National Aeronautics and Space Administration

NASA’s Sustainable Flight National Partnership

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Acting Chief, Propulsion Division

Purdue Sustainable Aviation-- Inaugural Symposium

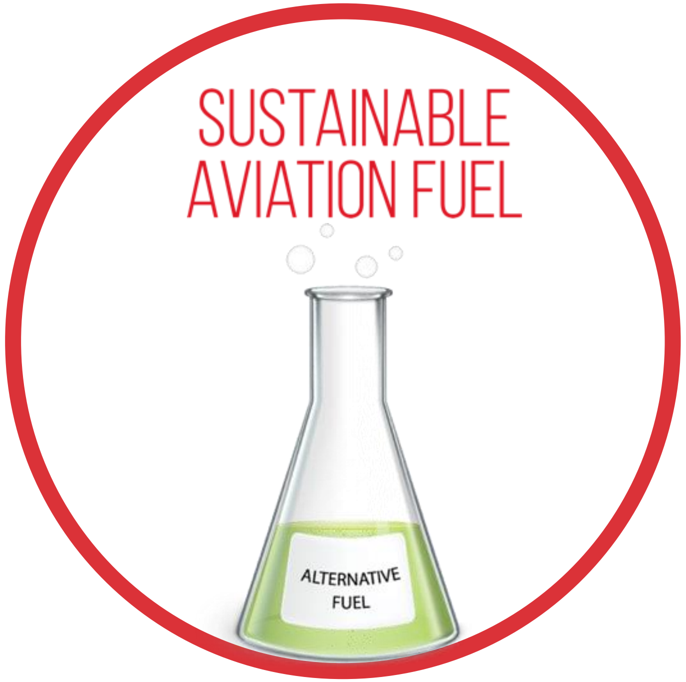
November 13, 2024

www.nasa.gov

Four Transformations for Sustainability, Greater Mobility, and Economic Growth

Sustainable Aviation Pillars

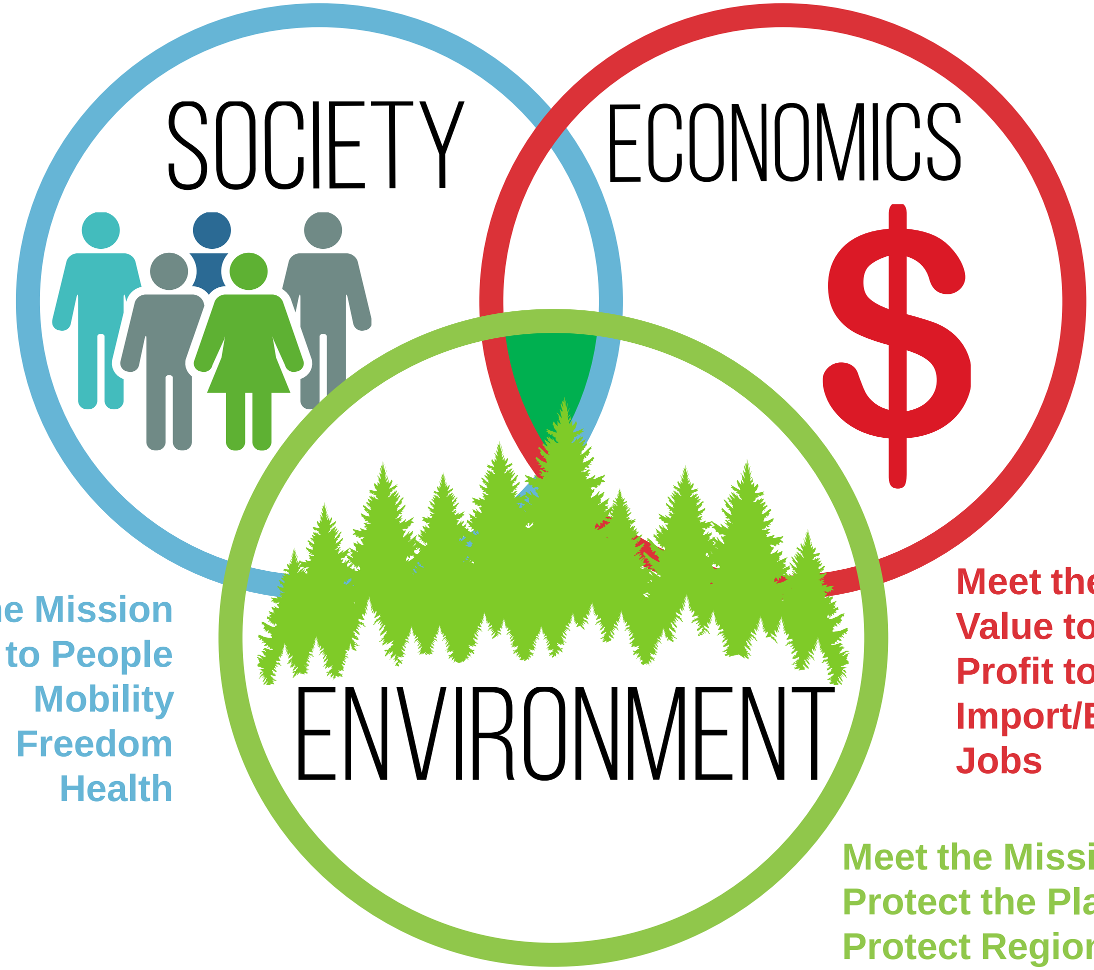
NASA = Primary Role



NASA = Supporting Role

NASA = Primary Role

Sustainability is Complex



Meet the Mission
Value to People
Mobility
Freedom
Health

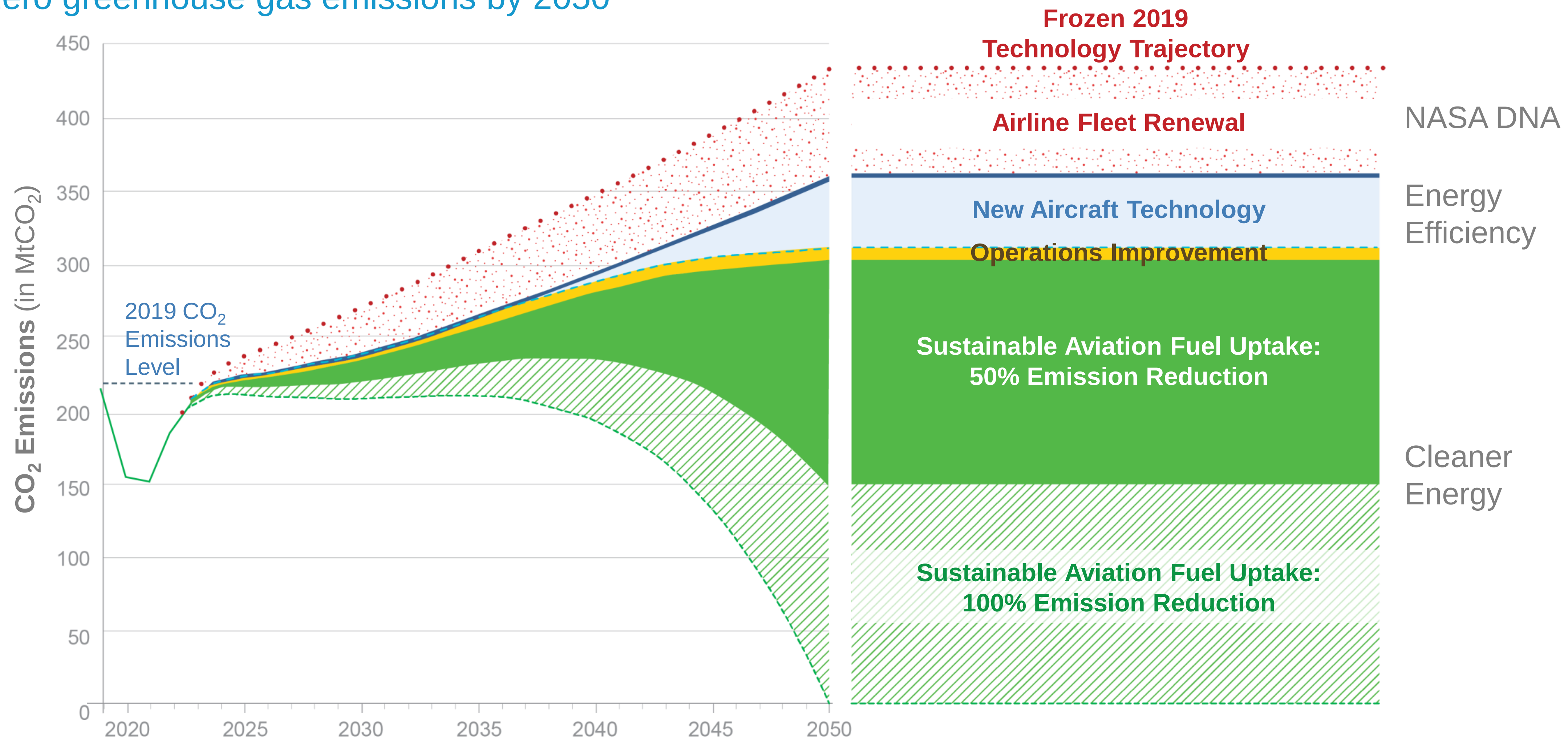
Meet the Mission
Value to Business
Profit to Shareholders
Import/Export Trade Balance
Jobs

Meet the Mission
Protect the Planet
Protect Regional & Local Ecosystems

Success requires meeting demand for mobility, connectivity, and improved quality of life with reduced energy/fossil fuel use, while remaining safe, quiet, economical and equitable.

U.S. Aviation Climate Action Plan – 2021

Net-zero greenhouse gas emissions by 2050



https://www.faa.gov/sites/faa.gov/files/2021-11/Aviation_Climate_Action_Plan.pdf

The U.S. is working with the global community to achieve net-zero greenhouse gas emissions by 2050 with reduced non-CO_2 (e.g. contrails), noise, and local air quality impacts

NASA Sustainable Aviation Strategy

