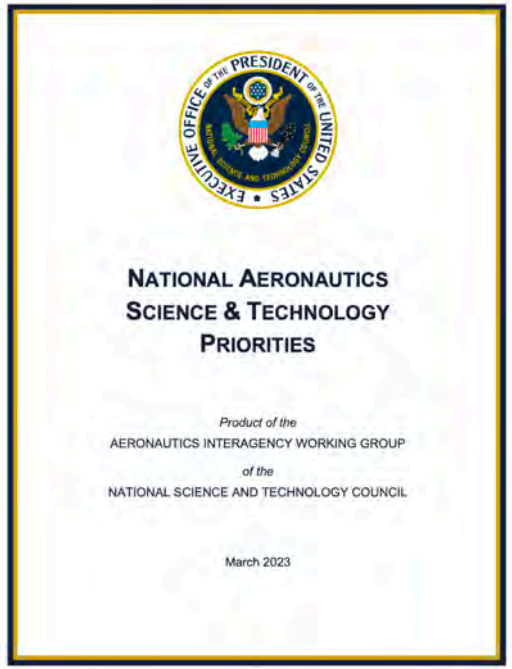
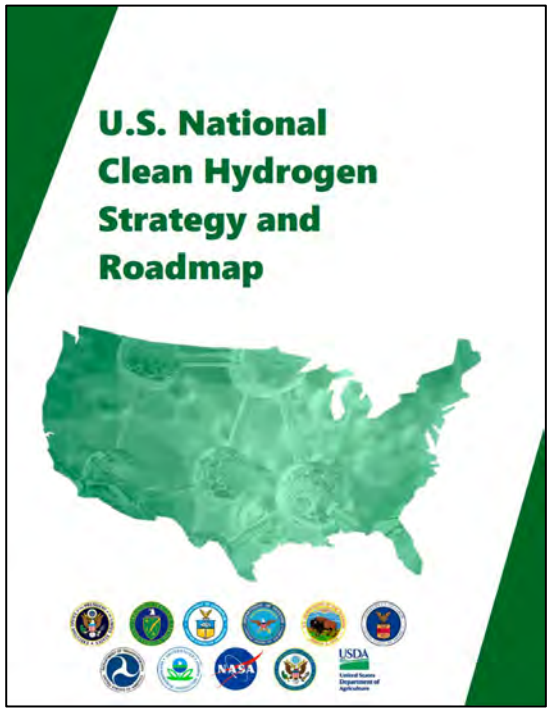
NASA Update

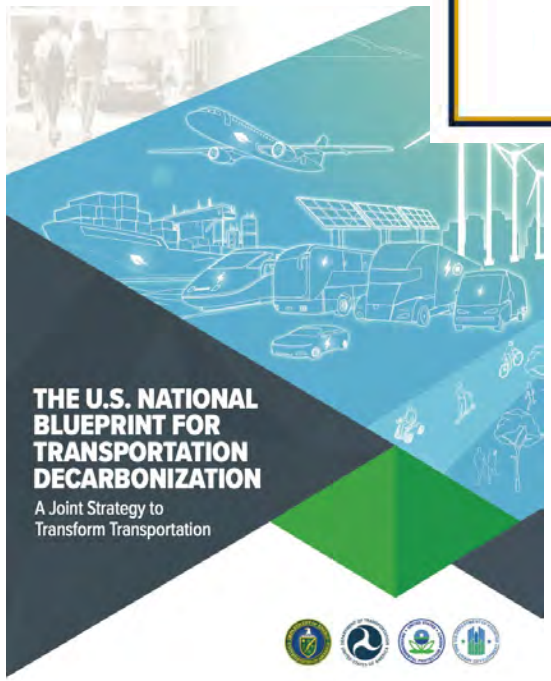
FAA CLEEN Consortium Meeting
May 6-10, 2024

Julia Stephens, Chief Technologist for Propulsion
NASA Advanced Air Transport Technology Project

NASA Aeronautics as Part of National Strategy







www.nasa.gov

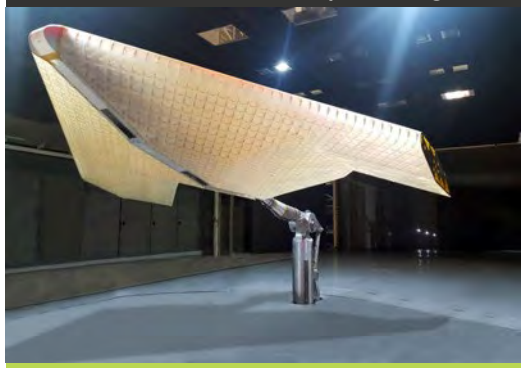
ARMD PROGRAMS

Airspace Operations and Safety Program

Advanced Air Vehicles Program

Integrated Aviation Systems Program

Transformative Aeronautics Concepts Program



Aerosciences Evaluation and Test Capabilities Portfolio

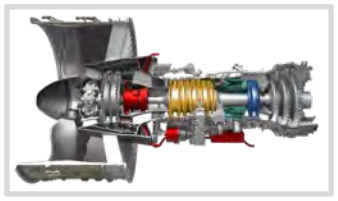
Four Transformations for Sustainability, Greater Mobility, and Economic Growth

ULTRA-EFFICIENT AIRLINERS

Real Progress. Real Value.

