NASA Aeronautics Research

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Aviation is Vital to our Nation's Economy

- 8.97 million flights by U.S. carriers worldwide in 2022
- 24 million tons of freight transported by U.S. airlines in 2022
- $1.9 trillion total U.S. economic activity in 2019
- $51.5 billion positive manufacturing trade balance in 2021
- 2.1 million aerospace/defense jobs; 575,000 in aeronautics/aircraft in 2021

NASA Aeronautics – Vision for Aviation in the 21st Century

Global

Sustainable

Transformative

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

ULTRA-EFFICIENT AIRLINERS

FUTURE AIRSPACE AND SAFETY

HIGH-SPEED COMMERCIAL FLIGHT

ADVANCED AIR MOBILITY

Four Transformations for Sustainability, Greater Mobility, and Economic Growth

Airspace Operations and Safety Program

Advanced Air Vehicles Program
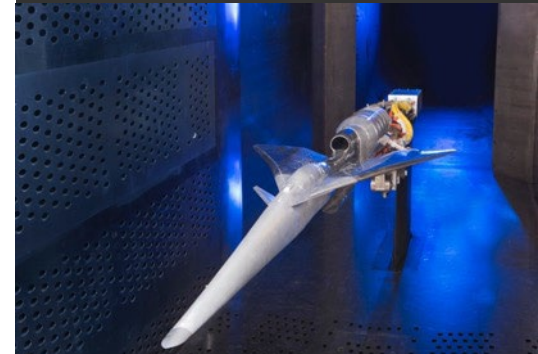
Integrated Aviation Systems Program

Transformative Aeronautics Concepts Program

Aerosciences Evaluation and Test Capabilities Portfolio

ARMD PROGRAMS

Aeronautics FY 2024 Budget Request

$ Millions	FY 2023 Enacted	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028
Aeronautics	**$935.0**	**$995.8**	**$1,015.7**	**$1,036.0**	**$1,056.7**	**$1,077.8**
Airspace Operations and Safety		158.7	164.4	179.4	198.2	202.8
Advanced Air Vehicles		295.2	311.6	305.0	273.6	257.5
Integrated Aviation Systems		264.9	260.5	263.5	279.7	305.5
Transformative Aeronautics Concepts		160.0	161.8	170.3	184.5	188.5
Aerosciences Eval and Test Capabilities		117.0	117.4	117.7	120.7	123.5

Aeronautics FY 2024 Budget Request

- Supports a robust Sustainable Flight National Partnership to enable highly efficient next generation aircraft and ensure U.S. leadership in aviation

- Conducts the first flight of the X-59 Low Boom Flight Demonstrator and envelope expansion flights to prove airworthiness. 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

- Enables the FAA adopted Extensible Traffic Management (XTM) concept to create safe airspace access for emerging aviation systems

- 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 and industry led studies

- Funds an effort to improve aerial responses to wildfires by leveraging NASA UAS traffic management technologies, in partnership with NASA's Science and Space Technology Mission Directorates

The Aviation Carbon Reduction Challenge

- By 2050, an estimated 10 billion passengers will fly each year a distance of 22 trillion revenue passenger kilometres.

- With today's fleet and operational efficiency, this activity would require over 620 megatonnes (Mt) of fuel and generate close to 2000 Mt of CO_2.

- Imagine enabling the same level of demand while reducing net CO_2 emissions to zero by 2050.

Meeting the challenge is the opportunity for the United States to lead the world 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).

U.S. Aviation Climate Action Plan

U.S. Aviation Climate Goal:

Net-Zero GHG Emissions* from the U.S. Aviation Sector** by 2050

"The United States believes that addressing the climate crisis through enhanced ambition is a defining priority of our time. This Aviation Climate Action Plan provides a whole-of-government approach and policy framework for the aviation sector to contribute to broader, economy-wide objectives."