2008-2013 | 2014-2019 | 2020-2025 | 2025-2030 | 2030+

Subsonic Concept/Technology Studies
Electrified Aircraft Propulsion
Transonic Truss-Braced Wing
Blended Wing Body

Environmentally Responsible Aviation Project

Flight Demonstrator Studies

Advanced Composites Project

SUSTAINABLE FLIGHT NATIONAL PARTNERSHIP

Sustainable Flight National Partnership to mature and integrate key technologies for next-generation subsonic transports (2030s)

TODAY

ACCELERATING TOWARD NET-ZERO CARBON

Cast a wide net for zero-emission concepts and technologies

Select and develop promising concepts in partnership with universities, industry

Create a credible mission, architecture, and technologies for beyond next-generation subsonic transports for 2050 horizon

POWERING AVIATION TO NET-ZERO CARBON AND BEYOND

Investment in innovation today paves the way
to a net-zero carbon and beyond aviation future.

Sustainable Flight National Partnership

Accelerating Toward Net-Zero Greenhouse Gas Emissions and Reduced Non-CO_2 Climate Impact in the 2030s

Advance engine efficiency and emission reduction

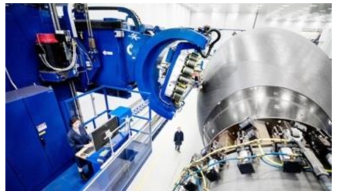
Enable integrated trajectory optimization

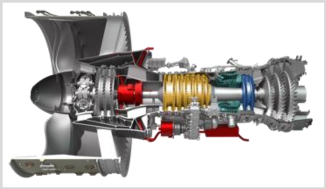
Advance airframe efficiency and manufacturing rate

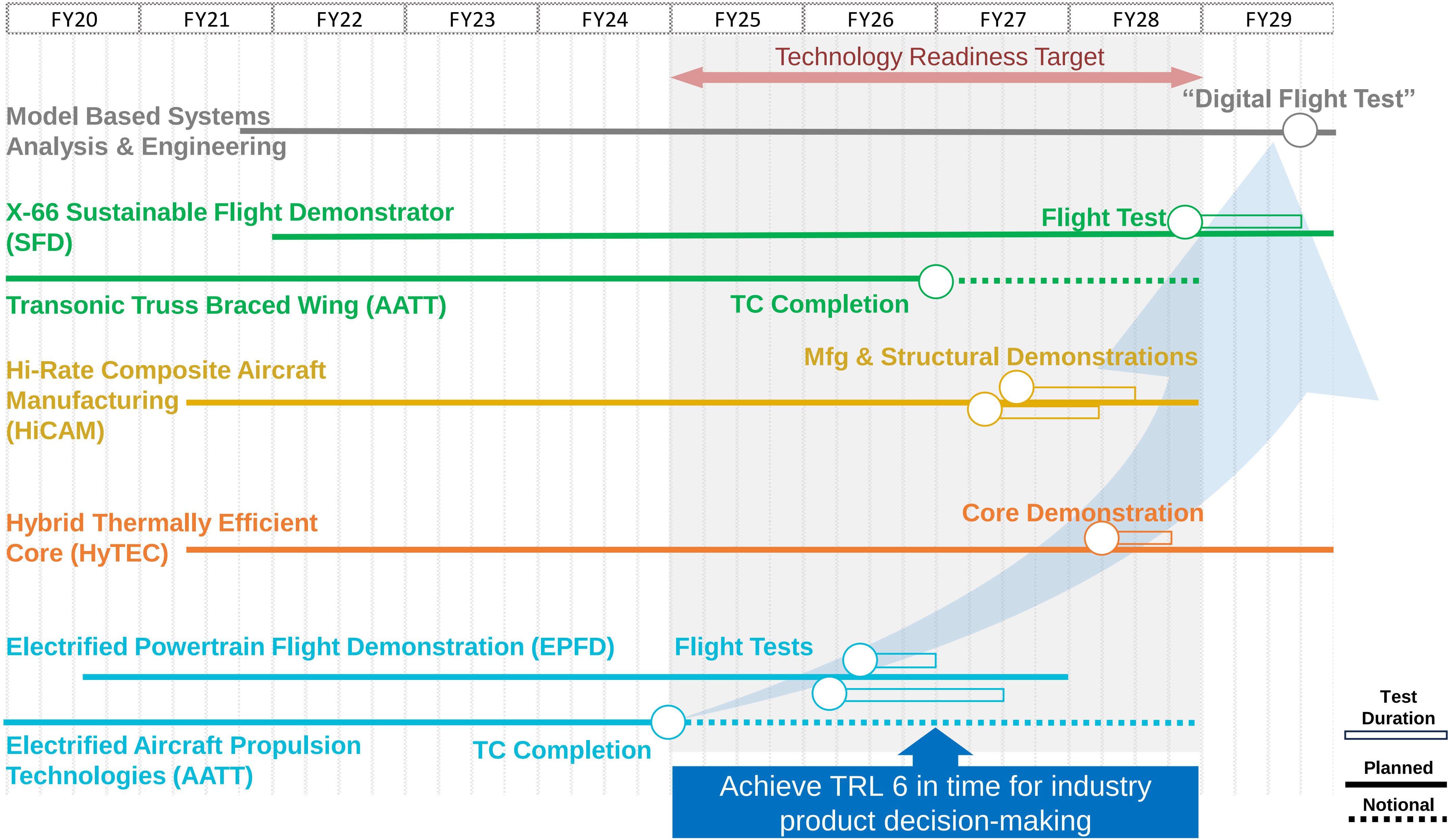
Enable use of 100% sustainable aviation fuels