Subsonic Transports: Integrated Technology Development

Image credit: CFM International



FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29

Technology Readiness Target

"Digital Flight Test"

Model Based Systems Analysis & Engineering (AATT)

Sustainable Flight Demonstrator (SFD) — Flight Test

Transonic Truss Braced Wing (AATT) — TC Completion

Efficient Quiet Integrated Propulsors (AATT)

Hybrid Thermally Efficient Core (HyTEC) — Core Demonstration

Hi-Rate Composite Aircraft Manufacturing (HiCAM) — Mfg & Structural Demonstration

Electrified Powertrain Flight Demonstration (EPFD) — Flight Tests

Electrified Aircraft Propulsion Technologies (AATT) — TC Completion

Achieve TRL 6 in time for industry product decision-making

Planned

Notional

Sustainable Flight Demonstrator Project

Demonstrate integrated airframe-focused technologies in flight

Scope

- Develop and flight test an advanced airframe configuration and related technologies to dramatically reduce aircraft fuel burn and CO_2 emissions to help enable the next-generation single-aisle aircraft in the 2030s
- Inform industry decisions to maximize the potential to meet U.S. environmental goals articulated in the U.S. Aviation Climate Action Plan

Benefit

- Reduce fuel consumption and emissions up to 5-10% relative to today's most efficient single-aisle aircraft