- U.S. Aviation Climate Action Plan

Aviation Pillars for a Sustainable Future

Global Aviation GOAL: net-zero carbon emissions by 2050

TECHNOLOGY

NASA = Primary Role

SUSTAINABLE AVIATION FUEL

ALTERNATIVE FUEL

NASA = Supporting Role

OPERATIONS AND INFRASTRUCTURE

NASA = Primary Role

Subsonic Airliner Technologies

Ensure U.S. industry is the first to establish the new "S Curve" for the next 50 years of airliners
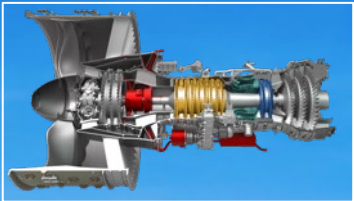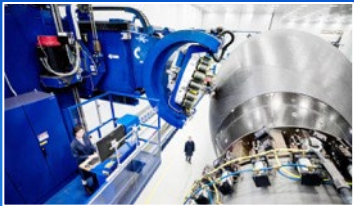
Integrated Aircraft System Efficiency
Propulsion Airframe Integration Opportunity

Aerodynamic Efficiency
Transonic Truss-Braced Wing
(5-10% fuel burn benefit)

Weight
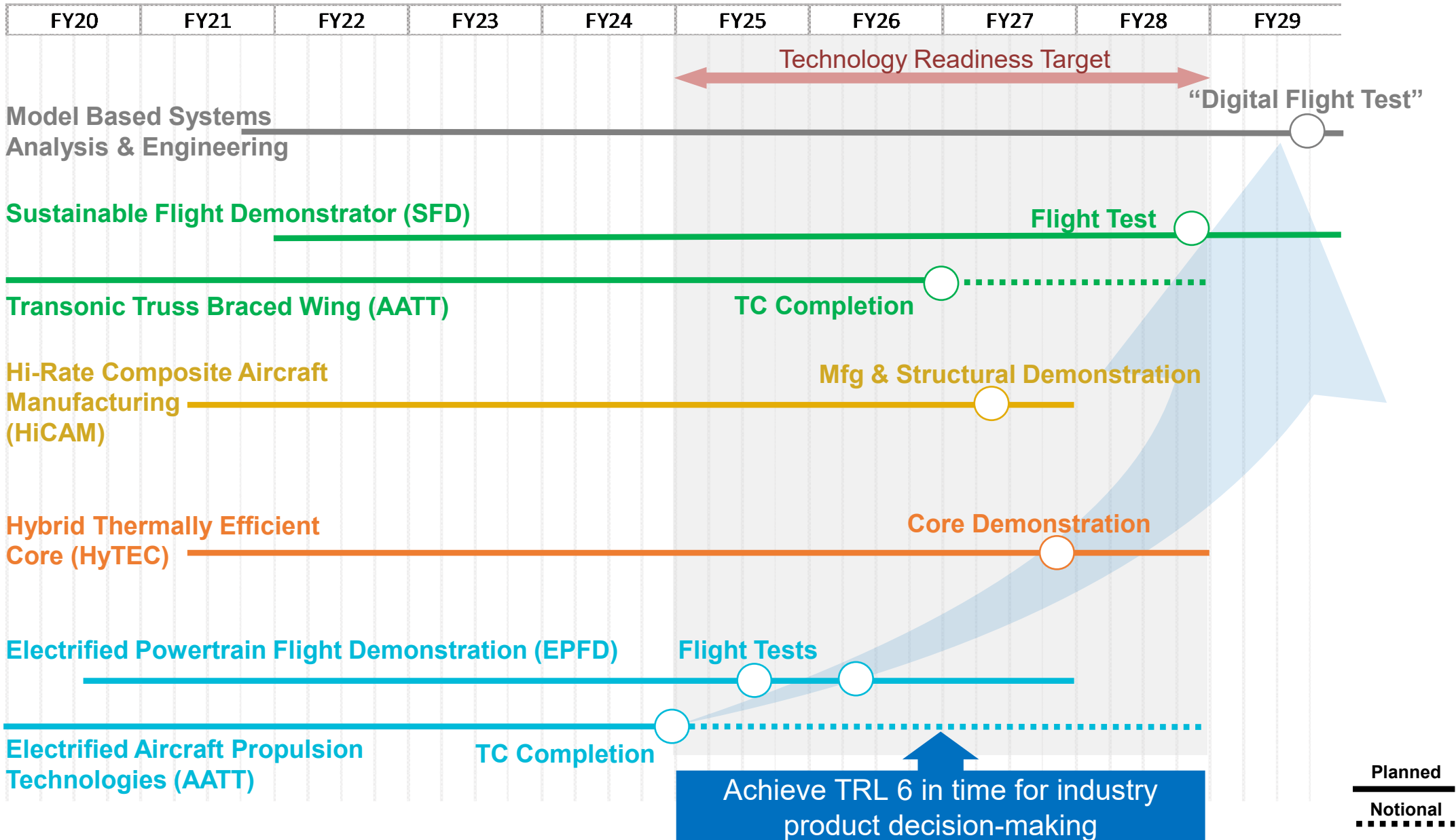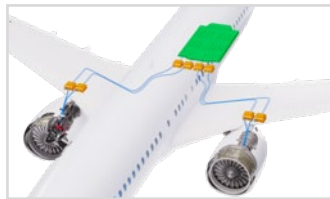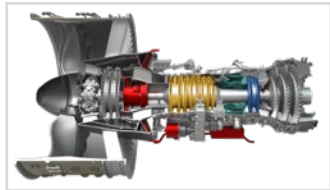High-Rate Composites
(4-6x manufacturing increase)

