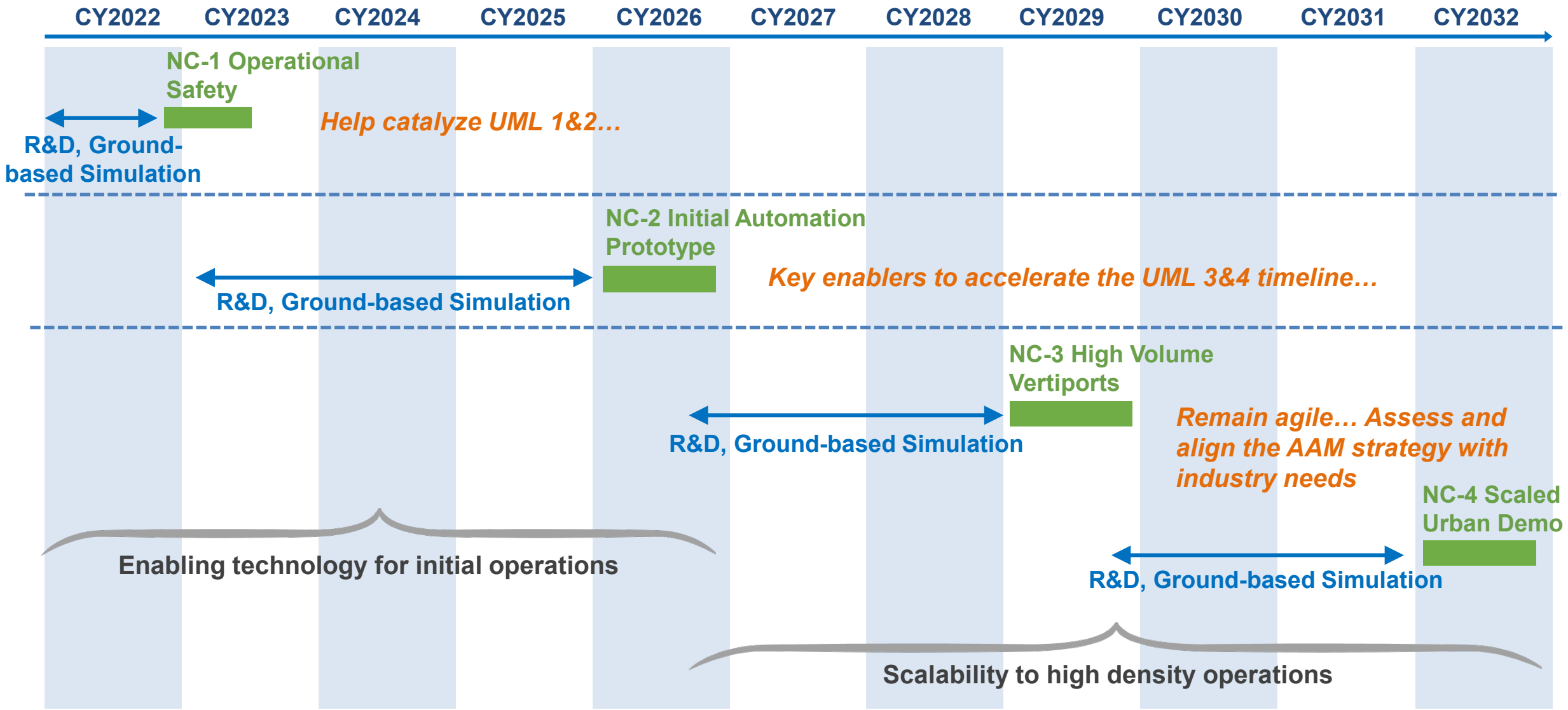
PUBLIC GOOD

CONSUMER/ ENTERPRISE GOODS AND SERVICES

PASSENGER TRANSPORT

Latest studies show an annual estimated advanced air mobility market of $115B by 2035.

National Campaign Series Support of the Industry Timeline

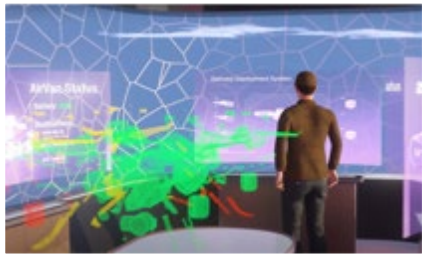


Future Airspace and Safety:
Sky for All

~ 2040: Planning to Achieve a Sky for All

Imagining tomorrow's aviation system today, leveraging FAA Info-centric NAS

Operator Optimization



Ubiquitous and Resilient Operations

Sustainable Solutions

Seamless Skies

Learning-Based Systems and Communities

- NASA-led effort to gather inputs from the aerospace community and FAA
- Co-developed vision of a mid-21st century shared airspace that is agile, scalable, optimizable, increasingly diverse, and equitable
- Evolution from trajectory-based operations to collaborative and highly automated operations
- Sky for All results will inform ARMD research and development portfolio and collaboration with FAA