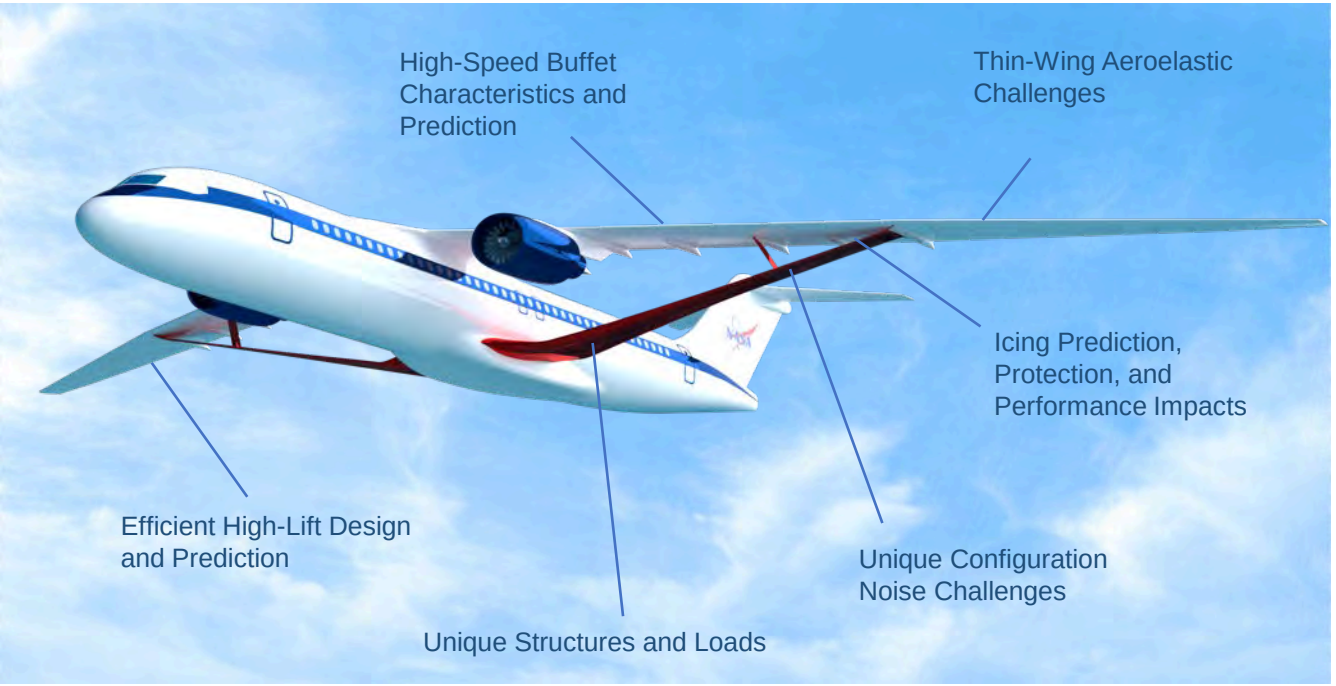
Approach

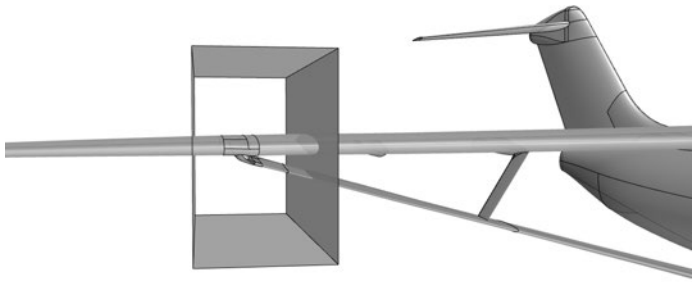
- NASA and Boeing are committed to a collaborative approach, consistent with the awarded Funded Space Act Agreement
- Obtain wind tunnel, ground and flight data that will be used by the NASA/industry teams to validate the transonic truss braced-wing configuration and associated technologies

First flight planned in 2028.
Value: Integrated technologies reduce fuel consumption/emissions up to 5-10%.

Transonic Truss-Braced Wing Technology Maturation

Address technology barriers and risks to adoption





Scope

- Mature and reduce risk of transonic truss-braced wing technology

Benefit

- 5-10% reduction in fuel burn through reduced drag

Progress

- High Speed Buffet, tested in 2022
- Low Speed Aero and Initial Icing Effects, tested in 2023
- Cooperative agreement with Boeing awarded 2023
- Deep Stall 4% scale model testing in 2024
- Scaling and icing effects, scheduled for 2024

Reducing Risks to Vision Configuration
not addressed by Subsonic Flight Demonstrator

Electrified Powertrain Flight Demonstrations

Demonstrate integrated electrified powertrains in flight using industry platforms

magniX Dash 7 Concept Art

GE Saab 340B Concept Art

Scope

- Conduct ground and flight tests of electrified aircraft propulsion technologies to enable a new generation of hybrid electric-powered aircraft
- Accelerate the transition of megawatt(MW)-class powertrains to single-aisle seat class commercial airliners
- Assess gaps in regulations/standards to support future Electrified Aircraft Propulsion (EAP) certification requirements.

Benefit

- Accelerate U.S. industry readiness to transition to EAP-based commercial transport aircraft.
- Meet U.S. environmental goals articulated in the U.S. Aviation Climate Action Plan

Approach

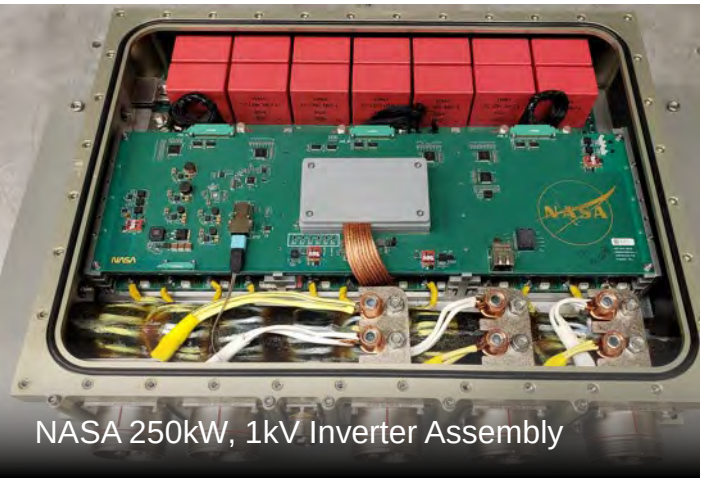
- Collaborate with GE Aerospace and magniX to conduct ground and flight tests of hybrid electric propulsion systems using existing testbed aircraft retrofitted with new EAP technologies
- Engage with the FAA and other organizations to contribute data that inform EAP standards and regulations

Flight tests begin in 2026.

Value: Accelerate ability to consider megawatt-class powertrains for single-aisle commercial airliners and to meet Electrified Aircraft Propulsion certification requirements.