Electrified Aircraft Propulsion
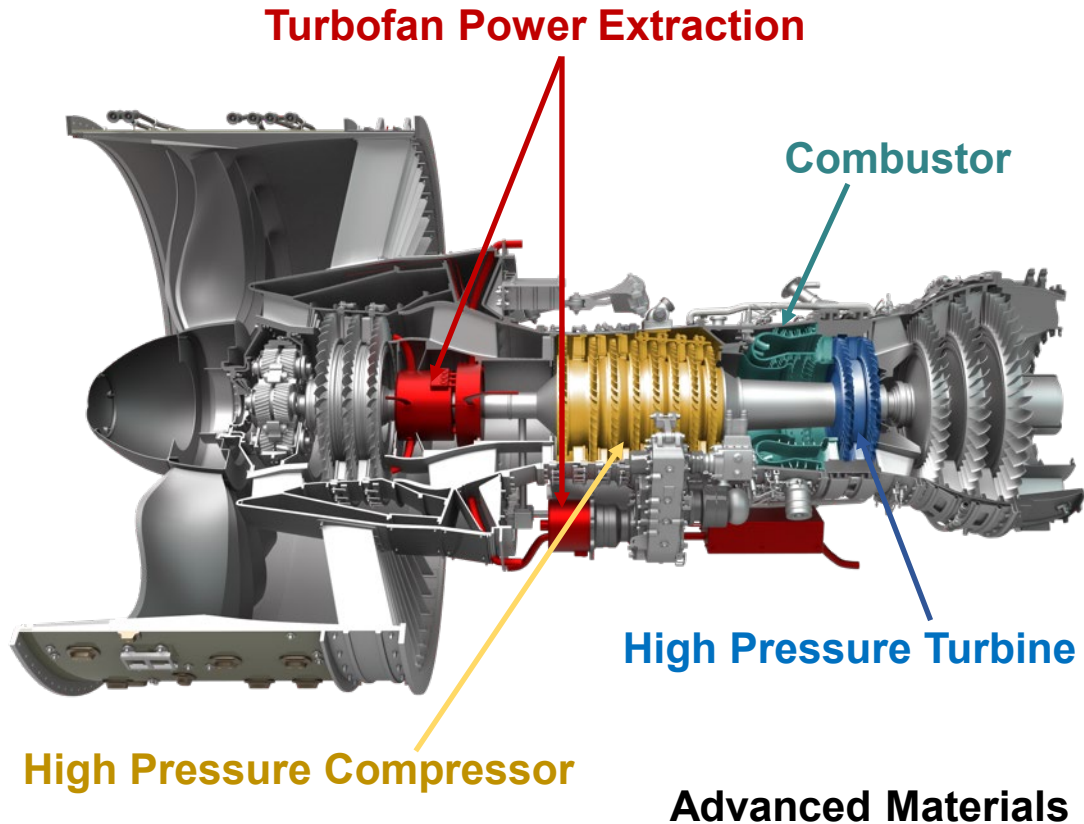~5% fuel burn and maintenance benefit

Engine Efficiency
Small Core Gas Turbine
(5-10% fuel burn benefit)

Subsonic Airliners: Integrated Technology Development

	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29

Technology Readiness Target

"Digital Flight Test"

Model Based Systems Analysis & Engineering

Sustainable Flight Demonstrator (SFD) — Flight Test

Transonic Truss Braced Wing (AATT) — TC Completion

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

Hybrid Thermally Efficient Core (HyTEC) — Core 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