Next-generation transports using up to 30% less fuel, current & future fleet flying optimal trajectories, and engines burning SAF with greater than 50% reduction in lifecycle GHG emissions

Ultra-Efficient Airliner Integrated Technology Development





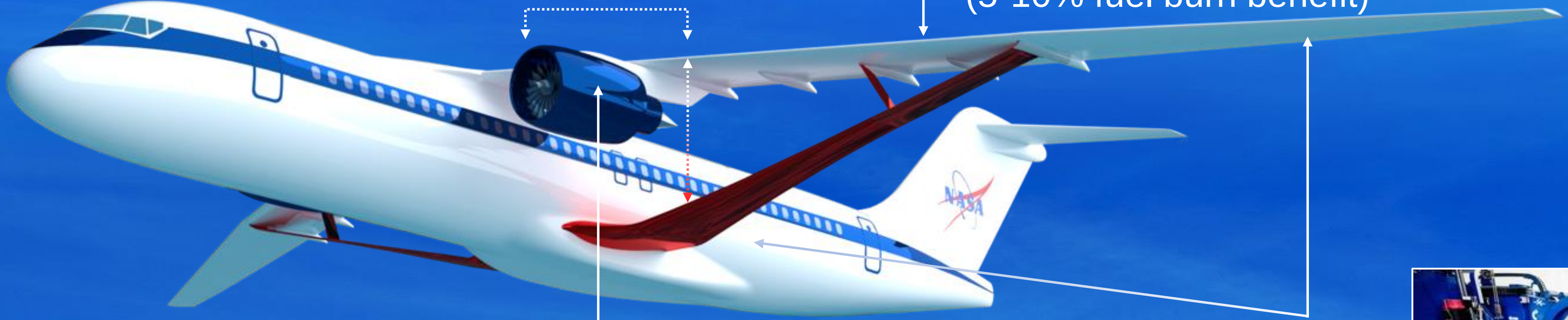


Ultra-Efficient Airliner Technologies

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

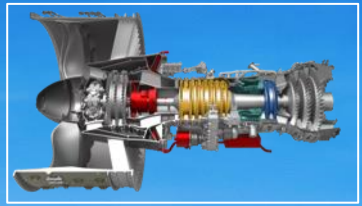
Integrated Aircraft System Efficiency
Propulsion Airframe Integration Opportunity

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



Lightweight Composites
4-6x manufacturing rate
(5-8% fuel burn benefit)

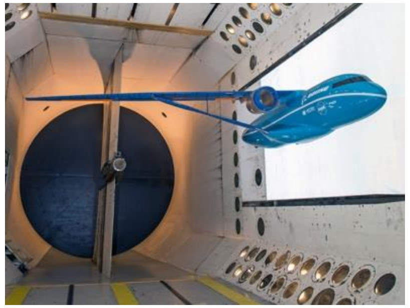
Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit



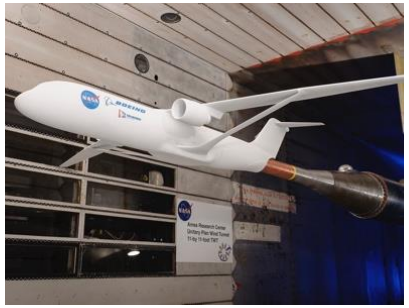
Engine Efficiency
Small Core Gas Turbine
(5-10% fuel burn benefit)