Focused Technologies for Electrified Aircraft Propulsion

Retire barrier technical and integration risks for megawatt-class electrified aircraft propulsion systems


NASA 250kW, 1kV Inverter Assembly


Navy Solid-State Breaker


Electrical Powertrain Components in NASA's Electrified Aircraft Testbed

Scope

- Address critical challenges for electrified aircraft propulsion by maturing and reducing risk for Electrified Aircraft Propulsion (EAP) technology, focused on:
  - Mass and weight reduction
  - Electrical losses
  - Reliability
  - EMI, power quality, dynamic stability
  - Limits on DC voltage levels
  - System design and integration

Benefit

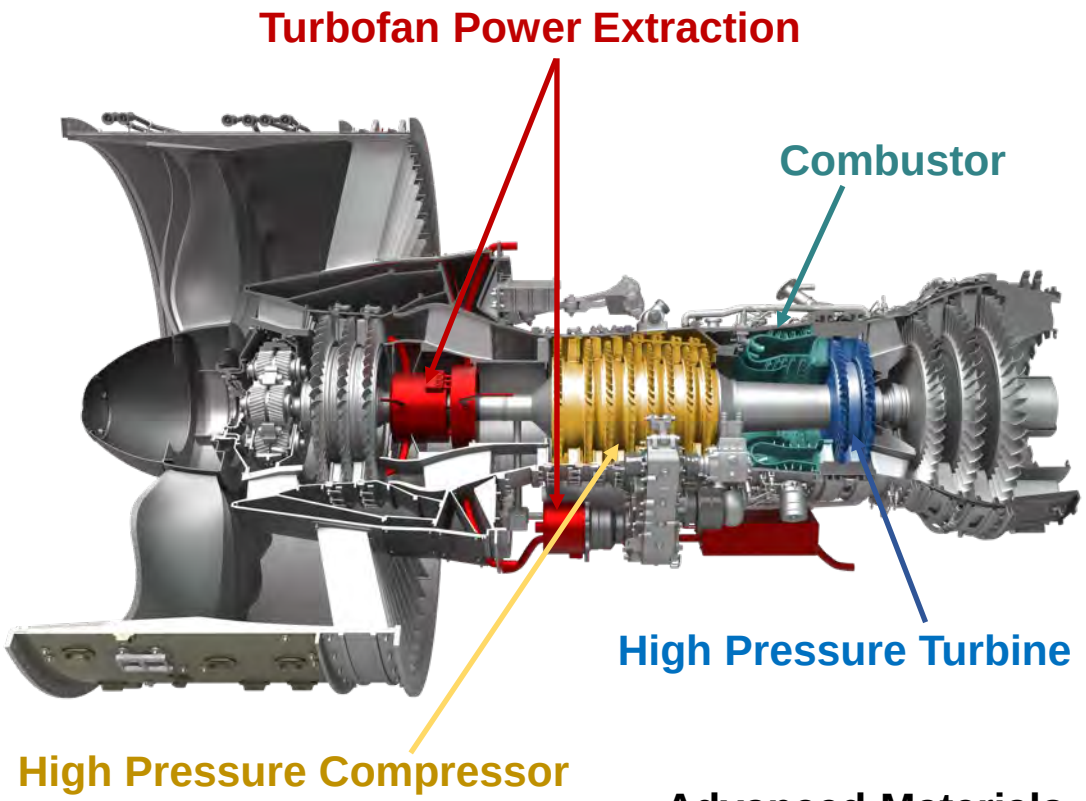
- Accelerate U.S. industry readiness to transition to EAP-based commercial transport aircraft
- Reduce key risks for a range of future applications and help enable new standards that are needed for EAP-based aircraft certification

Progress

- Conducting world's firsts in partnership with U.S. industry:
  - First megawatt motor tested under altitude conditions followed by full electrical powertrain
  - Now working to help certify motors and drives for emerging regional hybrid electric airplane market

Hybrid Thermally Efficient Core

Accelerate development and demonstration of advanced turbine engine technologies



Scope

- Develop and demonstrate in integrated ground tests engine core technologies that increase thermal efficiency, reduce engine core size, and facilitate power extraction for electric aircraft systems

Benefit

- Achieve **5-10% fuel burn reduction** versus 2020 best in class
- Achieve **up to 20% power extraction** (4 times current state of the art) at altitude to optimize propulsion system performance and enable hybridization

Approach

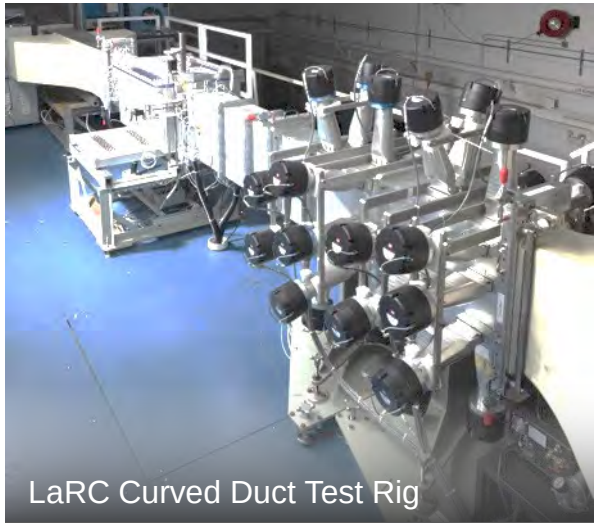
- Partner with industry to mature and demonstrate promising technologies

Six of nine Phase 1 technology demonstrations taking place now.
Value: Contributing reduced fuel burn and improved power extraction to SFNP goals.

