National Aeronautics and Space Administration



NASA Aeronautics Research

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June 10, 2022

www.nasa.gov

Aviation is Vital to the US Economy



Pre-COVID

- $78 billion positive trade balance; the largest positive trade balance of any U.S. manufacturing sector
- $1.8 trillion total U.S. economic activity
- 10.9 million direct/indirect jobs
- 21.3 billion tons of freight transported by U.S. airlines in 2019

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



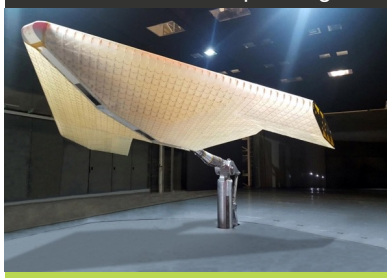
Advanced Air Vehicles Program



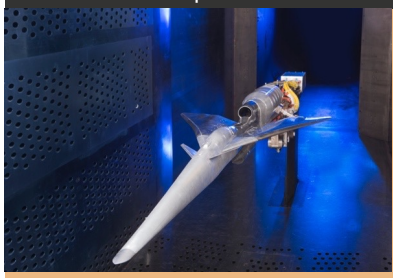
Integrated Aviation Systems Program



Transformative Aeronautics Concepts Program



Aerosciences Evaluation and Test Capabilities Portfolio





Four Transformations for Sustainability, Greater Mobility, and Economic Growth

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.



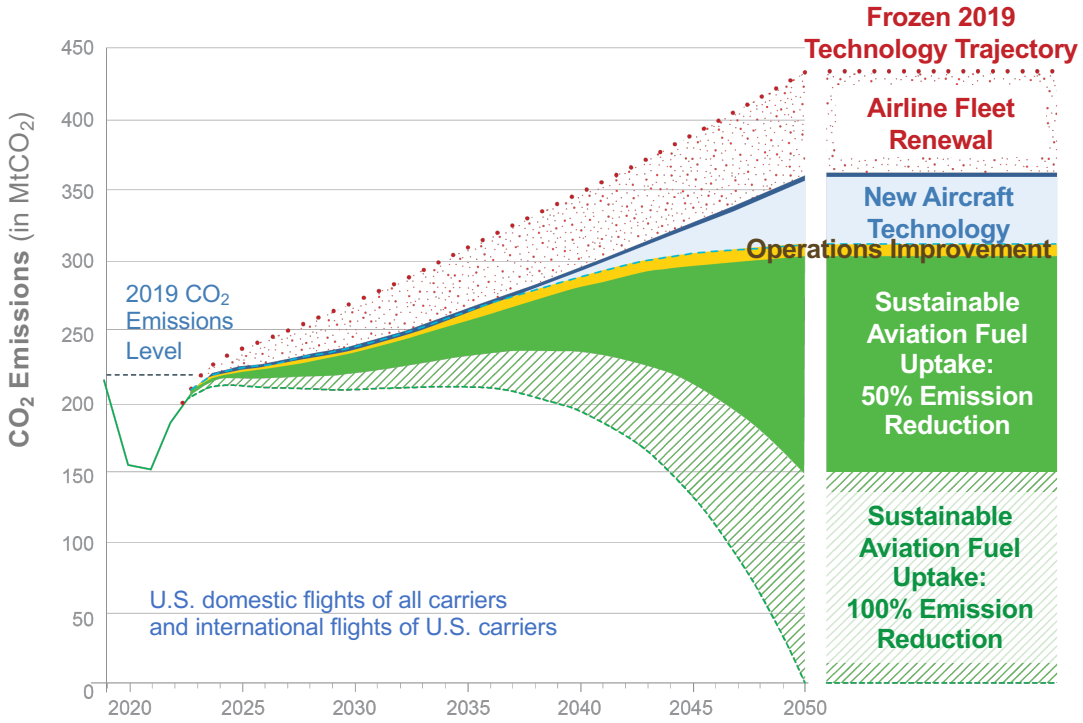
Meeting the challenge is the opportunity for the United States to lead the world in innovation and reductions in CO_2 aviation emissions, and to maintain economic competitiveness in a critical export industry ($6 trillion-plus market over the next 20 years).

U.S. Aviation Climate Action Plan

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



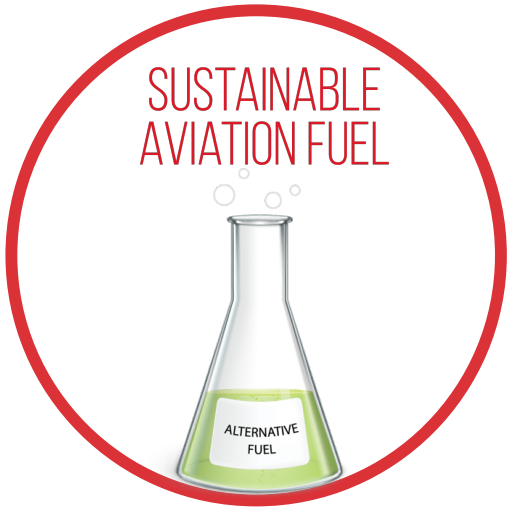
The U.S. is working with the global community to achieve net-zero greenhouse gas emissions by 2050 using a common basket of measures.

