NASA Aeronautics Research Mission Directorate

Program Read-Ahead
IFAR Summit, October 2021

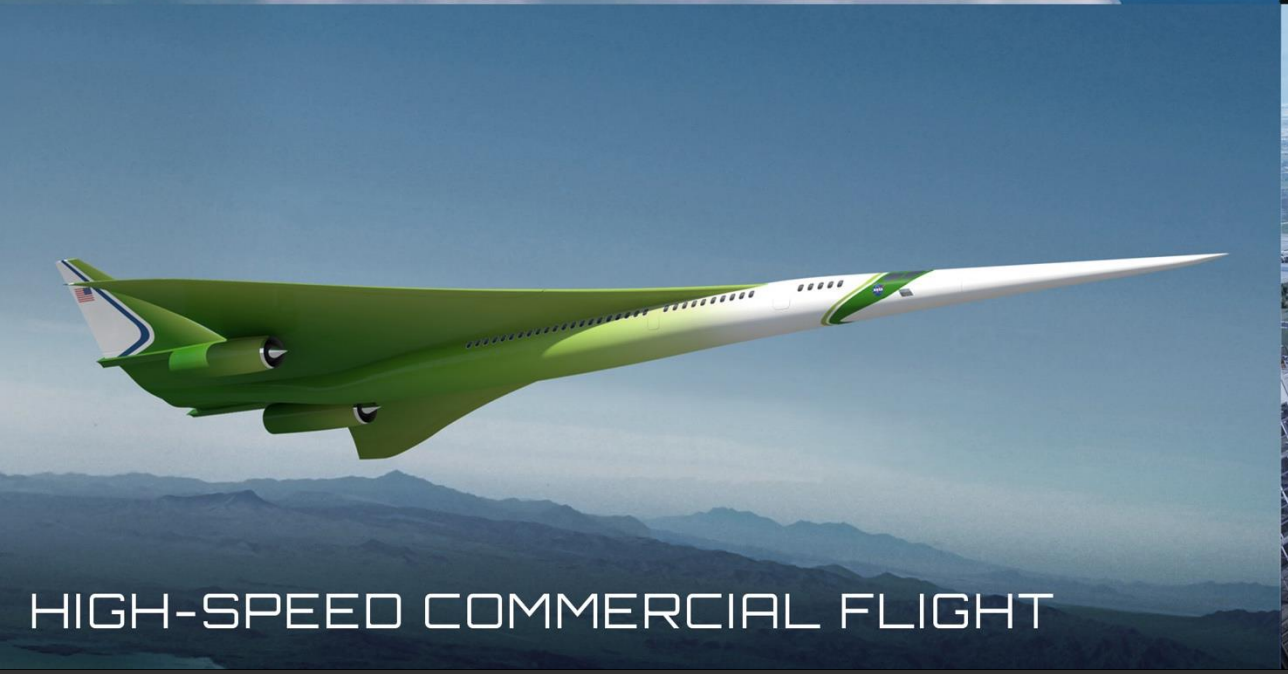
NASA Aeronautics – Vision for Aviation in the 21st Century

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



Four Transformations for Sustainability, Greater Mobility, and Economic Growth

The Aviation Carbon Reduction Challenge

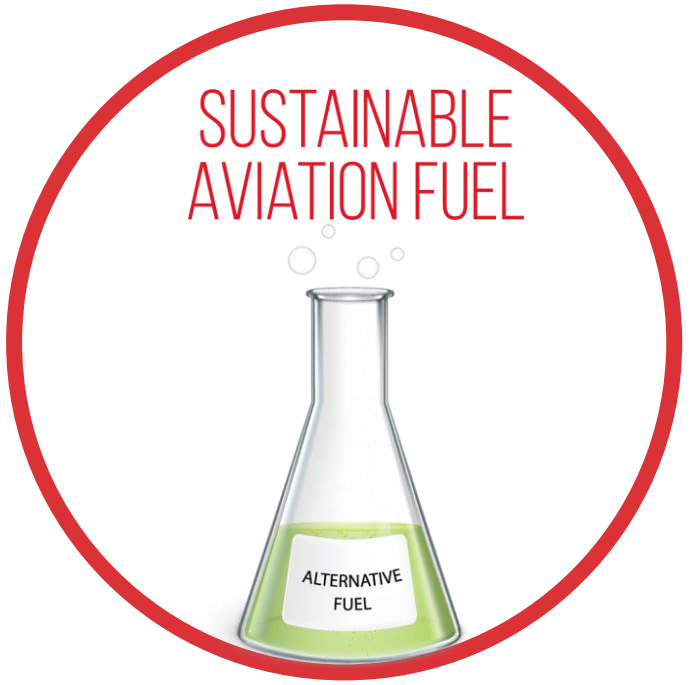
- By 2050, an estimated 10 billion passengers will fly each year a distance of 20 trillion revenue passenger kilometres.
- With today's fleet and operational efficiency, this activity would require over 570 Mt of fuel and generate some 1,800 megatonnes (Mt) of CO_2.
- Imagine enabling the same level of demand while reducing CO_2 by 82% to 325 Mt or less by 2050, and potentially zero by 2060.

Meeting the challenge is the opportunity for the U.S. to lead the globe in innovation and reductions in CO_2 aviation emissions and to maintain economic competitiveness in a critical export industry ($6 trillion-plus market over the next 20 years).

Aviation Industry Pillars for a Sustainable Future

Global Aviation Industry's GOAL: 50% reduction in carbon emissions by 2050 relative to 2005
and **possible net zero emissions by 2060 through these three means**

NASA = Primary Role



NASA = Supporting Role

NASA = Primary Role

Sustainable Flight National Partnership

Leveraging cost-sharing research partnerships

NASA

FEDERAL AVIATION ADMINISTRATION

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

INDUSTRY

ACADEMIA

Through advanced vehicle technologies, efficient airline operations and sustainable aviation fuels, collectively we aim to reduce carbon emissions from aviation by half by 2050, compared to 2005, and achieve net-zero emissions by 2060.