Efficient Quiet Integrated Propulsor

Accelerate development and demonstration of advanced propulsor technologies


Notional Next Generation Open Fan Vehicle Concepts


LaRC Curved Duct Test Rig


Unducted Fan Test in 8x6’ Wind Tunnel


Unducted Fan Test in 9x15’ Wind Tunnel

Scope

- Performance, aeromechanics and acoustic tests in partnership utilizing a public/private partnership between NASA / GE / FAA
- Assess issues associated with icing for this configuration
- Assess advanced noise reduction and novel liner technologies
- Assess vehicle integration issues, working with Boeing

Benefit

- Achieve 5–10% reduction in fuel burn through higher propulsive efficiency

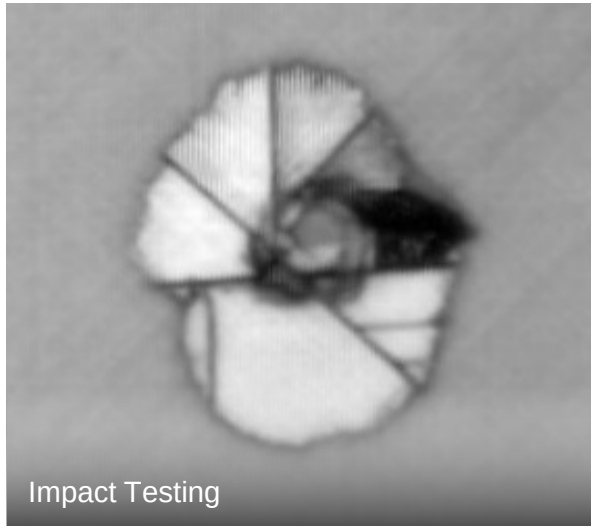
Progress

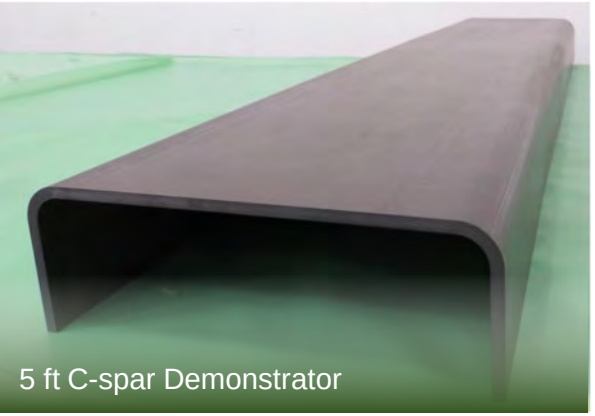
- Open fan testing scheduled to begin late 2024
- Planning for rotor icing test underway; testing in FY24
- Meetings with partners ongoing

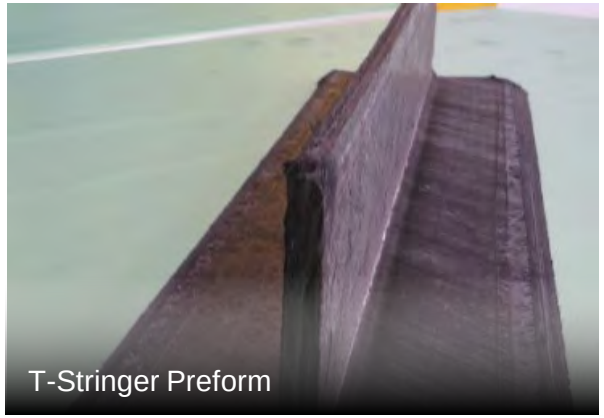
Accelerating development of advanced propulsor technologies that reduce fuel burn.
Value: Contributing tools and data to enable next-generation open-fan aircraft

Hi-Rate Composite Aircraft Manufacturing


Automated Stiffener Forming
Photo Credit: Northrop Grumman


Impact Testing


5 ft C-spar Demonstrator


T-Stringer Preform

Benefit

- High production rate (4-6x increase) to meet market demand, at reduced cost and with no weight penalty
- Lightweight composites for 5-8% fuel burn benefit
- Lower operational costs
- Improves air quality and the environment
- Sustainable manufacturing: lower energy, recyclability
- U.S. competitive advantage in the commercial aircraft industry

Progress

- Developed manufacturing processes at element level
- Completed stiffener and spar forming trials for resin-infused composites, and fabricated flat panels for testing
- Completed manufacturing trials and down-selected approaches for thermoplastics fiber placement, consolidation, and joining
- Validated performance with strength and impact testing

Work by NASA Composites Consortium members leads to large-scale demonstrations in FY 2027.
Value: Enabling high rate, more integrated structures for next-generation wing and fuselage needs.