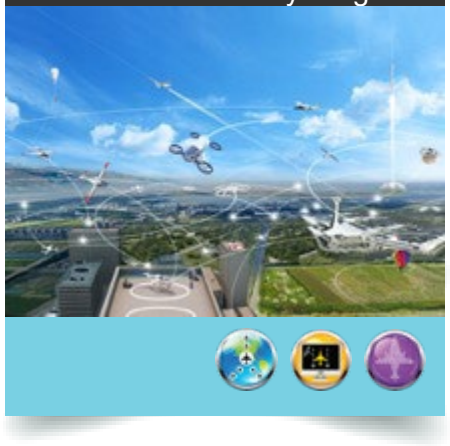
SKY for ALL

A thriving airspace must be scalable, accessible, safe, sustainable, and resilient.

Advanced Concepts for Emergency Response Operations

NASA Opportunity to Address a National Crisis

Airspace Operations and Safety Program



Transformative Aeronautics Concepts Program

NASA Research, Development, and Technology Transition Project

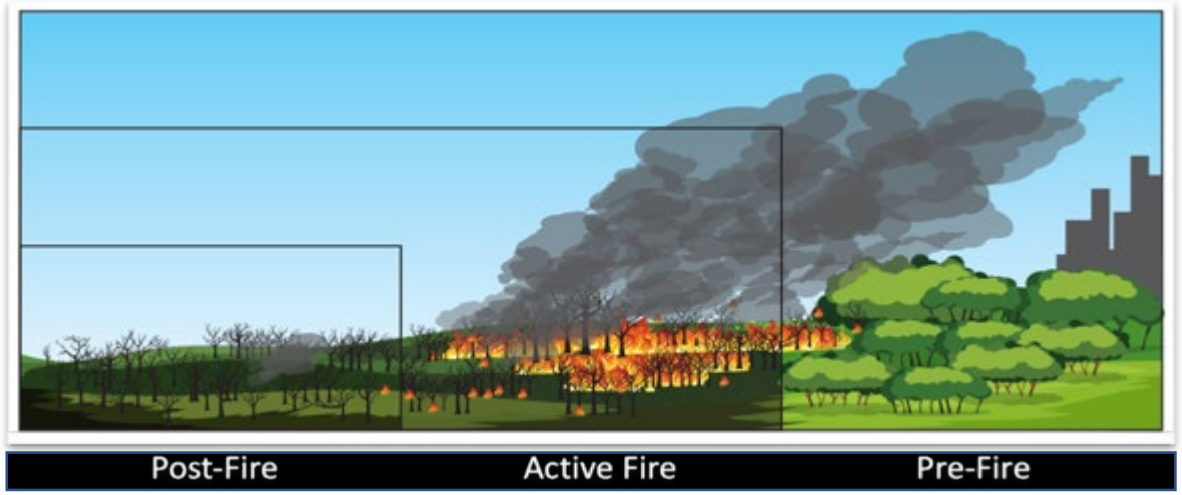
To advance our nation's ability to predict and manage wildfires and other national disasters and mitigate their impacts

Objectives

- Focusing on wildfire use case, develop and demonstrate evolving NASA technologies to reduce fire risk, improve monitoring and response to wildfires while mitigating impacts to enhance safety and prevent economic loss.

Approach

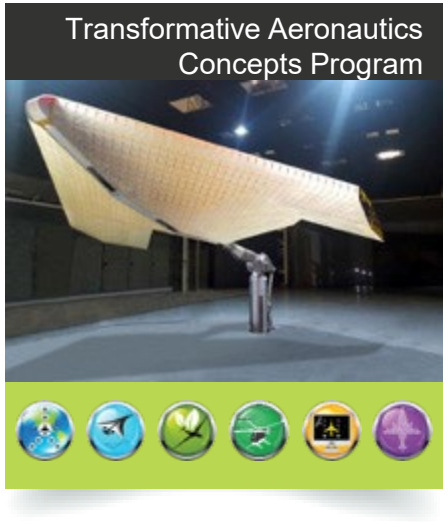
- In coordination with wildfire community, lead development of advanced airspace operations and sensing technologies, safety methods, communications and aircraft capabilities for persistent suppression operations
- Leverage and expand current R&D related to air traffic/uncrewed traffic operations, drones, and safety methods to coordinate remote sensing aircraft
- Fuse satellite/airborne observations with models to support fire research and management
- Establish Public-Private-Philanthropic Partnerships to test and implement prototype capabilities and support transition/adoption by stakeholders