Sustainable Flight National Partnership Benefits

Small Core Gas Turbine for 5%-10% fuel burn benefit

High-Rate Composites for 6x manufacturing rate increase

Sustainable Aviation Fuels for reduced lifecycle carbon emissions

Electrified Aircraft Propulsion for ~5% fuel burn and maintenance benefit

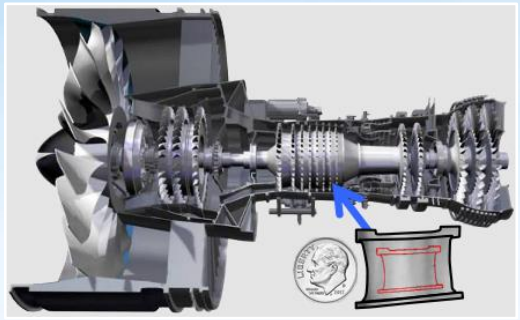
Integrated Trajectory Optimization for 1%-2% reduction in fuel required and minimization of contrail formation

Transonic Truss-Braced Wing for 5%-10% fuel burn benefit

Subsonic Transport Technologies

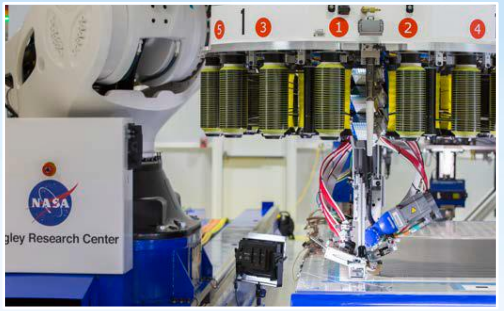
Ensure U.S. industry is the first to establish the new “S Curve” for the next 50 years of transports

Transonic Truss-Braced Wing
5-10% fuel burn benefit



Small Core Gas Turbine
5-10% fuel burn benefit

Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit

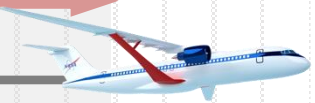


High-Rate Composite Manufacturing
4x-6x manufacturing rate increase

Subsonic Transports: Integrated Technology Development

FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Technology Readiness Target



Model Based Systems Analysis & Engineering

Sustainable Flight Demonstrator (SFD)

Flight Test

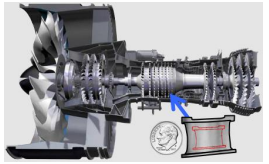
AATT - Transonic Truss Braced Wing

TC Completion

Leverage the Asset – Future Spirals

Hi-Rate Composite Aircraft Manufacturing (HiCAM)

Mfg Demo & Structural Test



Hybrid Thermally Efficient Core (HyTEC)

Core Demonstration & Test

Electrified Powertrain Flight Demonstration (EPFD)

Flight Test

AATT - Electrified Aircraft Propulsion

TC Completion

Planned

Notional

Achieve TRL 6 in time for Industry Product Decision-Making

Sustainable Flight Demonstrator

Demonstrate integrated technologies in flight

Scope

- Develop and fly an integrated multi-technology flight demonstrator with U.S. industry to mature technologies that enable the next-generation single-aisle aircraft in the 2030s.

Benefit

- Validate promising technologies, retire technical risks, and mature to TRL 6 key synergistic commercial transport vehicle technologies. Combined, these technologies could support efficiency and environmental performance goals for the 2030s.

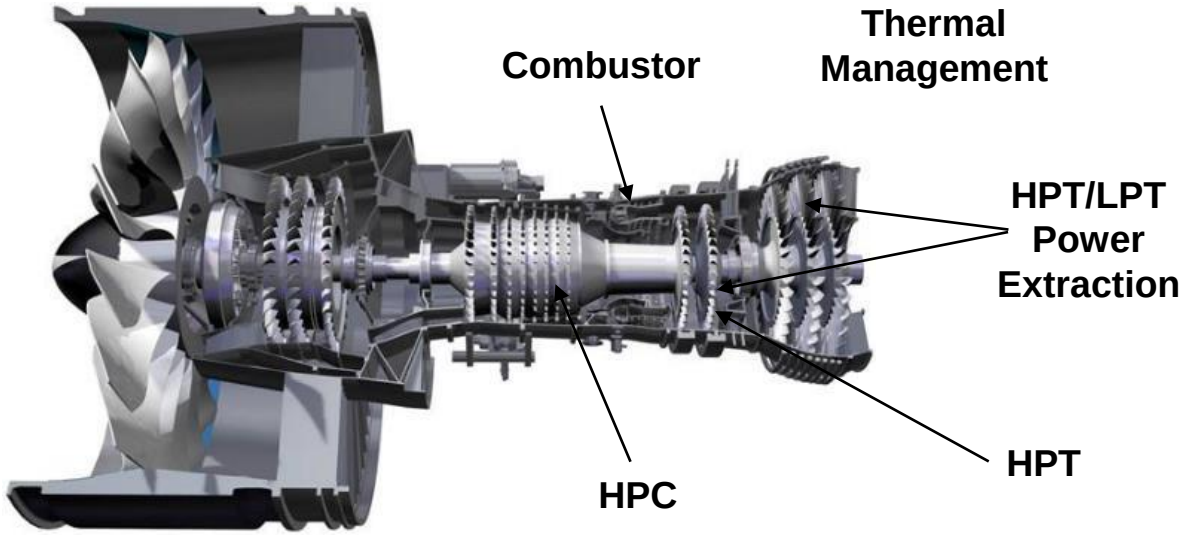
Approach

- Currently in pre-formulation
- Request for information in November 2020
- December 2020 industry day to discuss ideas

RISK REDUCTION CONTRACT AWARDS 2021, DESIGN/BUILD CONTRACT AWARD 2022

Hybrid Thermally Efficient Core

Accelerate development and demonstration of advanced turbine engine technologies



HyTEC
Hybrid Thermally Efficient Core

Scope

- Develop and demonstrate in integrated ground tests engine core technologies to Increase thermal efficiency, reduce engine core size and facilitate hybridization

Benefit

- Achieve **up to 20% power extraction** (2 to 4 times current state of the art) at altitude to optimize propulsion system performance and enable hybridization
- Achieve a **5 to 10% fuel burn reduction** versus 2020 best in class