NASA and Boeing ecoDemonstrator Test SAF Impact on Contrails

BOEING
ecoDemonstrator PROGRAM
GE Aerospace
Transport Canada
Transports Canada
FEDERAL AVIATION ADMINISTRATION
AERODYNE RESEARCH, Inc.
UNITED
MIT
DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center
MISSOURI S&T

Progress

- Contrail-cirrus clouds are net climate warming and form on engine-emitted particles
- Ground tests in 2021-22 lay groundwork for joint flight test in FY24
- Initial data reveals substantial cruise altitude soot particle reductions from burning 100% SAF in advanced GE lean-burn aircraft engine combustors
- Discovered the role of engine oil

- Small businesses developed and tested novel water vapor sensors through the NASA Small Business Innovation Research program
- Partnered with manufacturers, airlines, universities, and government agencies to design and execute the tests and to gather the data needed by national stakeholders
- Initiated National Academy of Sciences study to develop a national research agenda on potential mitigations for the impacts of persistent contrails (aviation-induced cloudiness)

A Look Ahead

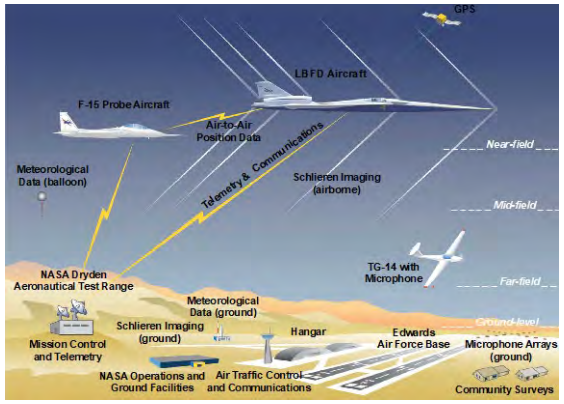
- Test results guide and motivate industry investment in SAF and engine technology R&D and jobs
- Unique in-flight data will be publicly available in Nov 2024 for use in climate and aviation model assessments, university research, industry model validation
- Beginning to develop future contrails research plans

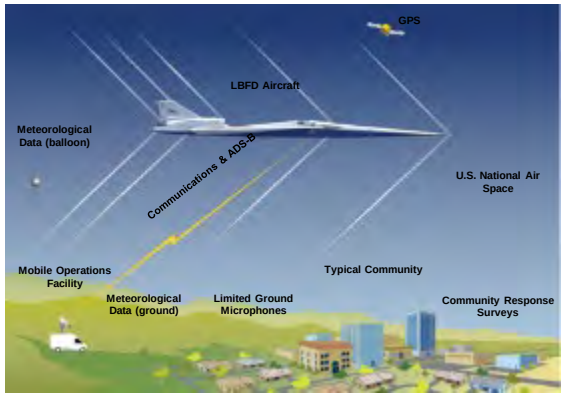
FY 2025 request includes funds to continue research in aviation contrail formation modeling and mitigation.

HIGH-SPEED FLIGHT

Real Progress. Real Value.

Quesst Mission Overview





QUESST

Phase 1 – Aircraft Development

In progress (FY18-25)

- 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 (FY18-26), Execution FY26