The technology developed in this program will be applicable to other disasters and climate driven events, e.g., floods and hurricanes

Wildfire Detection/Mitigation Concept of Operations

Energizing the U.S. Aeronautics Innovation Pipeline



Preparing the next generation of aeronautical innovators

NASA's University Leadership Initiative represents a new type of interaction between ARMD and the university community, where universities take the lead, build their own teams, and set their own research path.

University Leadership Initiative (ULI) Engaging the University Community

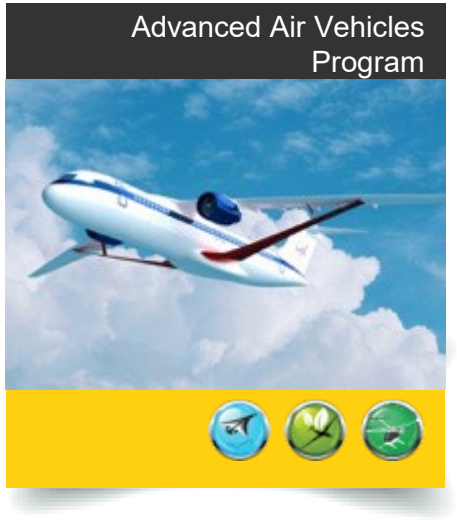
5 rounds of solicitations
$157M of awards

Seeking and awarding proposals addressing all strategic thrusts and special topics

- 23 awards with 64 universities
- 7 HBCUs and 10 other MSIs
- 406 proposals submitted
- 280 different proposing Principal Investigators
- 3189 team members
- 20–50 students per team

In ULI, the universities take the lead, build their own teams, and set their own research path.

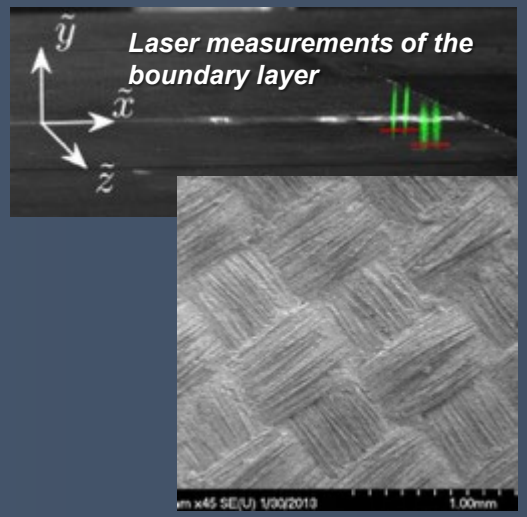
Hypersonic Technology



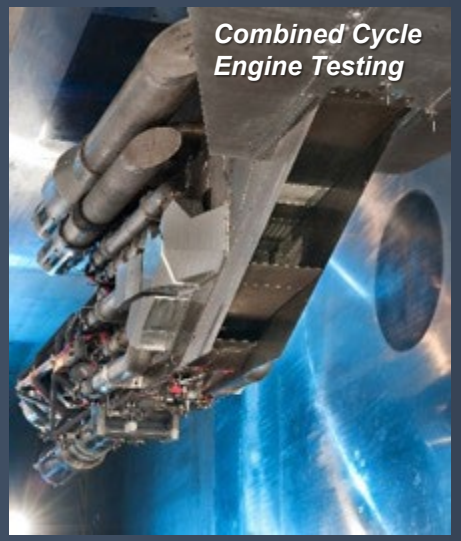
NASA Hypersonic Research

- NASA considering an integrated commercial high-speed strategy to leverage synergy across the portfolio
- Advance fundamental research and maintain strong partnership with DoD to support national security priorities, leverage DOD technology/flight demonstrations
- Understanding and solving significant technical challenges to enable commercial opportunities