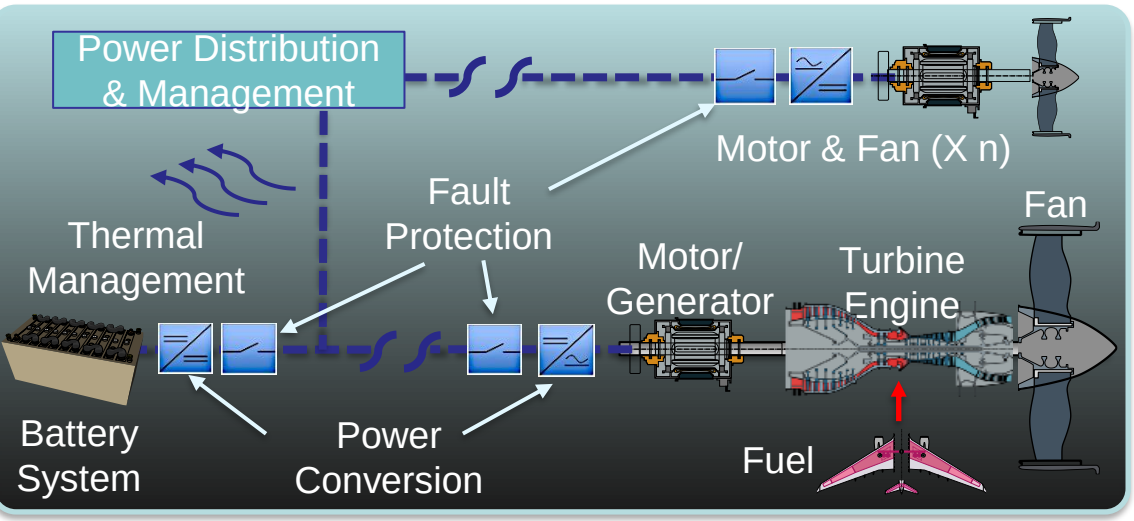
Approach

- Partner with industry to mature and demonstrate promising technologies

HyTEC PROJECT IN FORMULATION PHASE

Focused Technologies for Electrified Aircraft Propulsion

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



Scope

- Address critical challenges for electrified aircraft propulsion by maturing and reducing risk for 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 Electrified Aircraft Propulsion (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

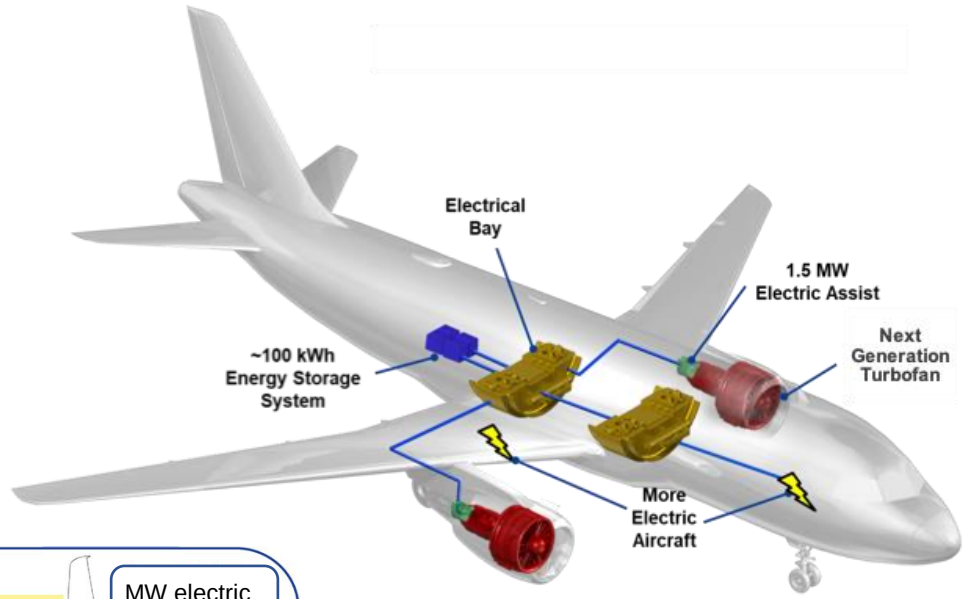
Approach

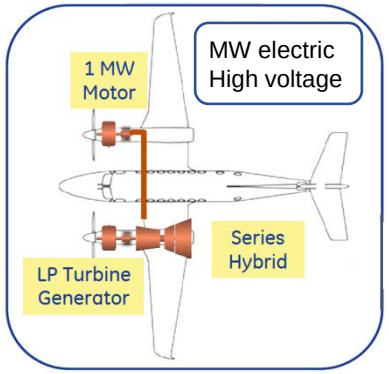
- Conduct technology-focused integrated ground tests
- Partner with industry on testing of electrified propulsion architectures and component technologies
- Leverage prior electric aircraft propulsion advances (TRL ~4)

TECHNOLOGY CHALLENGES UNDERWAY

Electrified Powertrain Flight Demonstration

Demonstrate integrated electrified powertrains in flight using industry platforms





FY21	FY22	FY23	FY24	FY25
Test 1 Prel / detail design / fab & integ.				
	First flight	Test 1		
Test 2 Prel / detail design / fab & integration				
			First flight	Test 2

Scope

- Demonstrate practical vehicle-level integration of megawatt-class electrified aircraft propulsion systems, leveraging advanced airframe systems to reinvigorate the regional and emerging smaller aircraft markets and strengthen the single aisle aircraft market.
- Assess gaps in regulations/standards to support future Electrified Aircraft Propulsion (EAP) certification requirements.

Benefit

- Accelerate U.S. industry readiness to transition to Electrified Aircraft Propulsion (EAP)-based commercial transport aircraft.
- Enable new standards that are needed for EAP-based aircraft certification.

Approach

- Engage with U.S. industry to integrate and demonstrate megawatt-class EAP machines in flight.
- Engage with the FAA, SAE, ASTM, etc. to contribute data that inform EAP standards and regulations.