Hybrid Thermally Efficient Core

Accelerate development and demonstration of advanced turbine engine technologies

Turbofan Power Extraction

Combustor

High Pressure Turbine

High Pressure Compressor

Advanced Materials

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

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

Small-core turbofan technology contract awards were made in September 2021.
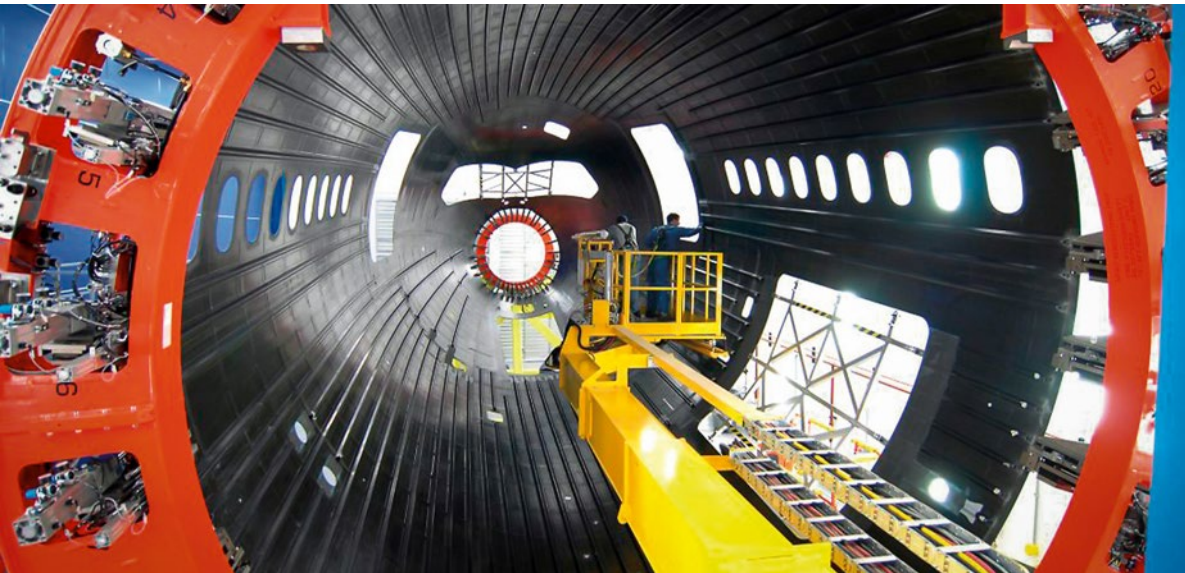Additional technology contract award in September 2022.

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

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

8 multi-party cooperative research teams developing technology
Awards made March 2023 to advance manufacturing process work.

Sustainable Aviation Fuels

Enable the use of 100% sustainable aviation fuels (SAF) and reduce climate impact