Transonic Truss-Braced Wing Technology Maturation

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

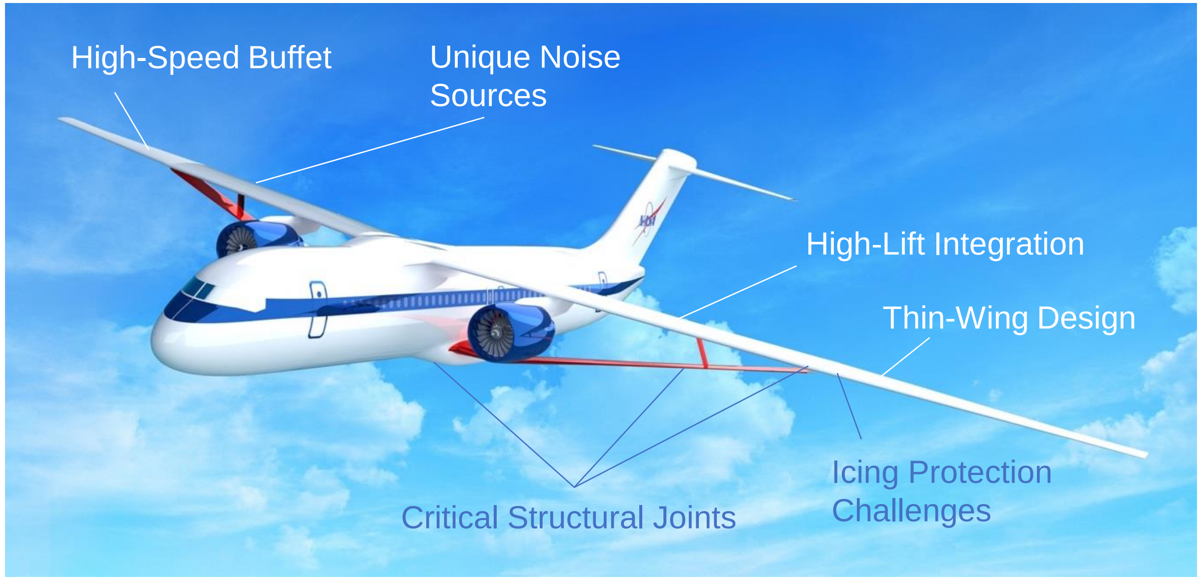


2013



2016

2022

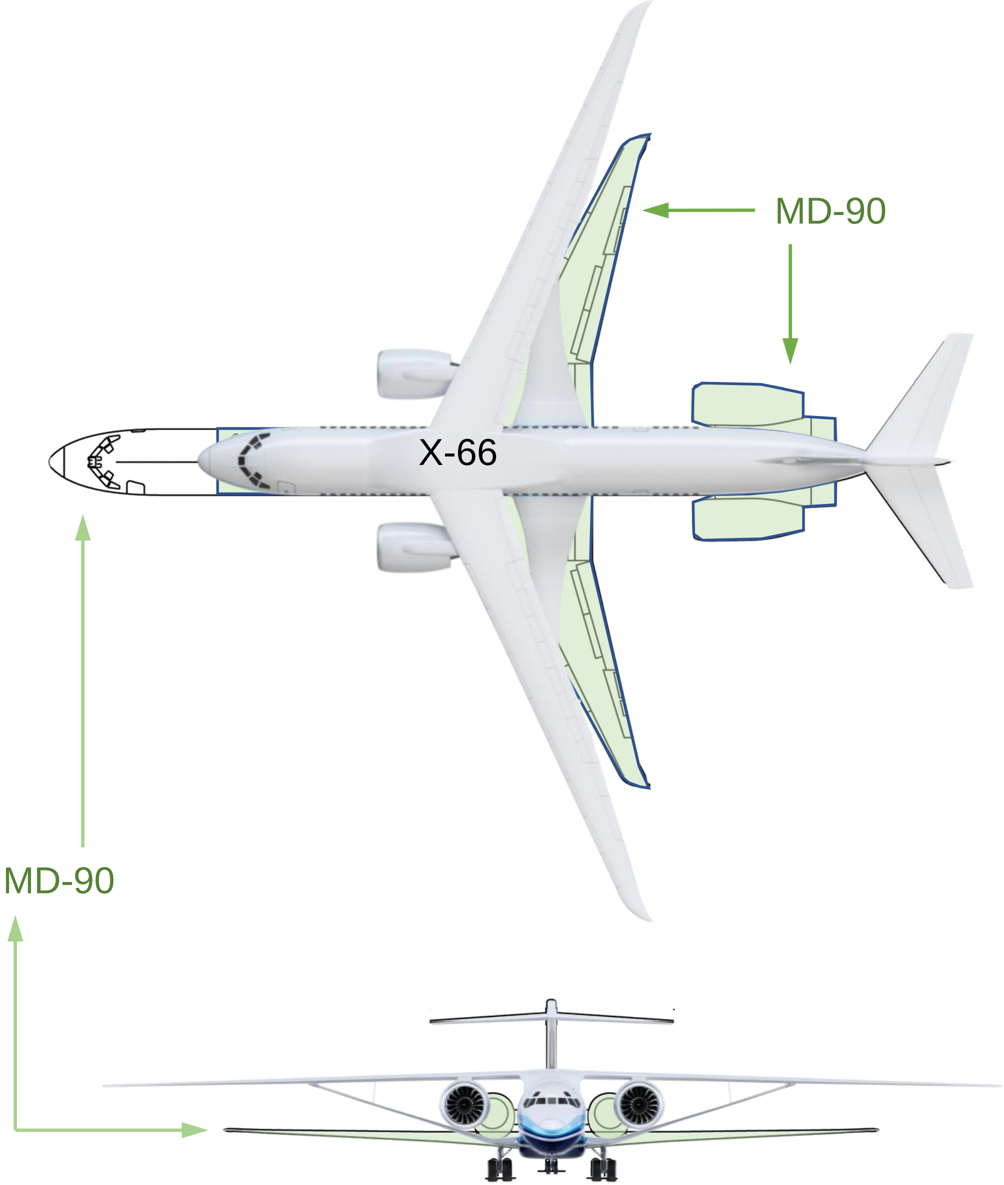


Now: Reduce risks of TTBW technology not addressed by the X-66 demonstrator

Maturation of the concept through progressive design/analysis studies and wind-tunnel tests since 2009
2024 testing focused on icing, high-lift system integration, and deep stall

Sustainable Flight Demonstrator Project

Demonstrate integrated airframe-focused technologies in flight



First flight planned in 2028.

TTBW concept can reduce fuel consumption/emissions up to 5-10%.

Video credit: NASA (wind tunnel testing)
Video credit: Boeing (MD90/X66)
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Hi-Rate Composite Aircraft Manufacturing (HiCAM)

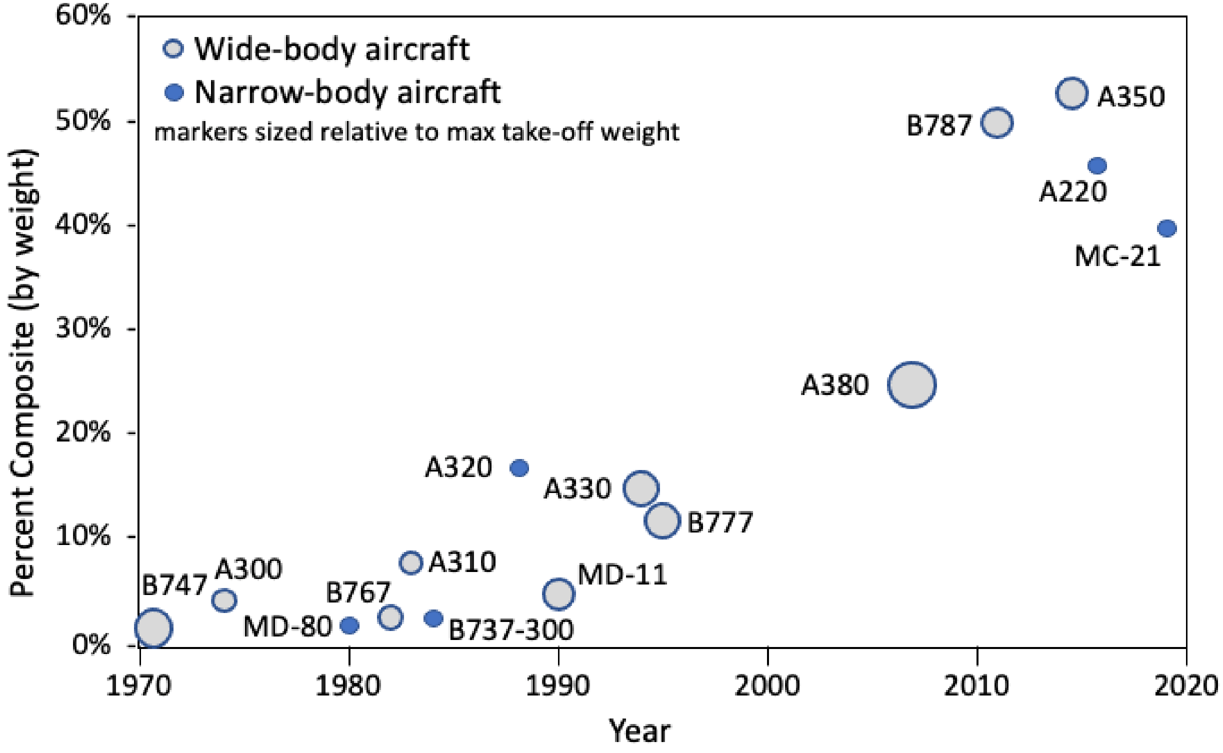
4–6x production rate increase without cost or weight penalty