Aviation Pillars for a Sustainable Future

Global Aviation Industry GOAL: net-zero carbon emissions by 2050



NASA = Primary Role



NASA = Supporting Role



NASA = Primary Role

Single-Aisle Transport Airplane Market

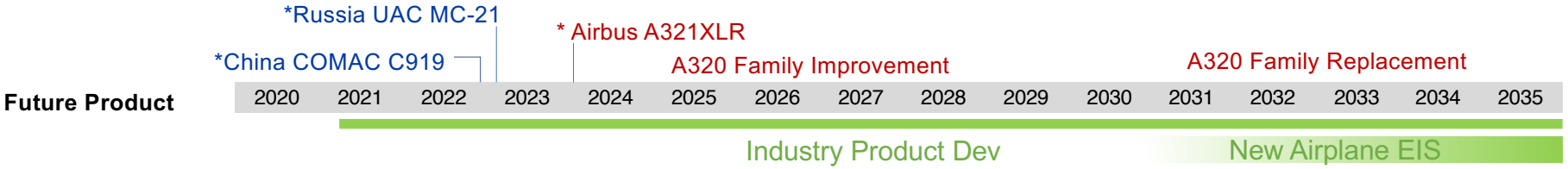


COMAC C919
Image Credit: Weimeng



UAC MC-21
Image Credit: Denis Fedorko


Airbus A321
Image Credit: Huy Bùi



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)

Sustainable Flight National Partnership

Next-Generation Capability on the Path to Net-Zero Greenhouse Gas Emissions by 2050



Advance engine efficiency and emission reduction

Enable integrated trajectory optimization

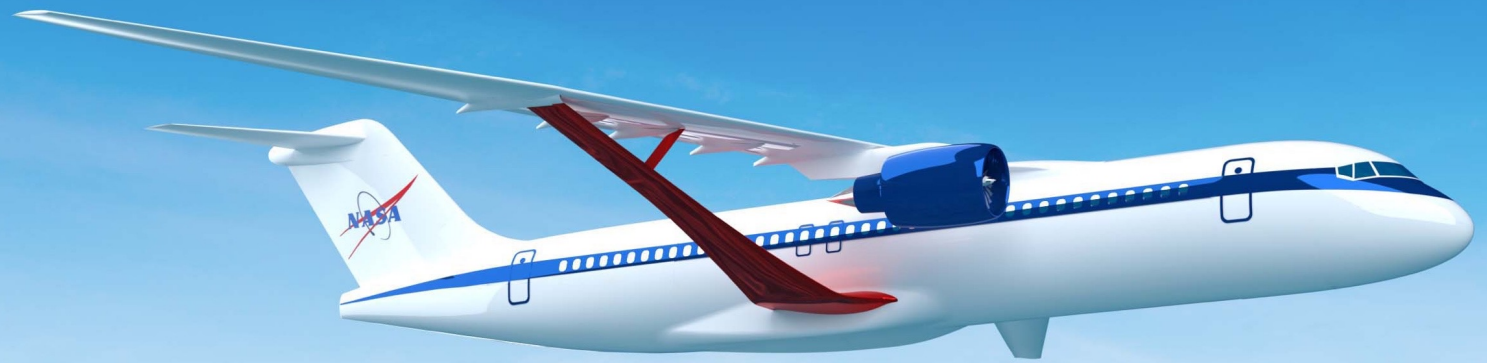
Advance airframe efficiency and manufacturing rate

Enable use of 100% sustainable aviation fuels

Achieve net-zero greenhouse emissions by 2050 through 25-30% energy efficiency improvements in next-generation transports, 100% sustainable aviation fuel, and optimal trajectories.

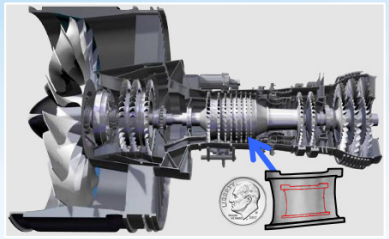
Subsonic Transport Technologies

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

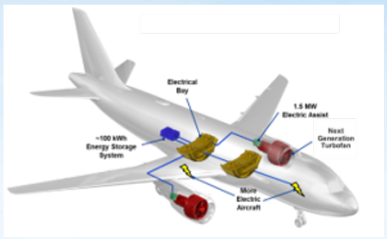




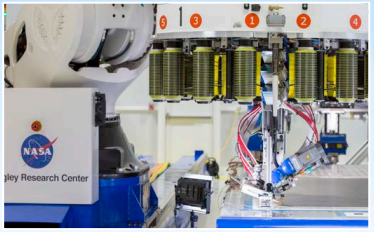
Transonic Truss-Braced Wing
5-10% fuel burn benefit