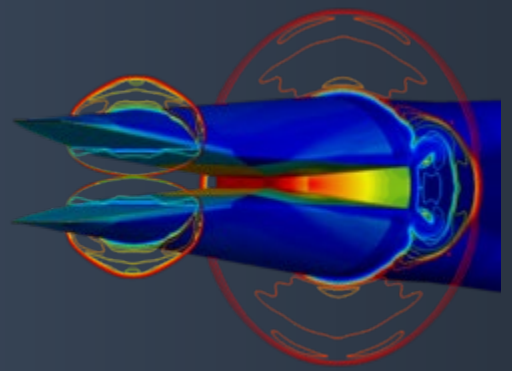
FOCUS AREAS



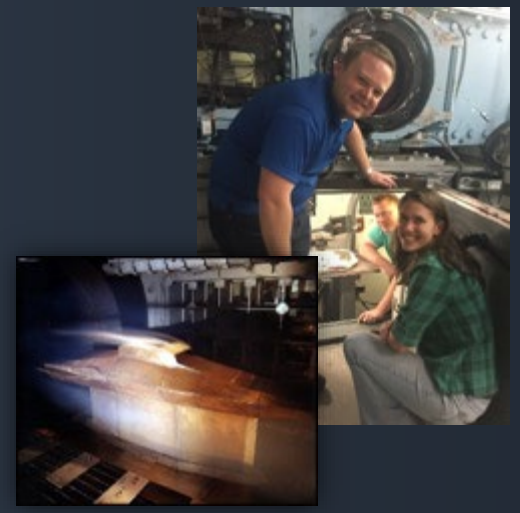
Fundamental Research
Flow Physics & High Temp Materials



Re-usable Hypersonic Propulsion

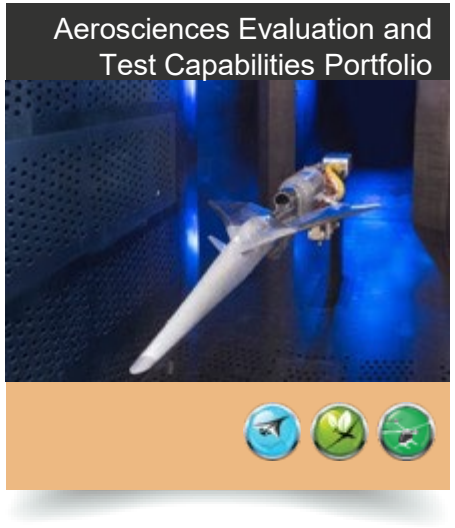


Design Tools & Uncertainty Quantification



Facility Capabilities and Workforce Development

Aerosciences Evaluation and Test Capabilities



Aerosciences Evaluation and Test Capabilities (AETC) Portfolio

NASA Ames Research Center (ARC)
Moffett Field, CA

NASA Glenn Research Center (GRC)
Cleveland, OH

NASA Langley Research Center (LaRC)
Hampton, VA

Portfolio Scope

- Aerosciences ground test facilities deemed critical to Agency
- Investments in operations, maintenance, new capability and test technology, data systems and security, and CFD-experimental integration investments

Portfolio Objectives

- **Strategically manage**, operate, sustain, and improve a critical portion of aerosciences ground test capabilities in support of Agency testing requirements, DOD collaboration
- Ensure the strategic **availability and ease of access** of a **minimum critical suite of aerosciences ground test assets** that are necessary to meet the long-term needs of the Nation.

Summary

ARMD Delivers Vision and Impact

- **Addresses the Climate Crisis by:**
  - Prioritizing **Sustainable Flight National Partnership** to ensure technology transfer to U.S. industry for the next generation single aisle aircraft
  - Demonstrating **Advanced Capabilities for Emergency Response Operations** (ACERO)
  - Supporting **Zero-Emissions Research** through University Innovation

- **Enhances U.S. Aviation Competitiveness through:**
  - Prioritizing the **Quesst Mission** to deliver community noise response data to the international community
  - Developing and maturing **Advanced Air Mobility** technologies required for urban environment operations
  - Supporting the development of **efficient future air traffic management operations**

- **Provides Innovation and Builds a Strong, Diverse Workforce of the Future by:**
  - Investing in **fundamental research** and **advancing engineering tools**
  - Developing the **next generation of scientists, researchers and engineers**
  - Advancing fundamental **hypersonic research** and evaluating the viability of a **commercial hypersonic market**
  - Supporting critical **Aeronautical Evaluation and Test Capabilities** for a broad customer base.

National Need – Stakeholder Alignment – Compelling Vision – Real Impact

Sustainable Flight National Partnership enables U.S. technological leadership in the cornerstone subsonic transport market

Low Boom Flight Demonstration Mission charts long-term path to commercial supersonic transportation

Advanced Air Mobility Mission enables emergence of a transformative new aviation transportation mode

Sky for All Airspace and Safety ensures the safe and efficient utilization of the National Airspace for all of these new capabilities

National Need – Stakeholder Alignment – Compelling Vision – Real Impact

Four Transformations for Sustainability, Greater Mobility, and Economic Growth