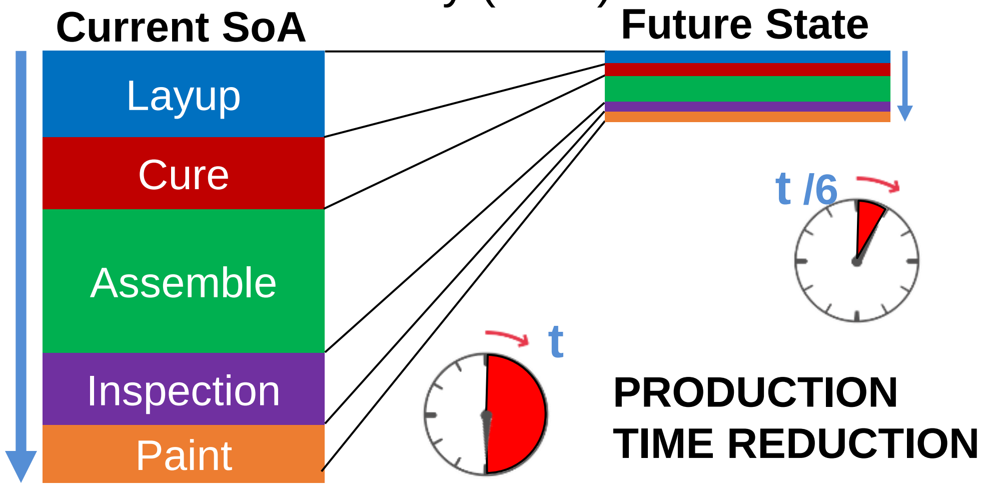
Production Rate per Month

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

Two Relevant Environments

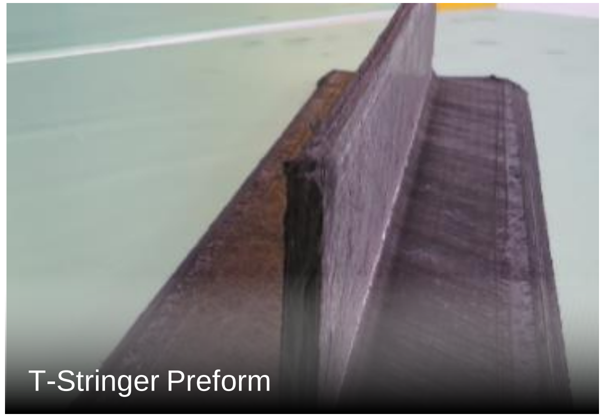
Flight (Weight) ← Cost → Factory (Rate)



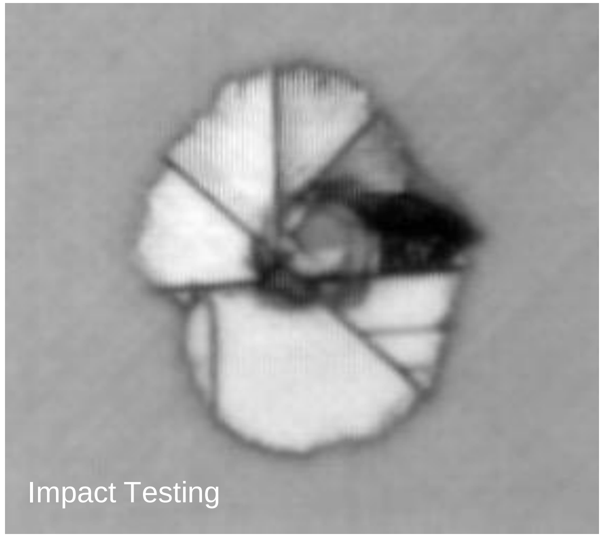


Hi-Rate Composite Aircraft Manufacturing

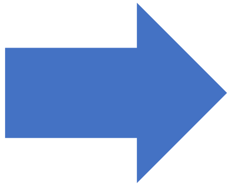
Phase 1 – Small Scale Tech Maturation



T-Stringer Preform



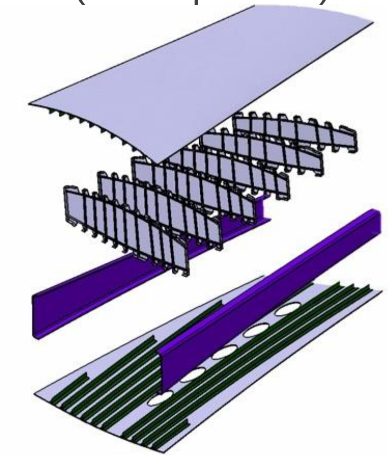
Impact Testing



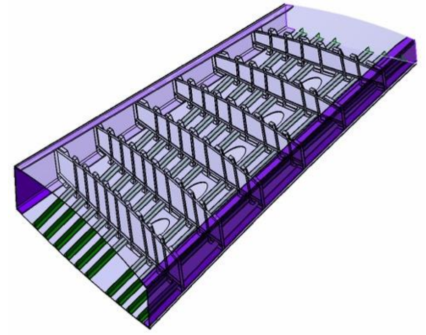
Phase 2 – Large Scale Demos (notional)

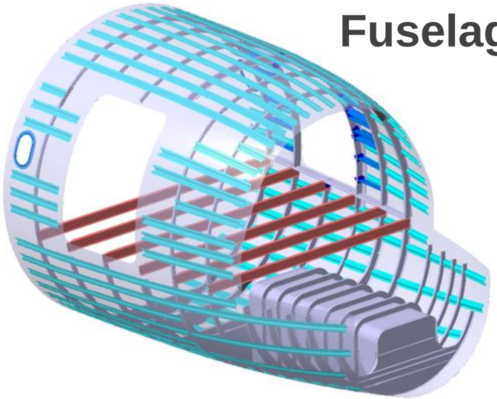
Wing box section near engine pylon

Subcomponents
(~10 replicates)



Assembled Component
(~3 replicates)





Fuselage forward section

Subcomponents
(~10 replicates)

Assembled Component
(~3 replicates)

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

Video credit: GE Aerospace
used with permission

Electrified Powertrain Flight Demonstration Project

Demonstrate integrated electrified powertrains in flight using industry modified aircraft