SOLICITATION RESPONSES SUBMITTED TO NASA IN MAY 2021

Hi-Rate Composite Aircraft Manufacturing

4–6x production rate increase without cost or weight penalty

Production Rate per Month

• Metals	SOA:	60
• Composites	SOA:	10-15
	Target:	80-100

Wing Section Fab

Scope

- Explore and advance high-rate composite manufacturing and assembly technologies
  - Evolving State of Art (SOA) thermosets, thermoplastics, resin transfer molding
  - Materials, processes, and architectures
- Develop model-based engineering tools for high-rate manufacturing concepts

Benefit

- Increased manufacturing rates for composite aircraft structures to meet future production requirements and enable market penetration for lightweight composite materials

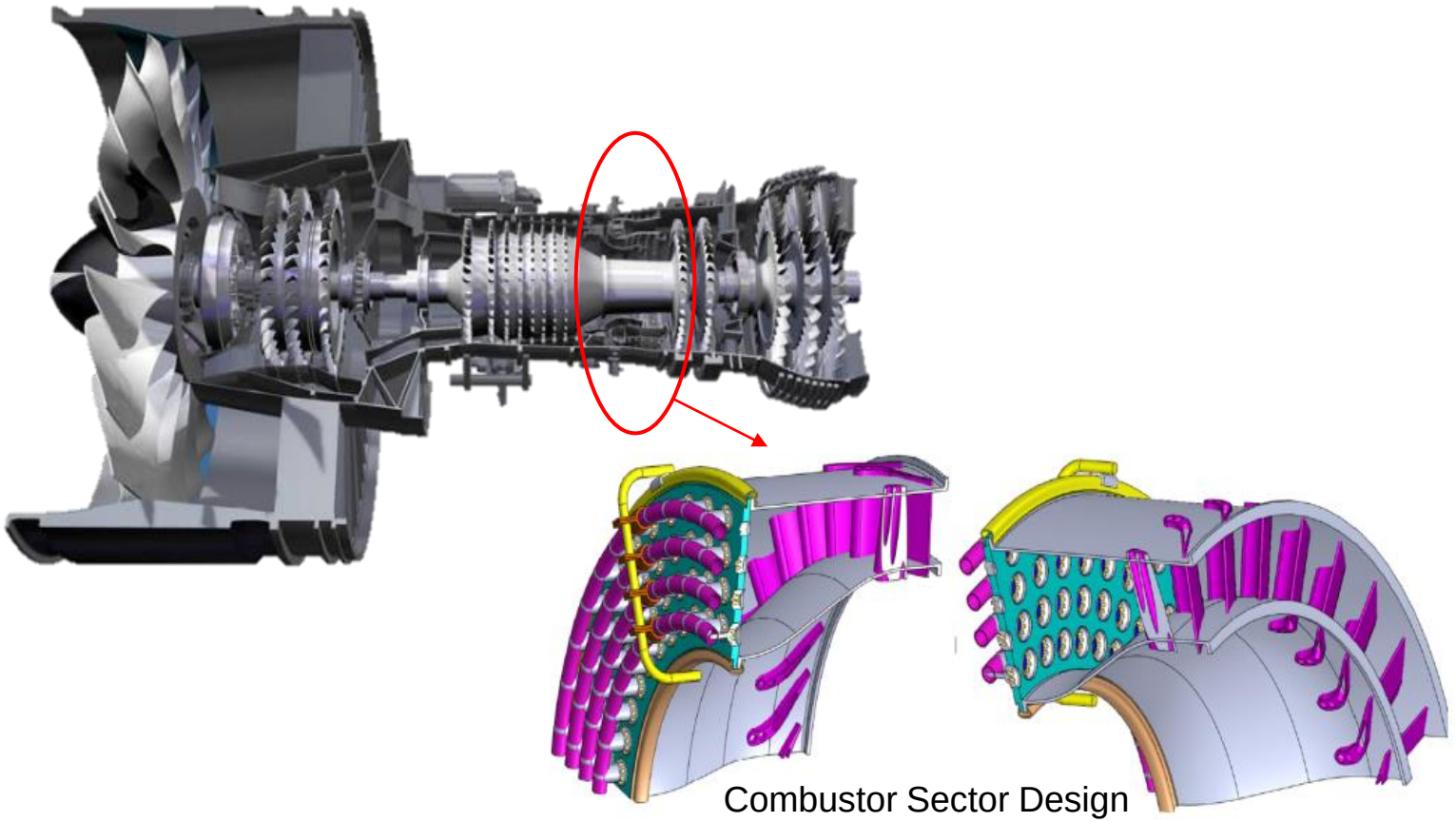
Approach

- Leverage advances in simulation including methods from Advanced Composites project
- Partner with industry for rapid prototype and evaluation of manufacturing concepts
- Demonstrate technologies in large structural ground tests

HiCAM PROJECT IN FORMULATION PHASE

Sustainable Aviation Fuels

Assess technology needs and impacts



Combustor Sector Design

- Improved efficiency/emissions with drop-in synthetic and biofuels
- Enable adoption of high-blend ratio sustainable alternative jet fuels – advance small core combustor design and address advanced small combustor operability and emissions
- High-blend sustainable alternative jet fuel emissions characterization

FUTURE RESEARCH PLANS IN DEVELOPMENT

NASA's Vision for Sustainable Aviation Operations

- Integrated trajectories optimized for environmental benefit
- Advanced flight deck capabilities to operate on those trajectories
- Tailored services that support safe integration of all diverse operations

Airspace Operational Tools Yield Immediate Benefits

Airspace Technology Demonstration (ATD)

Benefits to date from field demonstrations of ATD-2 technologies at the Charlotte Douglas International Airport (29 Sep 2017–31 Aug 2021)

Saved **1,088,888** gallons of fuel

FUEL

Saved **22,939,831** lbs. of CO_2 = **170,579** urban trees

EMISSIONS

Saved **5,948** hours of engine run time

MAINTENANCE

REDUCED DELAY BY 916.4 hours

Saving passengers an estimated **$4,399,066** in value of time and operators an estimated **$1,349,907** in flight crew costs