Small Core Gas Turbine
5-10% fuel burn benefit



Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit

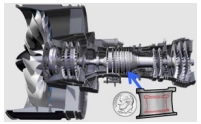


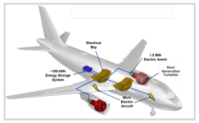
High-Rate Composite Manufacturing
4x-6x manufacturing rate increase

Subsonic Transports: Integrated Technology Development



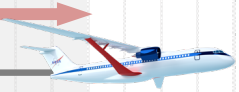






FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29

Technology Readiness Target



Model Based Systems Analysis & Engineering

Sustainable Flight Demonstrator (SFD) — Flight Test

AATT - Transonic Truss Braced Wing — TC Completion

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

Hybrid Thermally Efficient Core (HyTEC) — Core Demonstration & Test

Electrified Powertrain Flight Demonstration (EPFD) Flight Tests

AATT - Electrified Aircraft Propulsion Integrated Ground Test — TC Completion

Achieve TRL 6 in time for industry product decision-making

Leverage the Asset – Future Spirals

Planned

Notional

Sustainable Flight Demonstrator

Demonstrate integrated airframe-focused technologies in flight



Scope

- Develop and fly integrated airframe-focused 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.

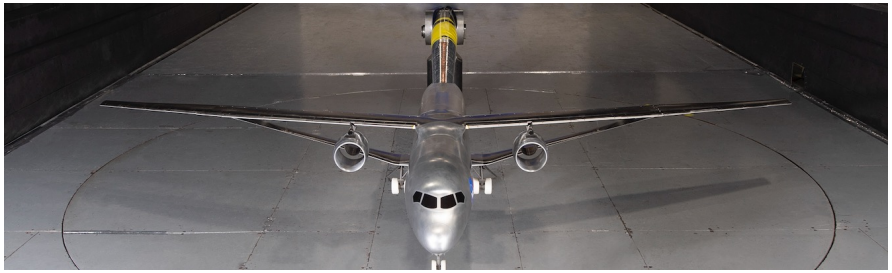
Approach

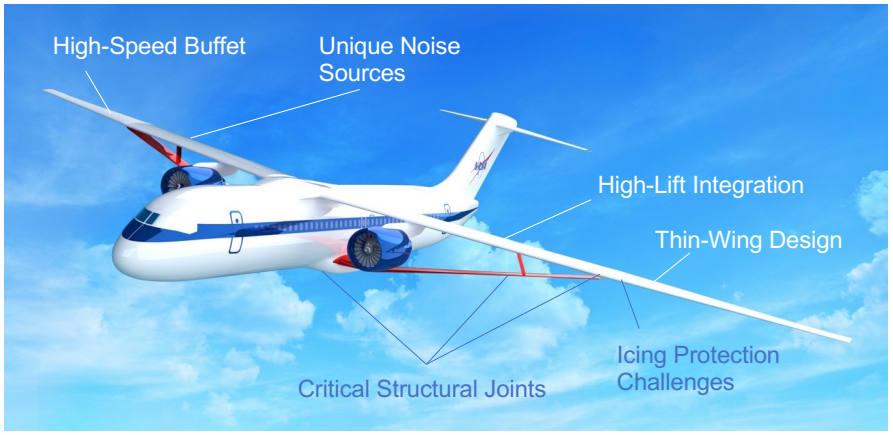
- Request for Information supporting Project Formulation 2020-21
- Project Formulation and Risk Reduction in 2021-22
- Competitive Request for Proposals in 2022

Risk Reduction Contract Awards Made August 2021
Design/Build Contract Award Anticipated Late 2022

Transonic Truss-Braced Wing Technology Maturation

Increase confidence in technology to be robustly integrated in the aircraft system





Scope

- Mature and reduce risk of Transonic Truss-Braced Wing (TTBW) technology, focused on:
  - Buffet boundary prediction
  - Stall characteristics
  - High-lift system integration
  - Acoustic assessment
  - Icing impact
  - Thin wing structural design
  - Unique structural joints

Benefit

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

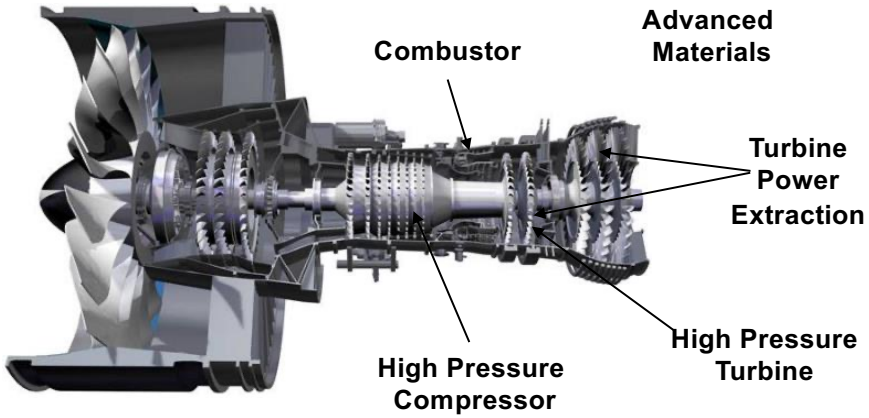
Approach

- Concept studies through scale model testing
- Perform high-fidelity prediction, testing and validation to increase confidence in fuel burn benefit

Design/analysis studies and wind-tunnel tests are underway.