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

Benefits

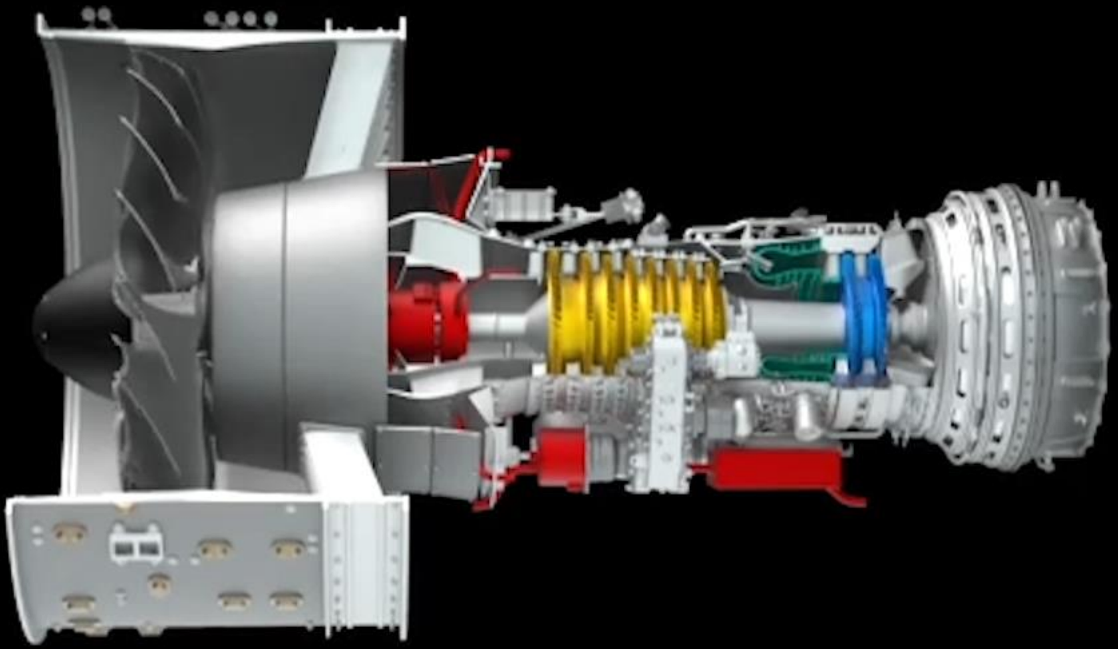
- Accelerate U.S. industry readiness to transition to EAP-based commercial transport aircraft that offer ~5% reduction in fuel burn
- Meet U.S. environmental goals articulated in the U.S. Aviation Climate Action Plan

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 FY 2026

Value: Accelerate ability to consider megawatt-class powertrains offering ~5% reduction in fuel burn and to meet Electrified Aircraft Propulsion certification requirements

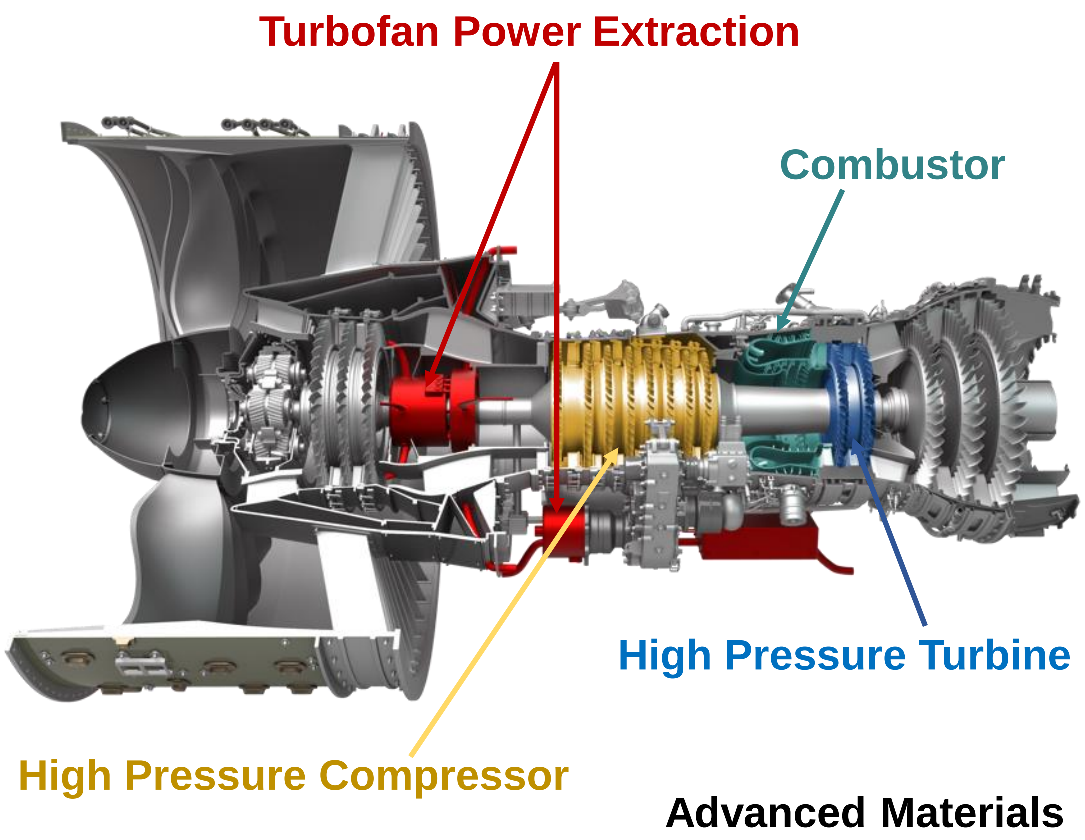


Compact Design for Small-Core Engines

Video credit: NASA

Hybrid Thermally Efficient Core Project

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 hybridization

Benefits

- 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

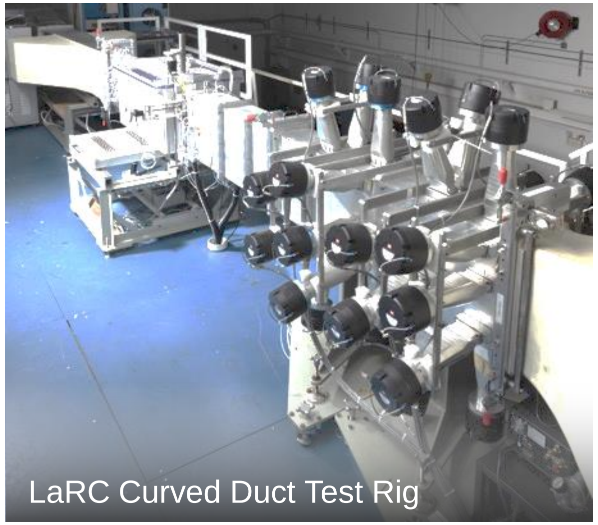
Integrated core demonstration in 2028

Value: Contributing 5-10% fuel burn reduction 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

Sustainable Flight National Partnership with ...