BENEFITS TODAY

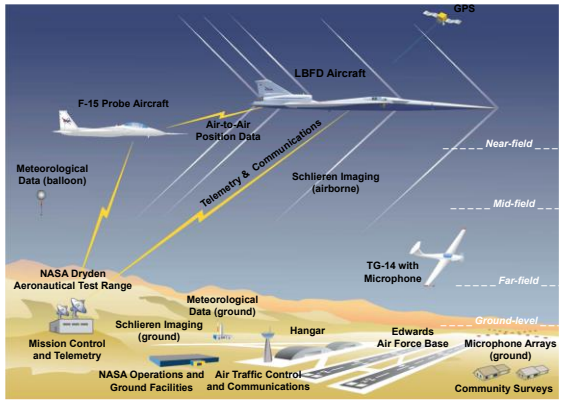
High-Speed Commercial Flight

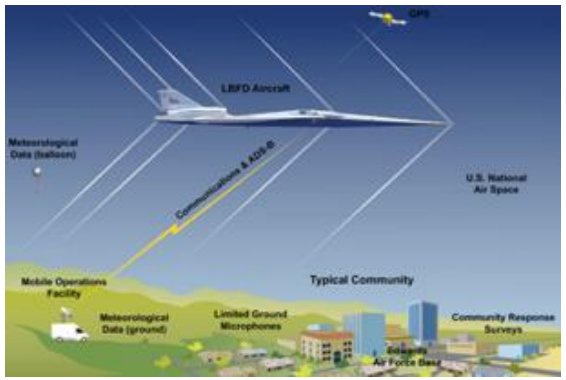
Sustainable transformation of the speed of air travel

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

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

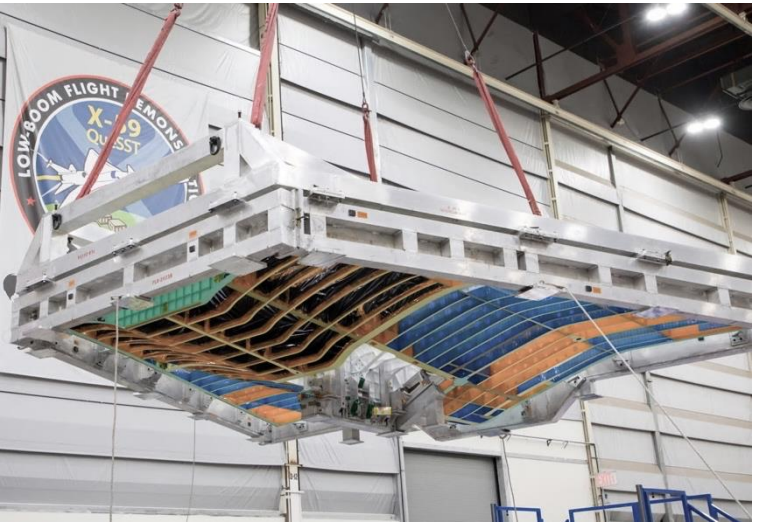
Phase 3 – Community Response Testing

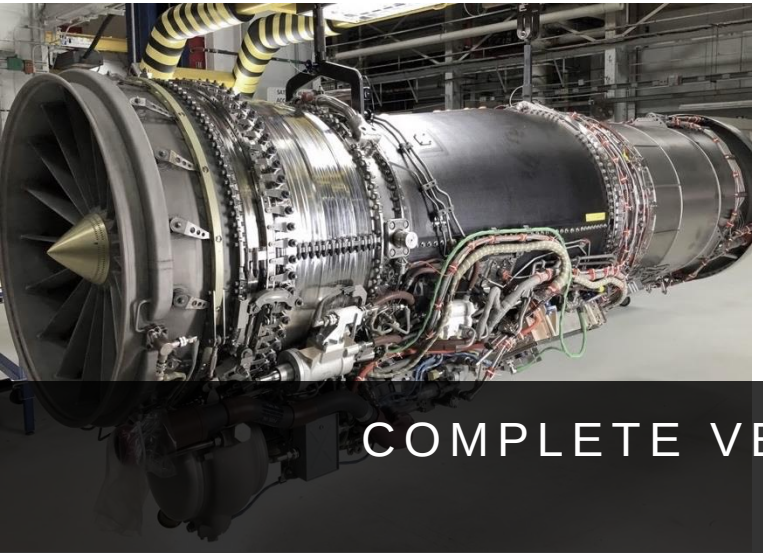
Preparation in progress (FY19-23), Execution FY24-27

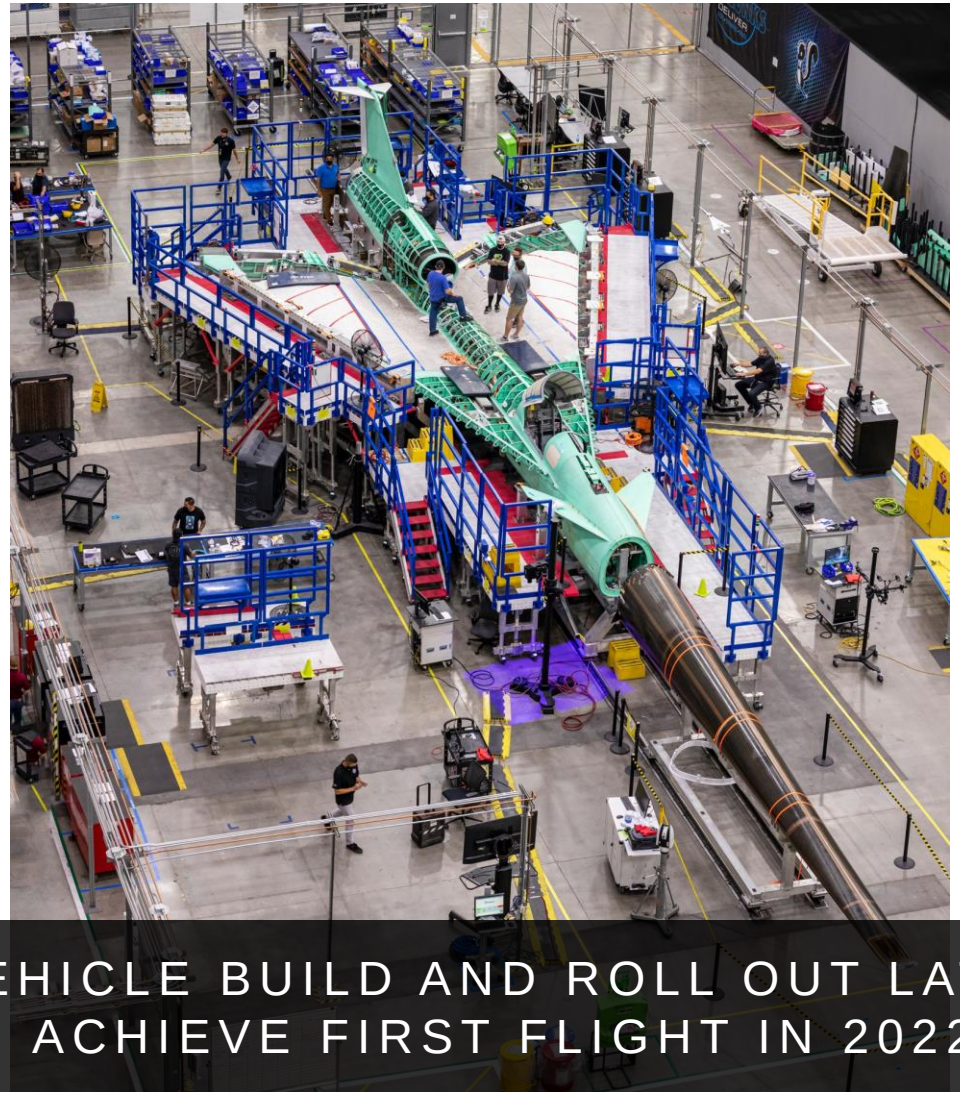
- Conduct community tests
  - Select communities
  - Outreach and engagement (including STEM)
  - Obtain necessary approval
  - Plan surveys and recruit participants
  - Collect ground measurements