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 **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

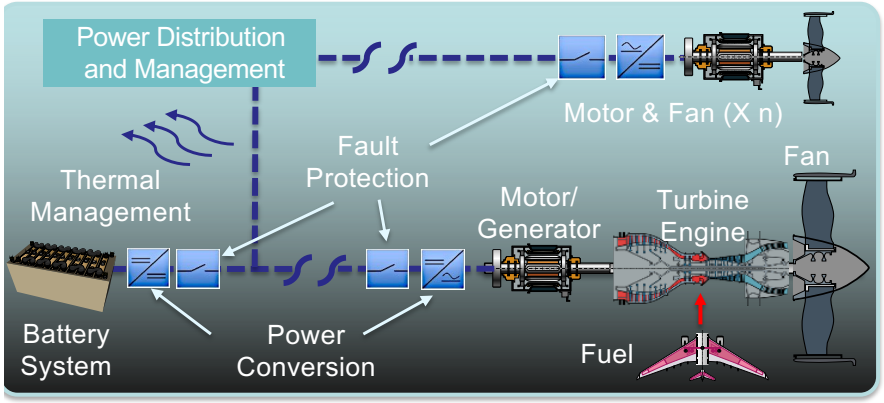
Approach

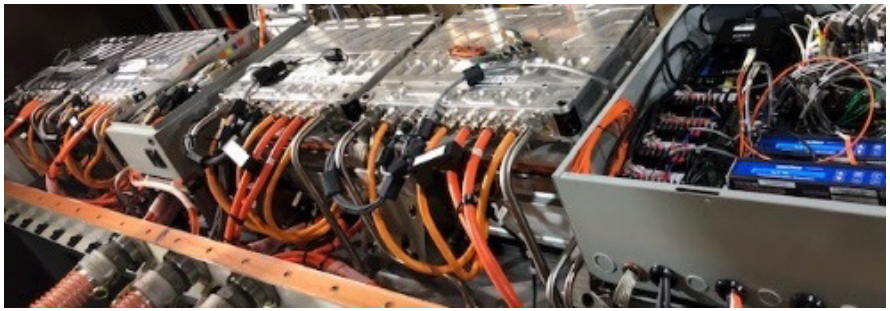
- Partner with industry to mature and demonstrate promising technologies

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

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 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

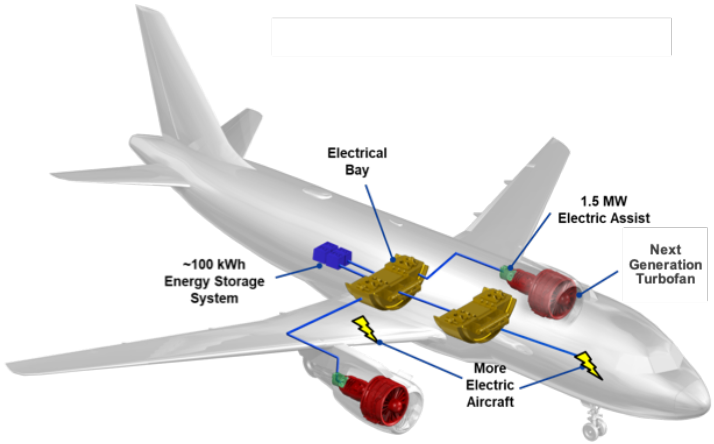
Approach

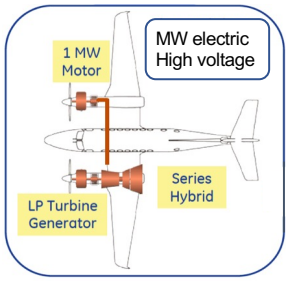
- Conduct technology-focused integrated ground tests
- Partner with industry on testing of electrified propulsion architectures and component technologies
- Leverage prior electric aircraft propulsion advances (TRL ~4)

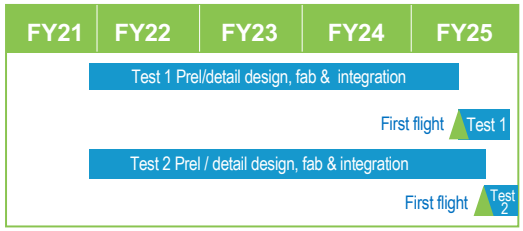
Architecture development and high-power component tests are underway.