- ATC Advanced Thermoplastic Composites
- Aurora Flight Sciences
- Boeing
- CGTech.com Vericut
- Collier Aerospace
- Convergent Manufacturing Technologies US
- Electroimpact
- Federal Aviation Administration
- GE Aerospace
- Georgia Tech
- Hexcel
- Lockheed Martin
- M4
- magniX
- Mississippi State University
- ACT
- Northrop Grumman
- NPS Praestantia per Scientiam 1909
- Pratt & Whitney Dependable Engines
- RTX
- Solvay
- University of South Carolina
- Spirit AeroSystems
- Toray Industries, Inc.
- NIAR Wichita State University National Institute for Aviation Research

As of May 2024

CONTRAILS

Real Progress. Real Value.

In-Flight Testing With 100% Sustainable Aviation Fuel Completed In October 2023 In Collaboration With Boeing, US, & International Partners

Video credit: NASA and Boeing
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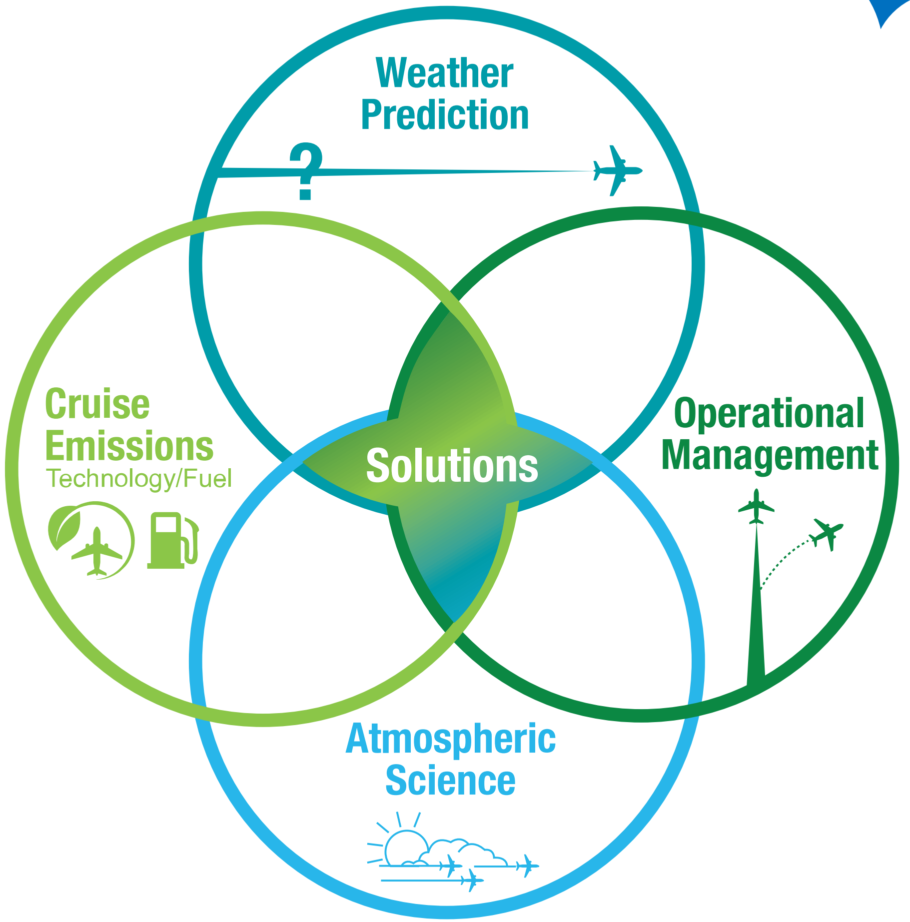
National Academies Study - Contrails



- January 2024 – Task Order Awarded
  "*Research Agenda for Reducing the Climate Impact of Aviation-Induced Cloudiness and Persistent Contrails from Commercial Aviation*"
- 18-month study
- Jointly funded by NASA ARMD and SMD

Link to the NASEM Study Site
https://www.nationalacademies.org/our-work/research-agenda-for-reducing-the-climate-impact-of-aviation-induced-cloudiness-and-persistent-contrails-from-commercial-aviation

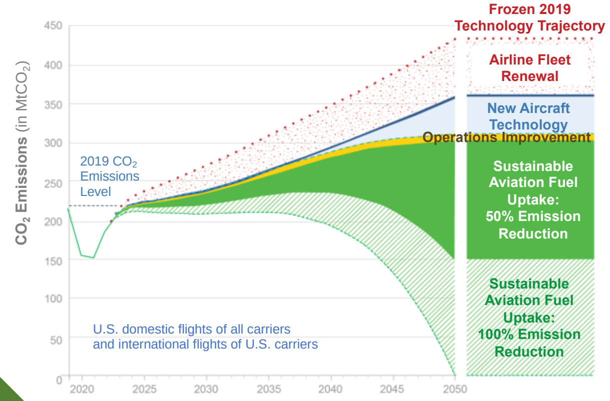
Beyond SFNP…

Powering Aviation to Net-Zero Carbon and Beyond!

The Long Game: Aviation Eras on the Path Toward Sustainability

Net-Zero GHG, 2050

2020s | 2030s | 2040s | 2050s | 2060s



Era One: Evolution *(Change is Coming)*

Tube-and-Wing, Existing Infrastructure, Transition to Drop-In SAF, Increasing Electrification

Era Two: Revolution *(SFNP Realized)*

Vehicle Architecture Change, Major SAF Adoption, Mild Hybrid EAP, Minor Infrastructure Change

Era Three: Transformation *(Paradigm Shift)*

Major Vehicle Architecture Change, Non-Drop-In Fuel Adoption, Many-MW EAP, Major Infrastructure Change

Growing Risk

Growing Potential Impact

ARMD must make deliberate, long-term investment in broad-ranging technologies outside industry’s risk tolerance