NASA Sampling Probe

CFM LEAP Engine Burning 100% SAF

Photo Credit: Boeing / Paul Weatherman

Flight-test planning underway

Scope

- Support adoption of high-blend ratio sustainable aviation jet fuels
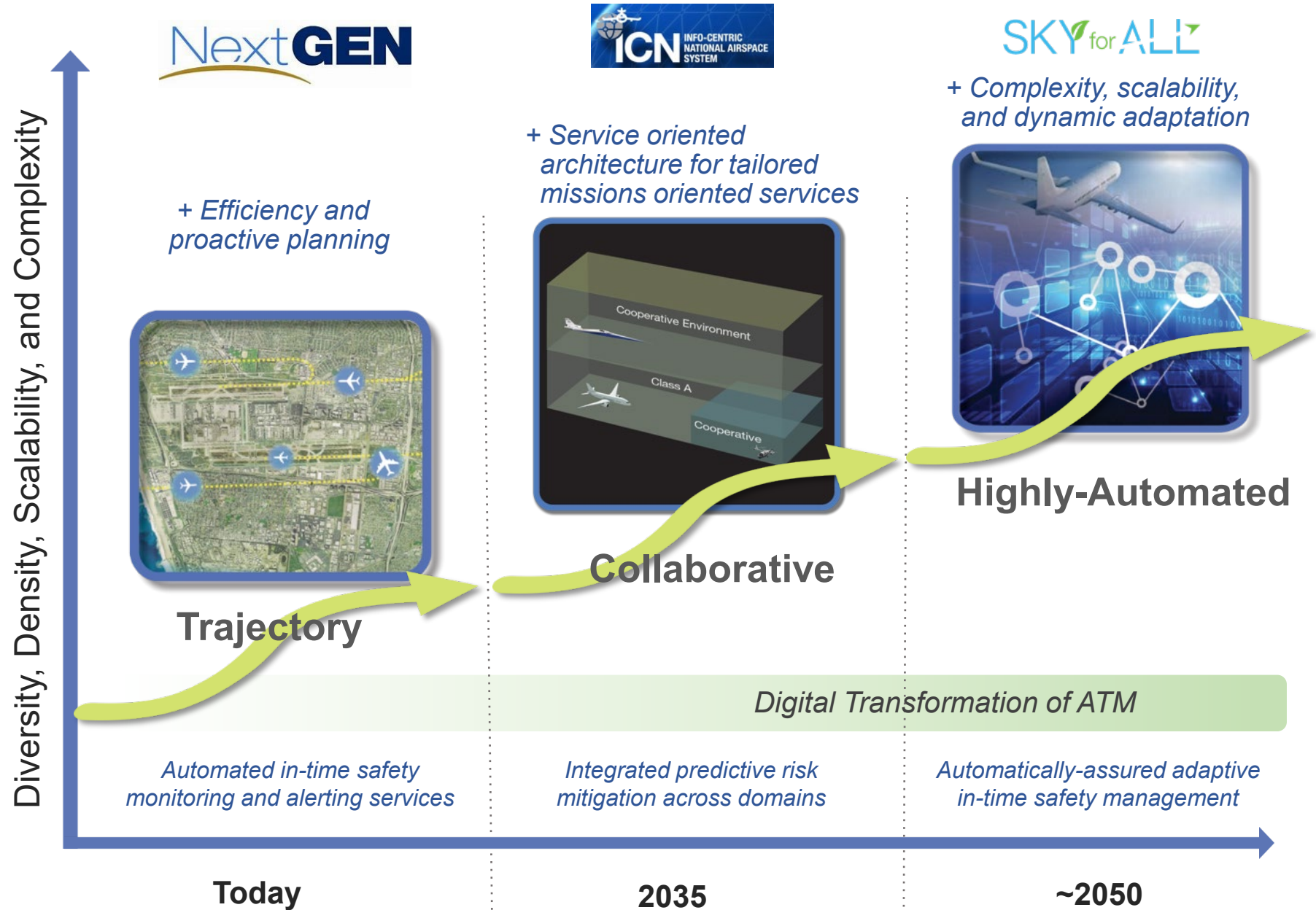
Benefits

- Reduced aviation environmental impact
- Reduced uncertainty for climate impact of aviation-induced cloudiness
- Improved efficiency/emissions with drop-in synthetic and biofuels

Approach

- Characterize high-blend sustainable aviation jet fuel emissions on ground and in flight

Future SAF Research Plans in Development

Evolution of Airspace Operations and Safety

Diversity, Density, Scalability, and Complexity

NextGEN

+ Efficiency and proactive planning

Trajectory

Automated in-time safety monitoring and alerting services

Today

ICN INFO-CENTRIC NATIONAL AIRSPACE SYSTEM

+ Service oriented architecture for tailored missions oriented services

Cooperative Environment

Class A

Cooperative

Collaborative

Integrated predictive risk mitigation across domains

2035

SKY for ALL

+ Complexity, scalability, and dynamic adaptation

Highly-Automated

Digital Transformation of ATM

Automatically-assured adaptive in-time safety management

~2050

~ 2035 (Info-Centric NAS): Integration 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

Increased operational efficiency reduces fuel burn,
carbon emissions, contrail formation, and ozone impact.

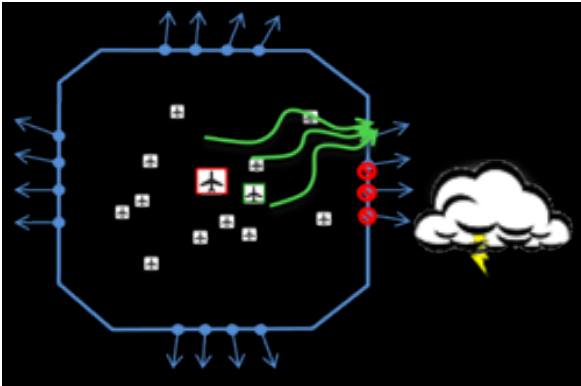# NASA-led SFNP Operations Demonstrations