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

Phase 3 – Community Response Testing

Preparation in progress (FY19-27), Execution FY27-29

Conduct community tests

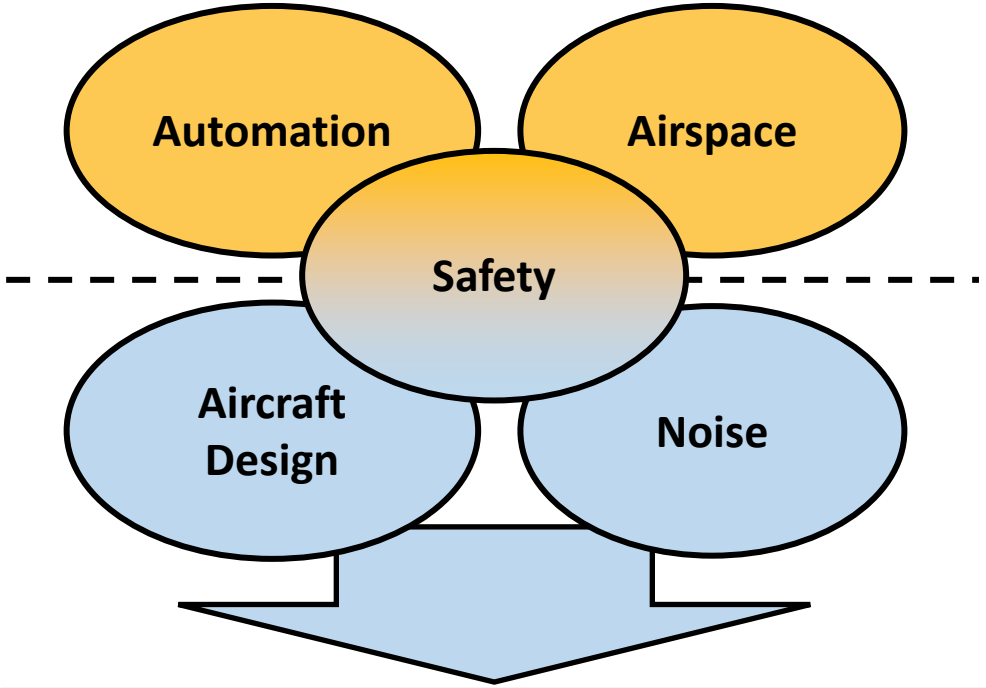
- Select communities
- Outreach and engagement (including STEM)
- Obtain necessary approval
- Plan surveys and recruit participants
- Collect ground measurements

Systematic Approach Leading to Community Testing

ADVANCED AIR MOBILITY

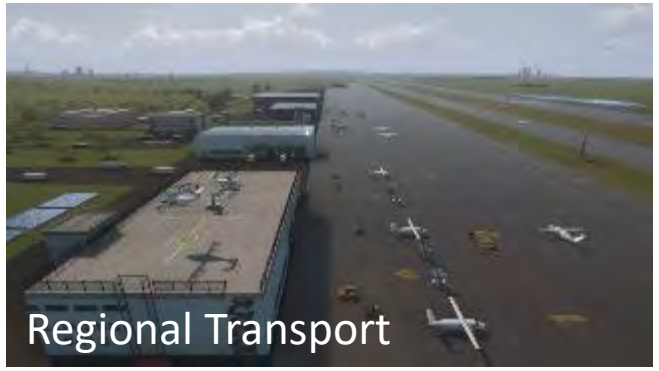
Real Progress. Real Value.

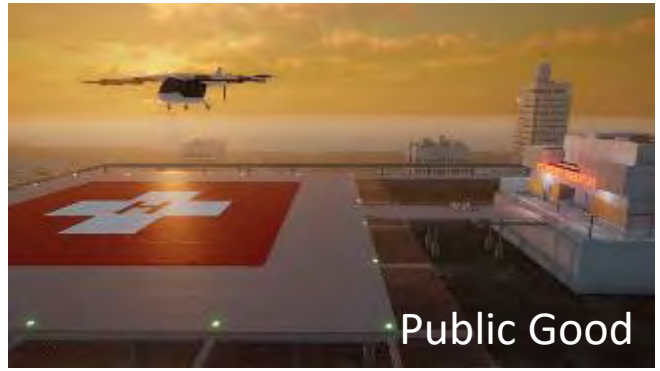
Advanced Air Mobility Mission – Vision & Framework

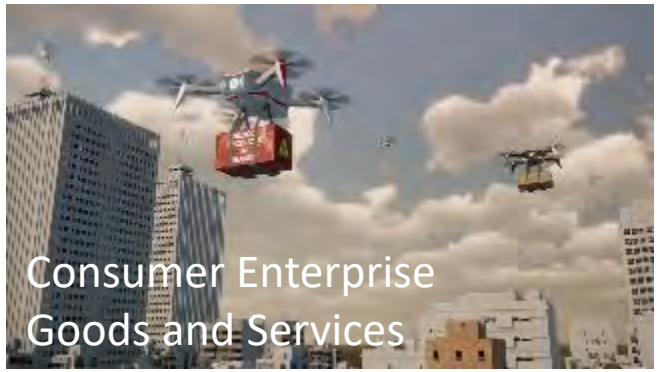


NASA AAM Vehicle Objectives:

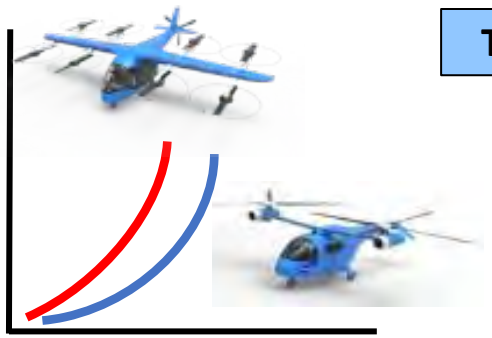
1. Integrated Design and Operations for Noise
2. Integrated Aircraft Propulsion System Performance and Reliability
3. Weather Tolerant Aircraft Technologies
4. Survivability in Off-Nominal Conditions
5. Cabin Acceptability