Systematic Approach Leading to Community Testing

Recent Scenes of X-59 Construction Progress







NASA's first piloted supersonic X-plane in a generation is nearing completion with its nose section recently put into position.

COMPLETE VEHICLE BUILD AND ROLL OUT LATER THIS YEAR
ACHIEVE FIRST FLIGHT IN 2022

NASA X-57 Maxwell All-Electric Flight Demonstrator

Mod II

Validates Cruise Motors & Subsystems

Ground and flight test validation of electric motors, battery, and instrumentation.

Mod III

Achieves High-Speed Objectives

Flight test electric motors relocated to wingtips on newly developed & fabricated DEP wing.

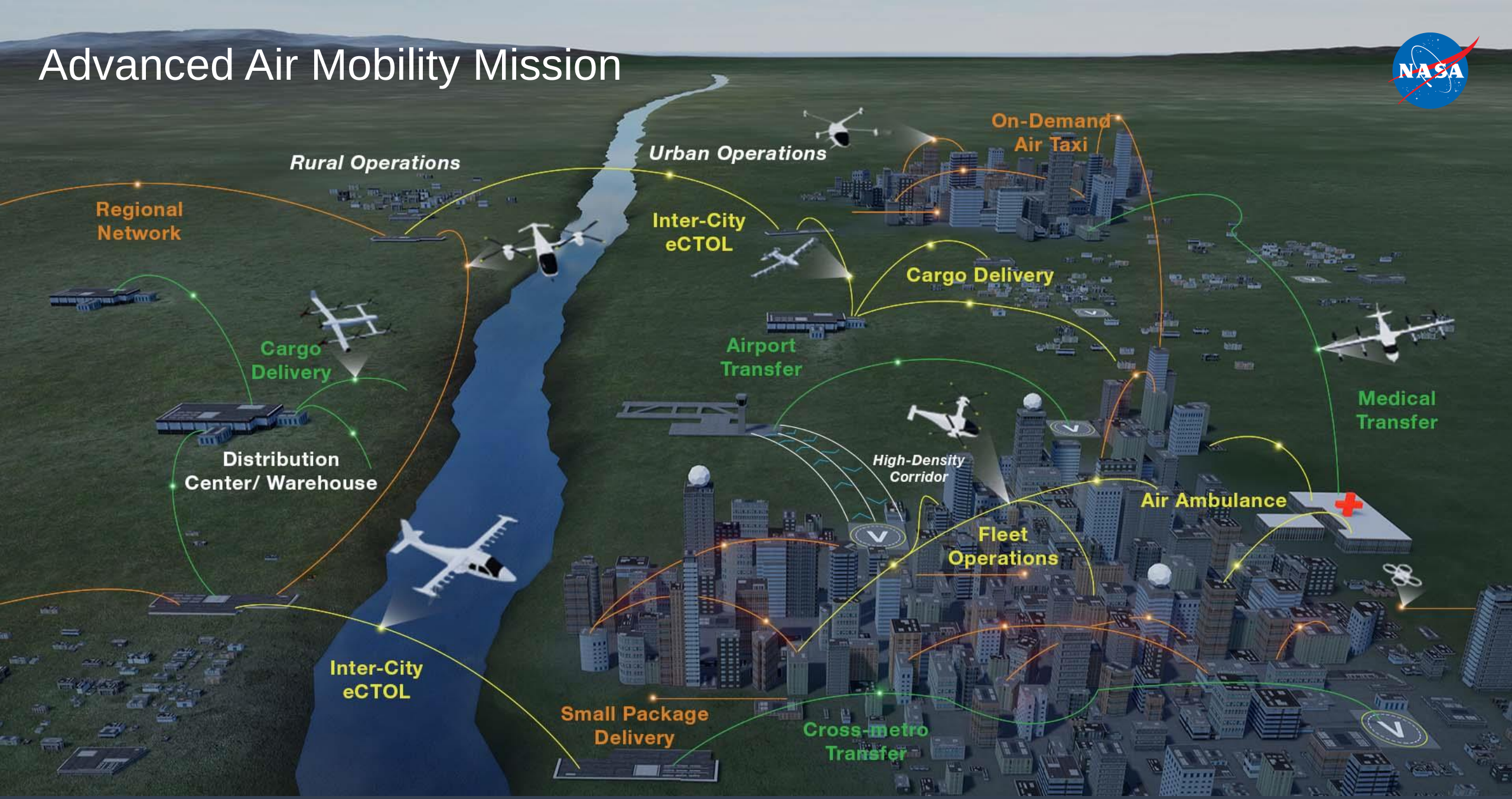
Mod IV

Achieves Low-Speed Objectives

Flight test with integrated DEP motors and folding props (cruise motors remain in wing-tips).