 TECHNOLOGY

 SUSTAINABLE AVIATION FUEL

 OPERATIONS AND INFRASTRUCTURE
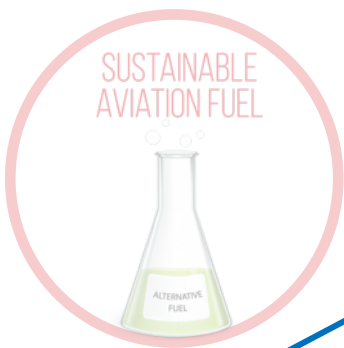
GLOBAL Aviation Goal: 2050 net-zero carbon
- *industry (ATAG)*
- *governments (ICAO)*
- *U.S. Aviation Climate Action Plan.*

Flight Deck Services

Ground Services

Collaborative Digital Departure Re-route (SFNP-Ops-1, FY22-25)

Sustainable Oceanic Airborne Re-Routing (SFNP-Ops-2, FY26)

Irregular Ops Recovery/Disruption Management (SFNP-Ops-3, FY27)

4D Trajectory Optimization (SFNP-Ops-4, FY28)

SFNP-Ops = Sustainable Flight National Partnerships - Operations

Sustainability Goals: Deliver reductions in emissions, fuel, and noise of aviation operations through digital services technology

~ 2050: Planning to Achieve a Sky for All

Imagining tomorrow's aviation system today

Sustainable Solutions

Seamless Skies

Ubiquitous and Resilient Operations

Operator Optimization

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.

High-Speed Commercial Flight
Sustainable transformation of the speed of air travel

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

QUESST

This mission will fly the X-59 with its quiet supersonic technologies over U.S. communities, yielding data that could lead to new en route certification standards based on acceptable sound levels.
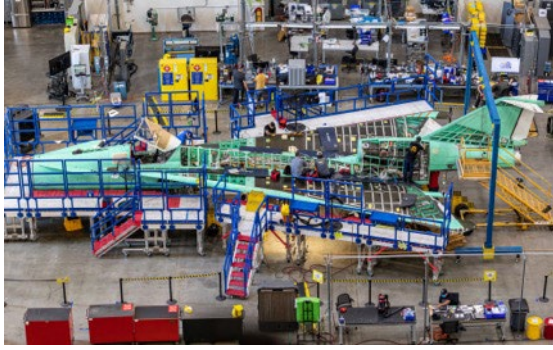
X-59

Photos: Lockheed Martin
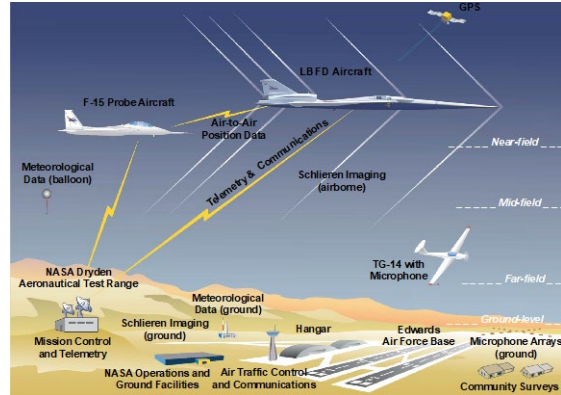
Planning for First Flight in Early CY 2024.

Quesst Mission Overview

QUESST

Phase 1 – Aircraft Development
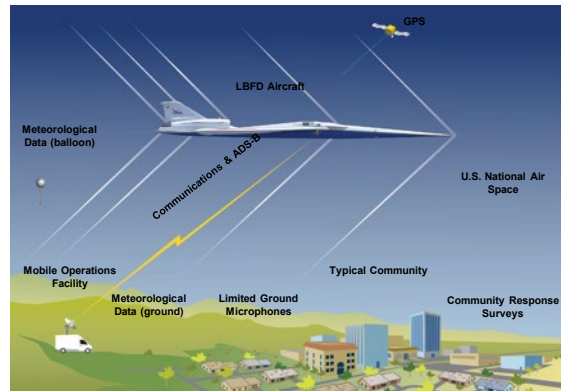*In progress (FY18-24)*
- Design, fabricate a quiet supersonic research aircraft
- Prove performance in test range flights
- Prove safety for flights in normal airspace