Electrified Powertrain Flight Demonstration

Demonstrate integrated electrified powertrains in flight using industry platforms







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 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.

Two Flight Demonstration Contracts Awarded in September 2021

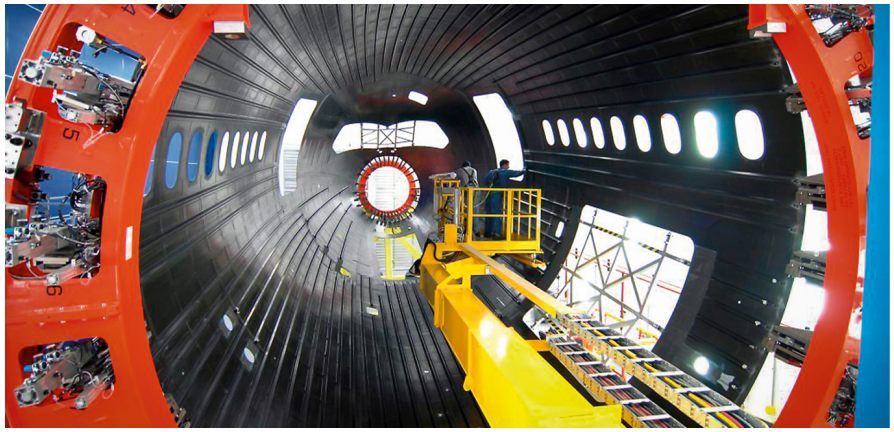
Hi-Rate Composite Aircraft Manufacturing

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



Production Rate per Month

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



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

12 Cooperative Tasks Awarded to Inform HiCAM Plans

Sustainable Aviation Fuels

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





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

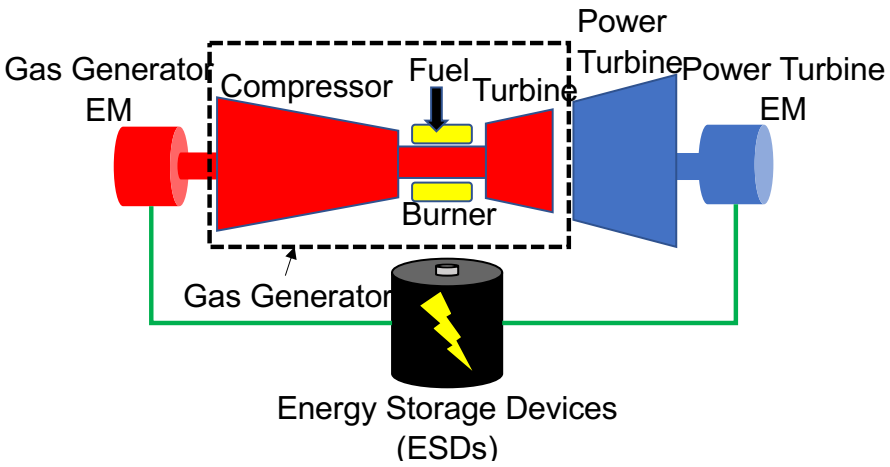
Approach

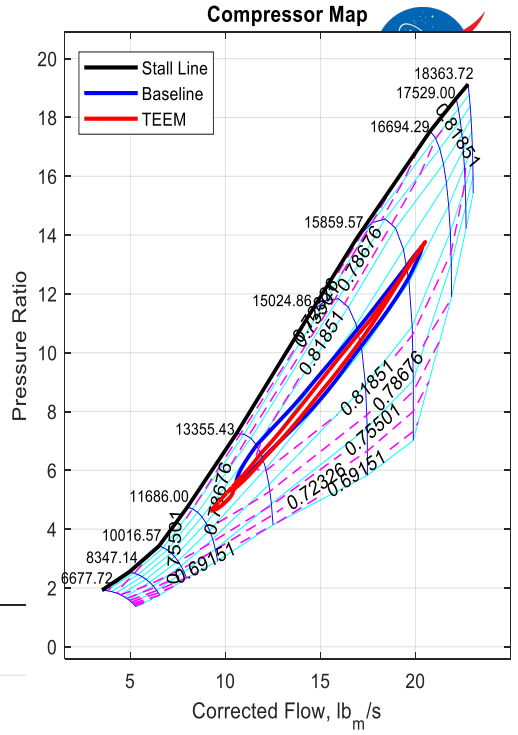
- Characterize high-blend sustainable aviation jet fuel emissions on ground and in flight