FIRST FLIGHT FEBRUARY 2022

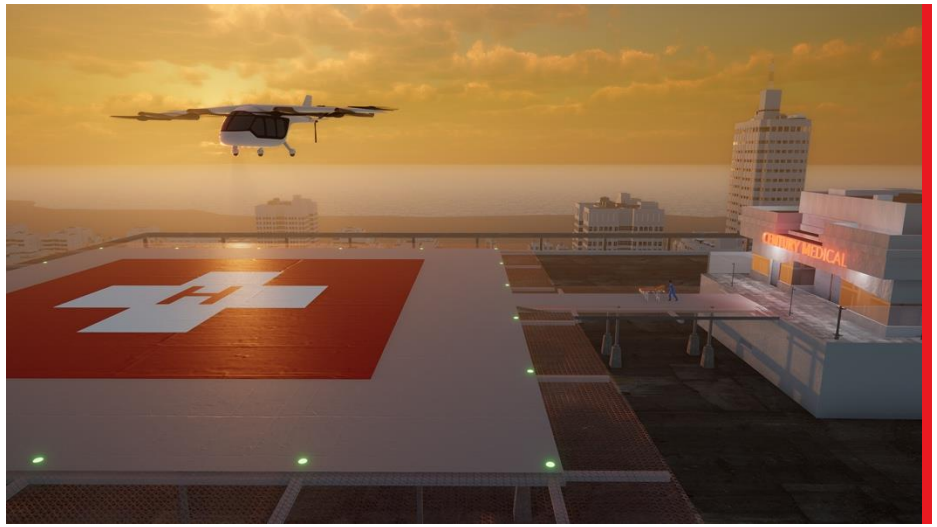
Advanced Air Mobility Mission



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

Advanced Air Mobility is Emerging

CARGO TRANSPORT



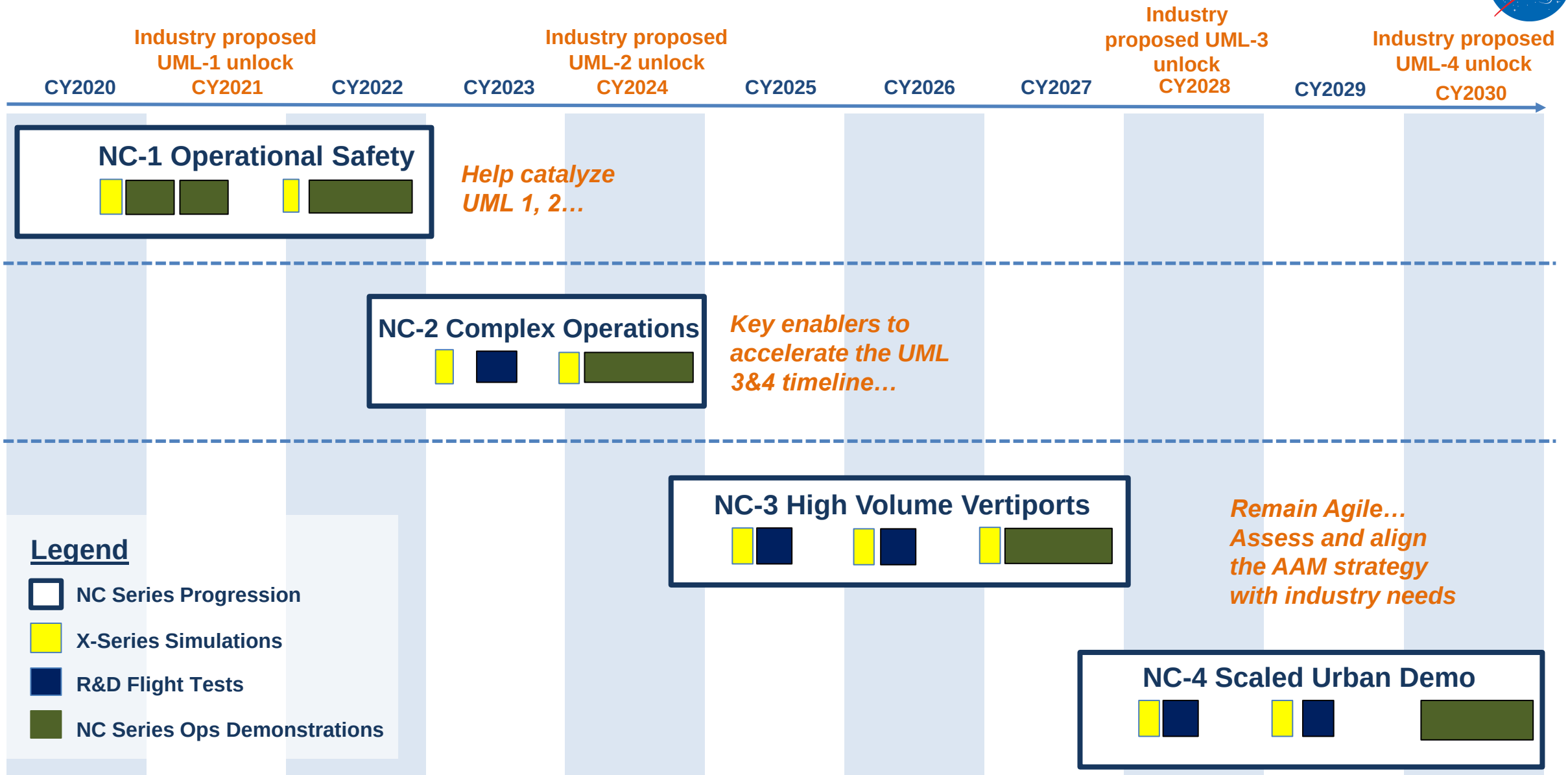
PUBLIC GOOD

CONSUMER/ ENTERPRISE GOODS AND SERVICES

PASSENGER TRANSPORT

Latest studies show an annual estimated market of $115B by 2035

National Campaign Series support of the Industry Timeline



UML ”unlocks” based on a range of publicly available industry projections and conversations with partners; not a consensus view

Wildfire Detection/Mitigation Concept of Operations

ARMD's Agile Innovation Ecosystem


Convergent Aeronautical Solutions


University Leadership Initiative


University Leadership Initiative

NASA Leadership for the Aviation Community – Exploration, Invention and Innovation

University Leadership Initiative Engaging the University Community

4 rounds of solicitations
$126M of awards

Seeking & awarding proposals addressing all Strategic Thrusts

- 19 awards with 59 universities
- 6 HBCUs and 9 MSIs
- 333 proposals submitted
- 245 different proposing Principal Investigators
- 2468 team members
- 1602 different people
- 20–50 students per team

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.