Phase 2 – Acoustic Validation
Preparation in progress (FY18-24), Execution FY24
- 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
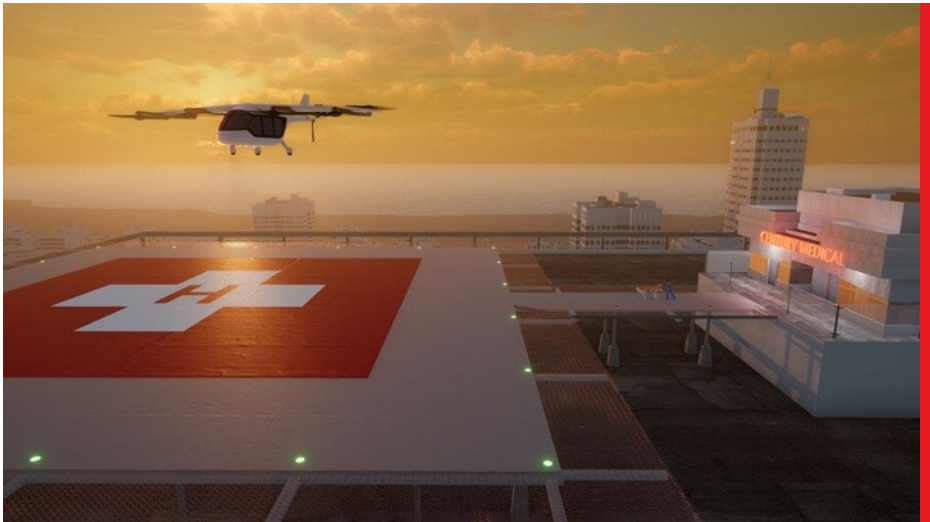 - Collect ground measurements

Systematic Approach Leading to Community Testing

Advanced Air Mobility Missions are Emerging

CARGO TRANSPORT

PUBLIC GOOD

CONSUMER/ ENTERPRISE GOODS AND SERVICES

PASSENGER TRANSPORT

AIA/Deloitte study shows annual estimated advanced air mobility market of $115B by 2035.