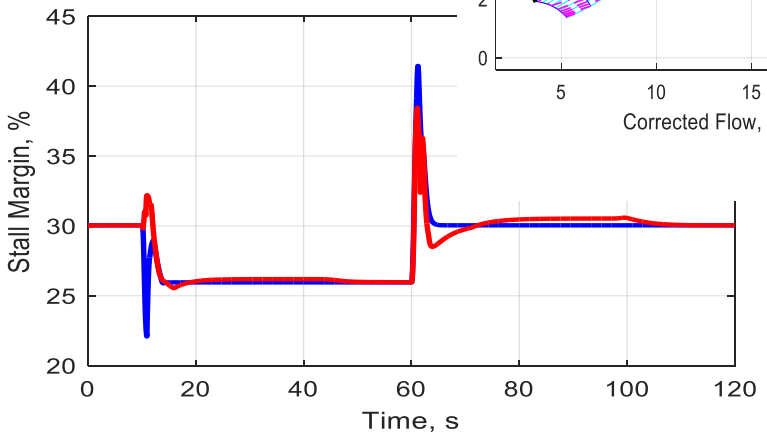
Future SAF Research Plans in Development

TEEM (Turbine Electrified Energy Management)

- TEEM is about managing energy in an electrified turbine engine propulsion system
  - Goal: Improve operability of the turbomachinery → enable better performing engine designs and/or enhance aircraft capabilities and safety
  - The Means: electric machines (EMs) coupled to the engine shaft(s)
    - EMs are new actuators that can alter engine operation
  - Superior Transient Operability Improved minimum stall margin during acceleration and tighter control of operating point on the map