Net Zero Aviation Emissions Innovation

NASA Distributed Propulsion Concept
- Turbo-Electric with superconducting electric drivetrain
- Over 70% reduction in energy use

Examples of current Research at Low TRL

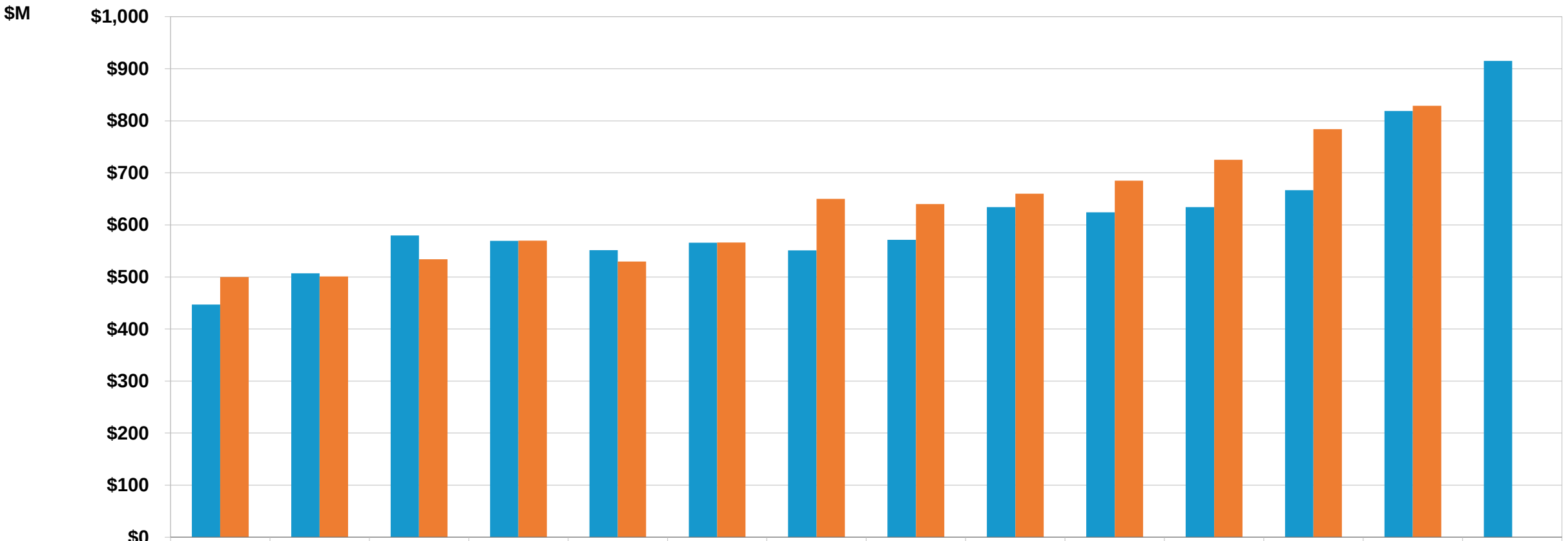
University of Illinois, Urbana-Champagne (NASA ULI) fully electric concept
- Hydrogen fuel cell, superconducting electric drivetrain
- Zero carbon emissions

Foster radical aviation technology advancement – new energy sources, aircraft architectures – necessary for large aircraft with extremely low or zero emissions

Low TRL concepts can be further conceptualized, researched, developed, ground and flight tested and advanced for late 2030s / early 2040s

Recent University Leadership Initiative solicitation (March 2021) included net-zero emissions topics

ARMD Budget FY 2014 to FY 2022



	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22
Pres Budget	$447	$507	$580	$569	$552	$566	$551	$571	$634	$624	$634	$667	$819	$915
Enacted	$500	$501	$534	$570	$530	$566	$650	$640	$660	$685	$725	$784	$829	

Summary

- NASA is leading transformation across the aviation sector, including next generation large civil aircraft, quiet supersonic flight, advanced air mobility and the next evolution of air traffic management.
- NASA Aeronautics is partnering with industry, academia and other Federal agencies through the Sustainable Flight National Partnership to accomplish the aviation community's aggressive climate change mitigation agenda through dramatic efficiency gains.
- We have accelerated our plans to demonstrate high-risk, high-payoff technology advancements that will be critical for U.S. aerospace manufacturers to bring to market innovative, cost-effective and sustainable products and services demanded by airlines and customers.
- The FY22 budget will enable technology maturity at the pace required for continued U.S. competitiveness in global markets.
- NASA Aeronautics continues building on decades of contributions to aviation to persistently and consistently improve environmental sustainability, global mobility, and economic growth.

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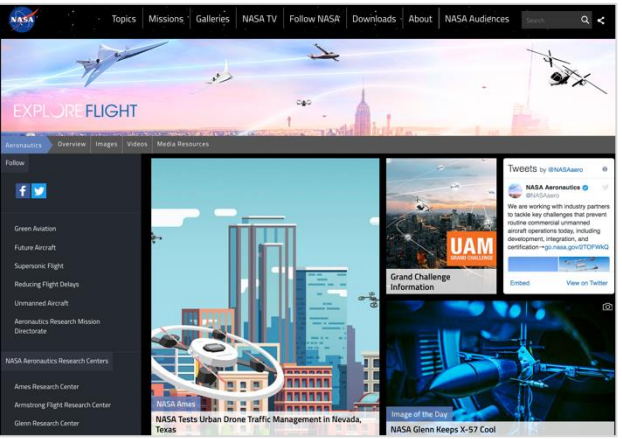

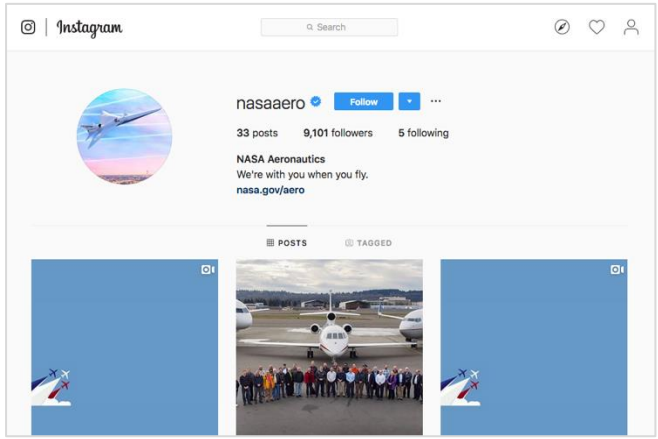

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