Advanced Air Mobility Mission

Wildfire Fighting Operations

Rural Operations

On Demand Air-Taxi

Urban Operations

Regional Network

Inter-City eC/STOL

Cargo Delivery

Inter-City eVTOL

Airport Transfer

Cargo Delivery

Air Ambulance

Cargo Delivery

Distribution Center/Warehouse

Fleet Operations

Medical Supply Delivery

Inter-city eCTOL

Small Package Delivery

Cross-metro Transfer

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

Advanced Capabilities for Emergency Response Operations
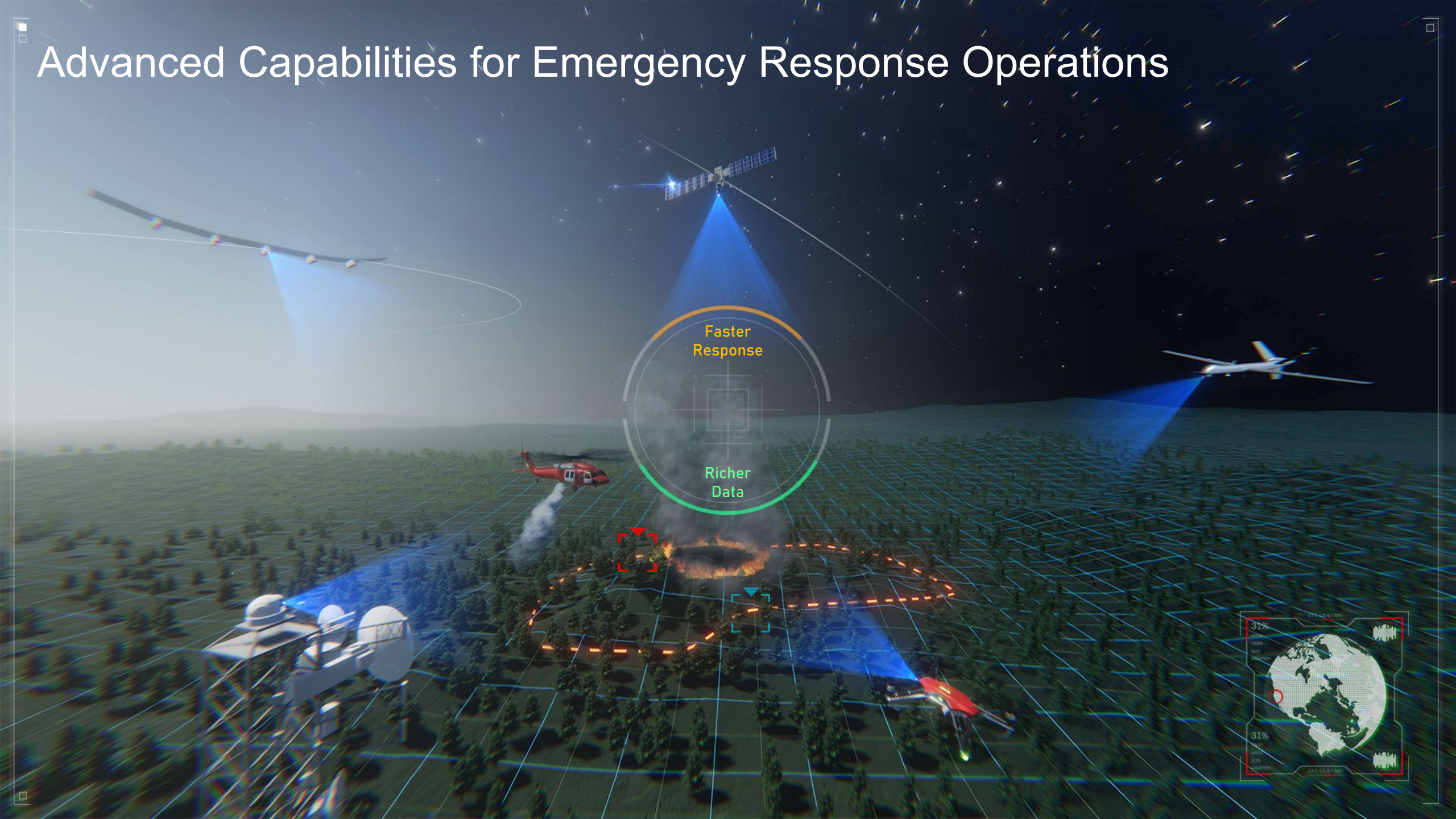
Faster
Response

Richer
Data
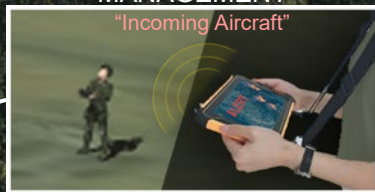
University Leadership Initiative (ULI) Engaging the University Community

6 rounds of solicitations
$178M of awards

Seeking and awarding proposals addressing all strategic thrusts and special topics

- 23 teams awarded to date
- 80 universities including 11 Historically Black Colleges and Universities / 16 other Minority Serving Institutions
- 507 proposals submitted
- 377 different proposing Principal Investigators
- 4,023 total team members
- 20–50 students per team

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

Aerosciences Evaluation and Test Capabilities (AETC) Portfolio

NASA Glenn Research Center (GRC)
Cleveland, OH

NASA Langley Research Center (LaRC)
Hampton, VA

NASA Ames Research Center (ARC)
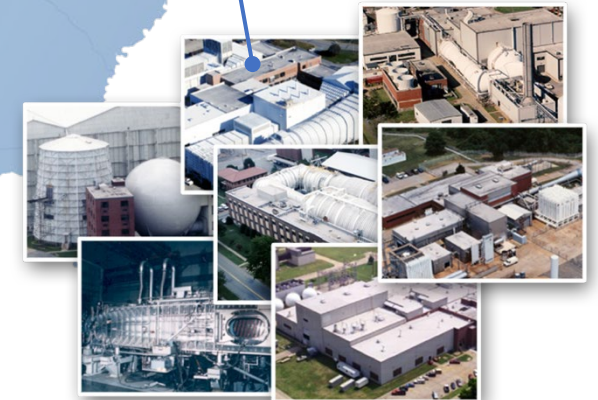Moffett Field, CA

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.

National Need – Stakeholder Alignment – Compelling Vision – Real Impact

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

ULTRA-EFFICIENT TRANSPORT   FUTURE AIRSPACE

Quesst 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

HIGH-SPEED COMMERCIAL FLIGHT   ADVANCED AIR MOBILITY

Four Transformations for Sustainability, Greater Mobility, and Economic Growth