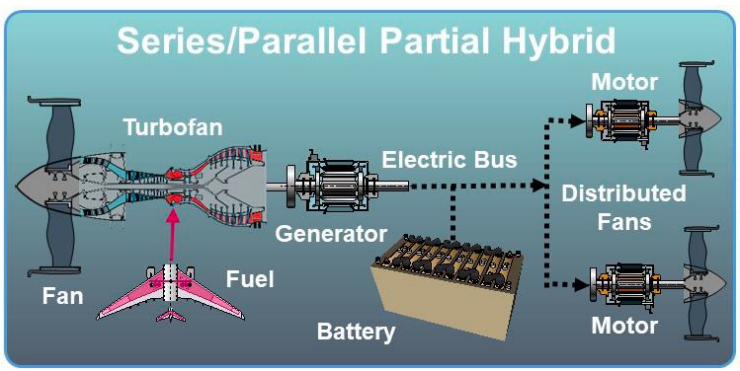




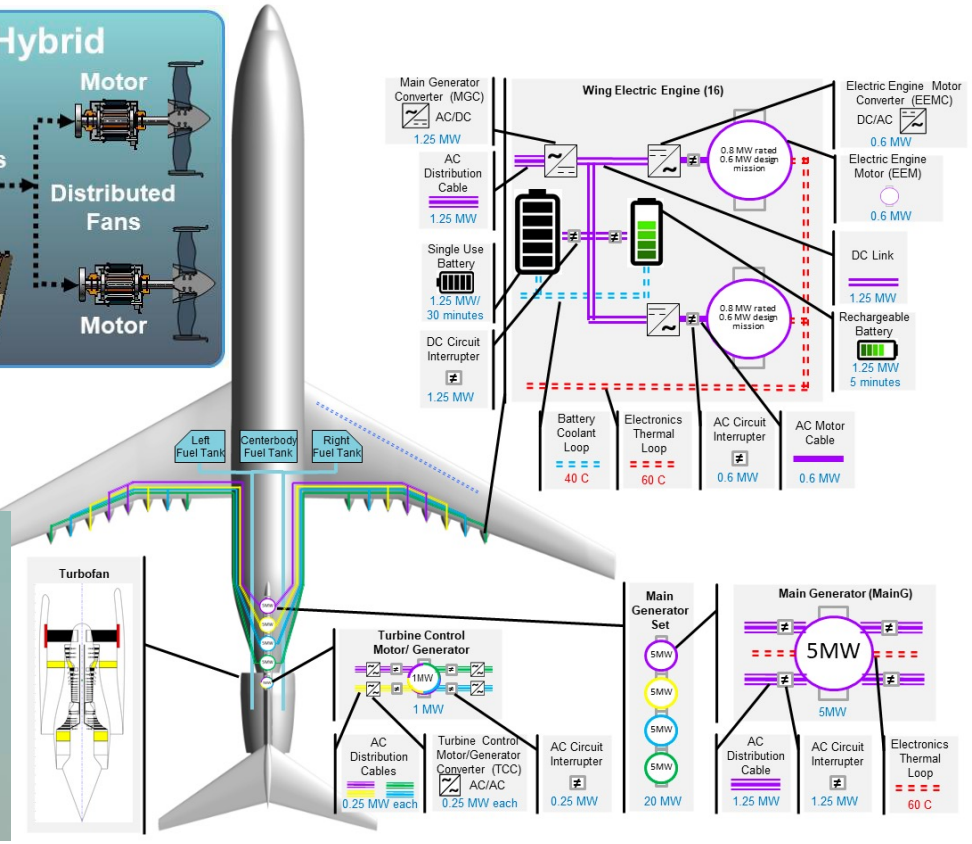


Subsonic Single Aft eNgine (SUSAN) Electrofan Concept

- 10 papers at AIAA 2022 SciTech
- 2040 time frame entry into service

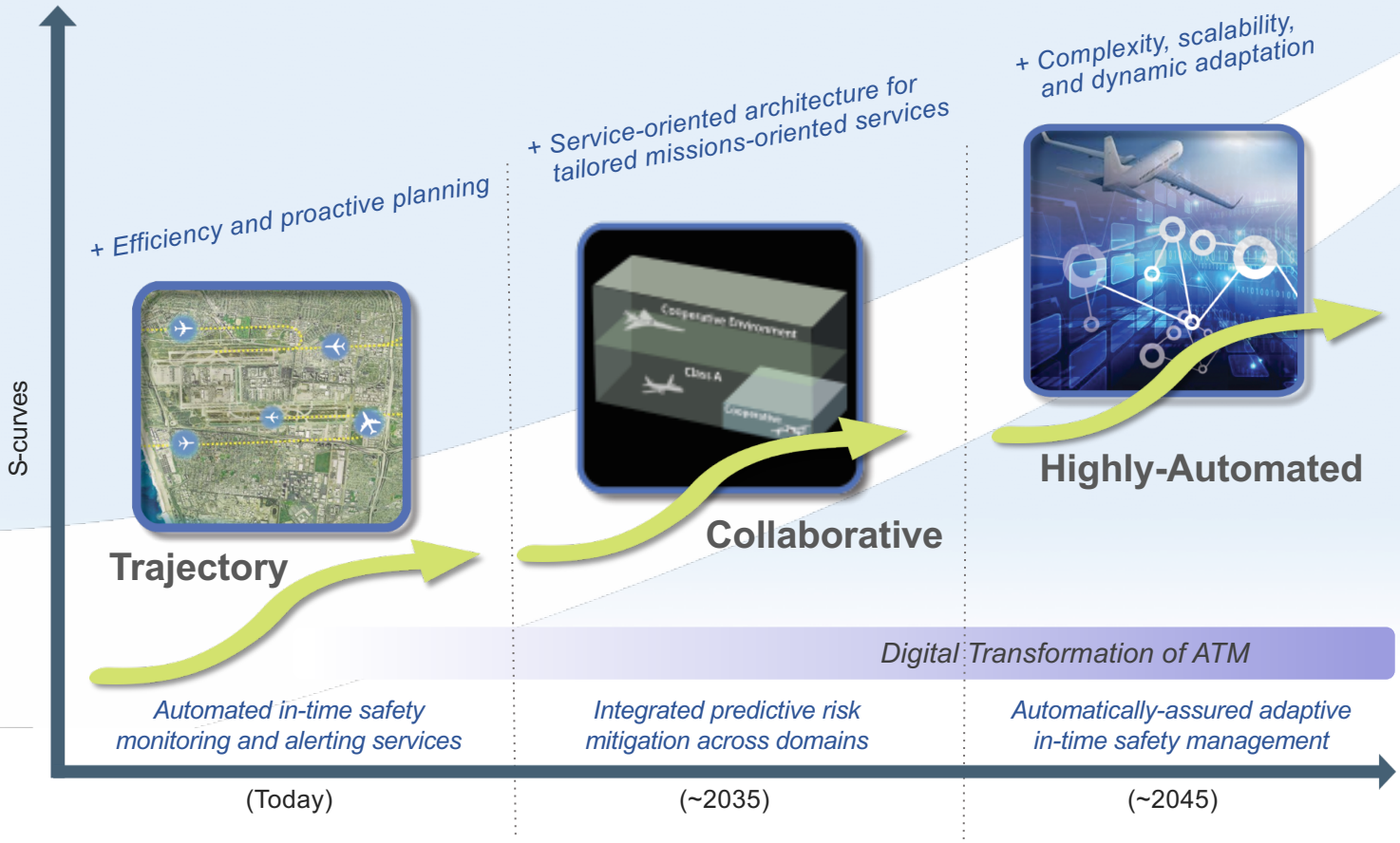






Figures from AIAA-2022-2306, Litt et al., “Implementation Approach for an Electrified Aircraft Concept Vehicle in a Research Flight Simulator”

Evolution of Airspace Operations and Safety



Today: Airspace Operational Tools Yield Immediate Benefits

Airspace Technology Demonstration 2

Benefits from field demonstrations of ATD-2 technologies at the Charlotte Douglas International Airport
(29 Sep 2017–30 Sep 2021)

Saved **1,101,768** gallons of fuel

FUEL

Saved **23,211,172** lbs. of CO_2 = **172,597** urban trees

EMISSIONS

Saved **6,016** hours of engine run time

MAINTENANCE



REDUCED DELAY BY 933.6 hours

Saving passengers an estimated **$4,481,569** in value of time and operators an estimated **$1,375,224** in flight crew costs

ATD-2 delivered immediate benefits to aviation stakeholders and passengers.