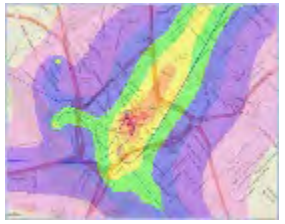
Revolutionary Vertical Lift Technology Project
Research Focus – Vehicle Noise and Safety



Tools to Explore the Noise & Performance of Multi-Rotor UAM Vehicles

- Validation experiments
- Efficiency & accuracy of conceptual design tools
- Design & analysis tools to OGA & US community

UAM Operational Fleet Noise Assessment



- Noise Power Distance (NPD) database for several UAM ref. configurations & trajectories
- AEDT evaluation for UAM fleet noise assessments; provide feedback on findings & usage
- Psychoacoustic tests to assess human response

Reliable & Efficient Propulsion Components for UAM

- Electric power & powertrain experimental capabilities
- Tools to assess electric motor reliability & new design concepts
- Validated models & test guidelines for eVTOL propulsion & thermal components

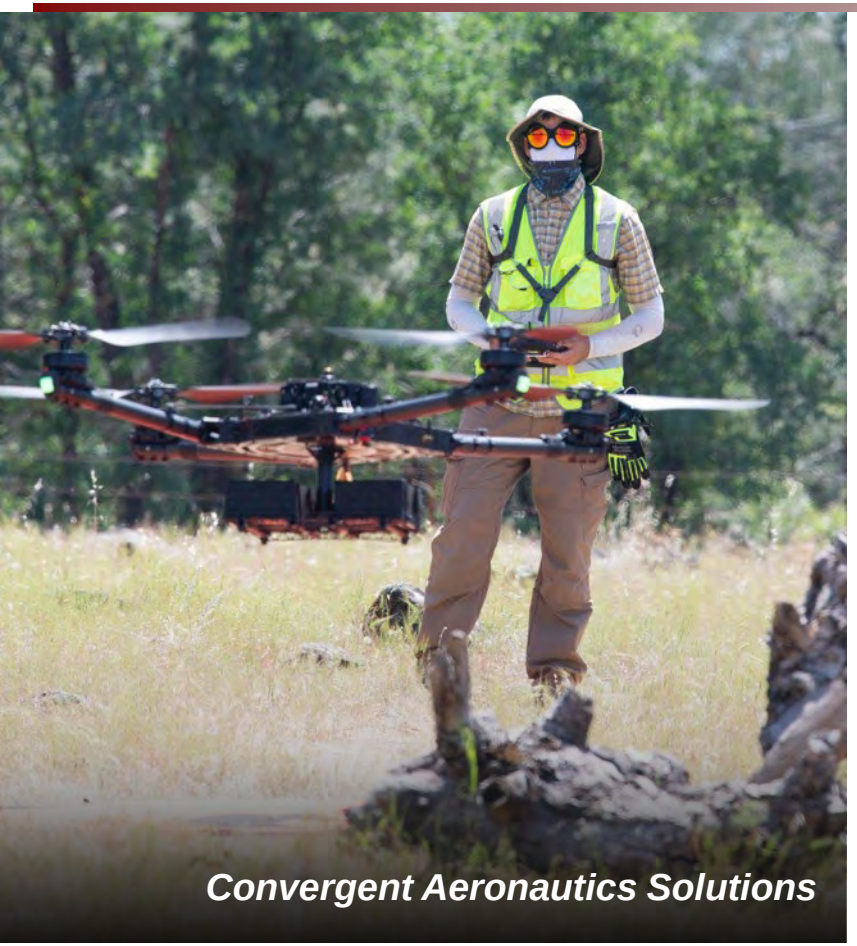
UAM Crashworthiness & Occupant Protection

- Full-scale & component level tests
- Test guidelines, modeling best practices, & vehicle technologies for crash mitigation
- Crash & impact data to consensus standards organizat

Acceptable Handling and Ride Qualities for UAM

- Human subject testing to assess handling & ride qualities
- Handling & ride qualities guidelines for UAM vehicles
- Flight dynamics & control modeling tools for conceptual design

Innovation Ecosystem: NASA Leadership for the Aviation Community



Fosters a culture of innovation within ARMD by advancing disruptive system-level concepts and early-stage technologies for transformational impact

University-led innovation addresses aviation challenges Inspires and supports the next generation of researchers and entrepreneurs

Discovers, develops, and transitions innovative solutions through foundational research and cross-cutting tools and technologies for the aviation community

www.nasa.gov | 20

Thank you