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.


Advanced Air Mobility Mission
Wildfire Fighting Operations
On Demand Air-Taxi
Rural Operations
Urban Operations
Regional Network
Inter-City eV/STOL
Cargo Delivery
Cargo Delivery
Airport Transfer
Air Ambulance
Distribution Center/Warehouse
High Density Corridor
Medical Transfer
Fleet Operations
Inter-city eCTOL
Small Package Delivery
Cross-metro Transfer
Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

NASA's X-57 is Pathfinder for Electric Propulsion

First flight is summer 2022



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

FEDERAL AVIATION ADMINISTRATION

INDUSTRY

ACADEMIA

Enable new configurations



Share technical insights and lessons learned



LEAPTech experiment



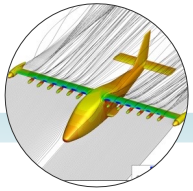
Wind-tunnel validation



Motor nacelle design & testing



Structural testing



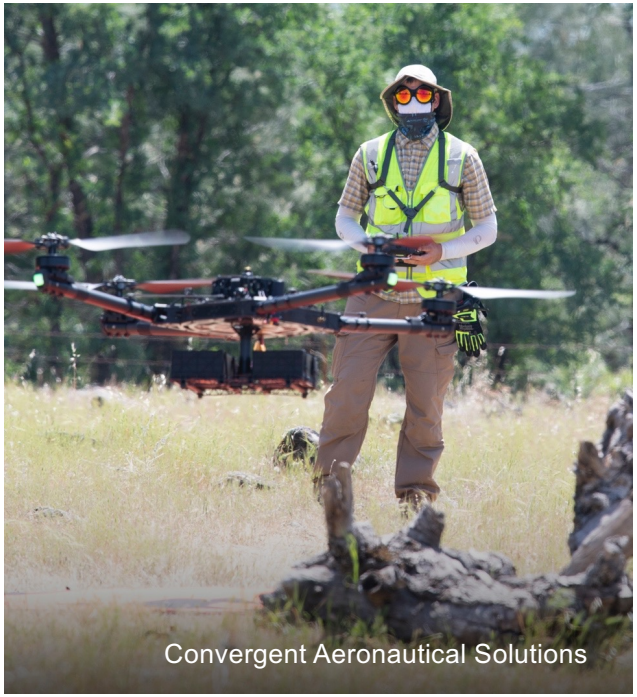
Computational simulations



Operational checkouts

Inform Small Electric Aircraft Propulsion Standards and Certification

ARMD's Agile Innovation Ecosystem


Convergent Aeronautical Solutions


University Leadership Initiative


University Student Research Challenge

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

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.

Net-Zero Aviation Emissions Innovation

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

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

Recent University Leadership Initiative awards included teams working on net-zero emissions topics



Research currently underway at low Technology Readiness Levels

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

University of Illinois, Urbana-Champaign (NASA ULI) All-electric Concept
- Hydrogen fuel cell, superconducting electric drivetrain
- Zero carbon emissions





Long-Term Transport Technology and Innovation

Generational studies to inform future technology investments

2008-2019	2020-2029	2030 - 2039	2040 - 2050

Subsonic Fixed Wing

N+2 Studies, ERA for the 2020s Impact

N+3 Advanced Concept Studies SFNP for 2030s Impact

Concept Studies and Technology Development Needed for 2040s Impact

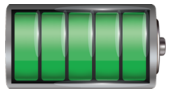




Opportunities to Define Future Aviation Systems and Concepts

- Advanced Concept Studies for 2040+ EIS
- Net-Zero Emissions Concepts
- Promising Technologies and Architectures
- Support Aviation Community with NASA-unique Contributions









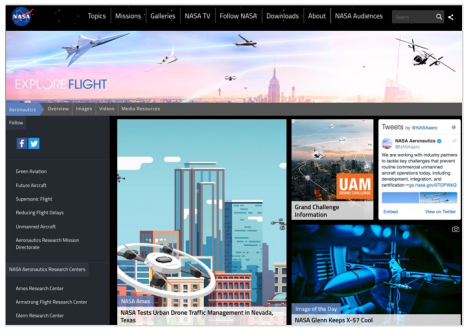
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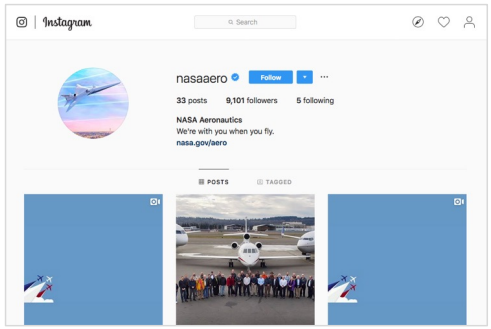
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