Beyond SFNP: 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

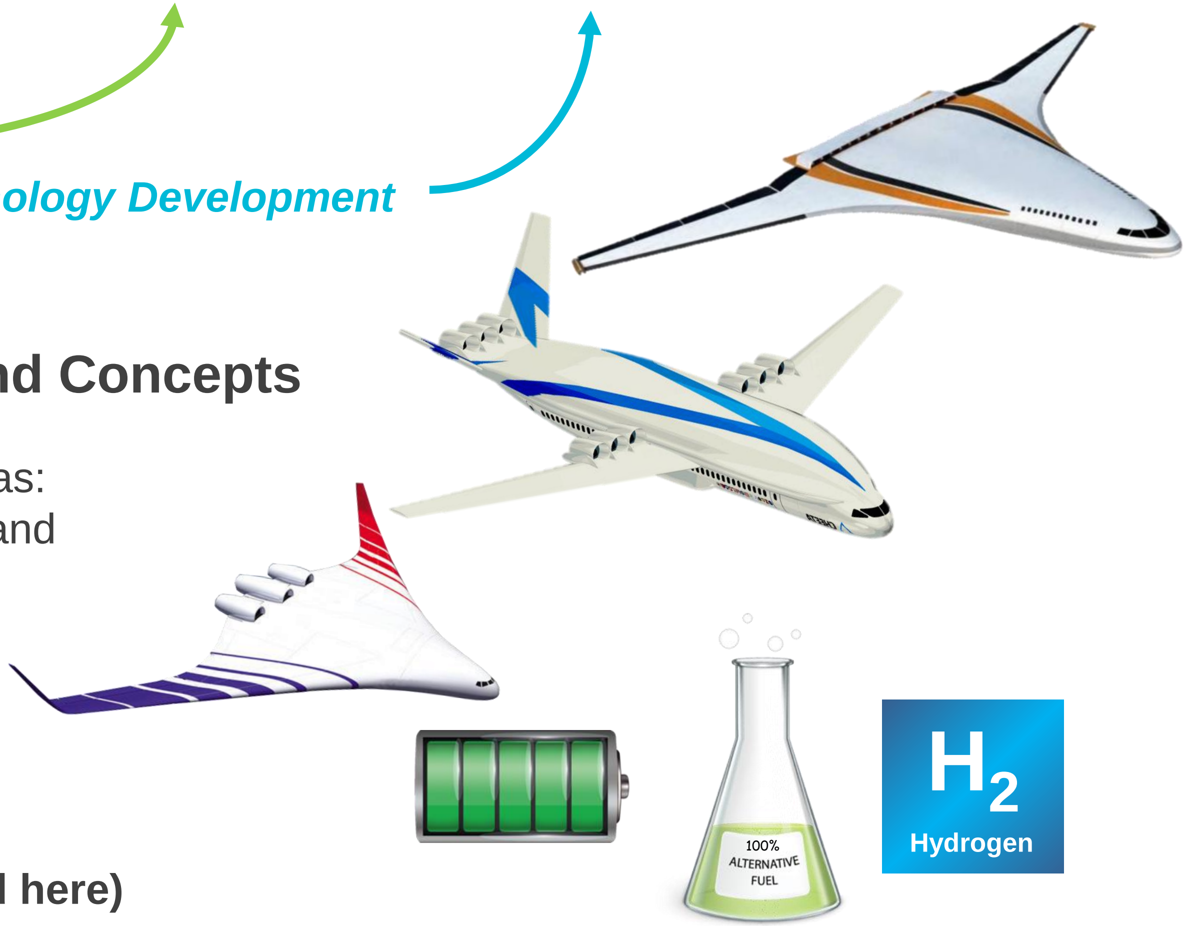
N+3 Advanced Concept Studies for 2030s Impact

Concept Studies and Technology Development Needed for 2040s Impact

Opportunities to Define Future Aviation Systems and Concepts

- ARMD-commissioned strategic assessments across multiple areas: Propulsion; Electrified Aircraft Propulsion; Materials, Structures, and Manufacturing; Future Flight Demonstrations
- AACES Advanced Concept Studies for 2040+ EIS
- Net-Zero Emissions Concepts
- Promising Technologies and Architectures
- Support Aviation Community with NASA-unique Contributions

Note: Advanced Airspace Operations is also key (not discussed here)



Key Findings from ARMD Strategy Assessment Studies

Considered information from multiple sources… and still collecting more

- ARMD strategy studies; Gov/Industry Workshops; Internal Studies; AACES; OGA/Industry Engagement

Key themes emerging

- Likelihood of multiple fuels availability
- Heightened opportunities around vehicle integration
- Leveraging Computational Materials and Structures
- Increased need to consider market dynamics and implications beyond the vehicle

Initial assessment identified multiple research and technology opportunities:

- Power and Energy: Superconducting EAP; High-Perf Heat Exchange and TMS; Advanced Cycles
- Aircraft Integration Technologies: Distributed Propulsors; Cryo Fuels; Advanced CFD and MDAO for PAI
- Materials and Structures: Computational Materials; Cryo Tanks and Integrated Structures; Next Gen Manufacturing – Qual/Cert for Additive Manufacturing, and Digital Engineering

- Assessing critical gaps requiring further study

The time is now for ensuring the future ARMD portfolio reflects complexity of achieving sustainability. Balanced investment in light of significant uncertainty beyond SFNP is critical to making impact.

Measuring Progress: Updated Subsonic Transport Metrics

Approach for updating table:

- Move toward current standards
- Timeframes reflect current strategy
- Goals traceable to studies
- Balanced goals - aspirational and technically feasible

- Mid Term goals reflect latest SFNP strategy and sync with FAA CLEEN Phase IV goals for the same metrics

- Far Term goals reflect the uncertainty in the fuel/energy landscape beyond 2040 (i.e., SAF-dominant vs. beyond-SAF)

AIRCRAFT TECHNOLOGY BENEFITS	TECHNOLOGY GENERATIONS (Technology Readiness Level = 5-6)	
	Mid Term By 2030	**Far Term** By 2040-2045
Energy Consumption[1,2] (below CAEP 10)	35%	50% / 35% w/ zero operational GHG emissions
LTO NO_x Emissions[2,3] (below CAEP 8)	75%	>75%
LTO nvPM Emissions (below CAEP 11)	50%	75%
Noise (cum below Stage 5)	25 dB	35 dB

1) CAEP 10 CO_2 metric is energy-use based; energy use per available seat-mile also tracked
2) Life-Cycle GHG emission benefit from sustainable aviation fuels (SAFs) is additional, with possible trades between energy efficiency and non-drop-in fuels recognized in the Far Term
3) CAEP standards for Cruise NO_x are not yet established
4) Aircraft operations improvements may yield significant system-level efficiencies and reduced atmospheric impacts in time at the fleet and vehicle levels

The updated metrics table represents a move toward standards-based metrics and traceable goals, while acknowledging uncertainty of Far Term energy futures in the Beyond-SFNP timeframe.

Thoughts on a Beyond SFNP National Partnership

THE U.S. NATIONAL BLUEPRINT FOR TRANSPORTATION DECARBONIZATION

NATIONAL CLIMATE RESILIENCE FRAMEWORK

Joint Office of Energy and Transportation

U.S. National Clean Hydrogen Strategy and Roadmap

U.S. Department of Transportation

ASCEND

REEACH

arpa·e

U.S. DEPARTMENT OF ENERGY

U.S. Department of Defense

Department of Defense Operational Energy Strategy

DEFENSE INNOVATION UNIT

AFRL

AIR FORCE RESEARCH LABORATORY

Federal Aviation Administration

United States 2021 Aviation Climate Action Plan

SAF Grand Challenge Roadmap

Flight Plan for Sustainable Aviation Fuel

One Hundred Eighteenth Congress of the United States of America

ROLLS ROYCE

PRATT & WHITNEY

UNIVERSITY of VIRGINIA

UCONN

STATE

Academic CoEs + UTCs

The next National Partnership will require us to think broadly - *beyond the OML*.

Strong cross-government and academic partnership will be critical to enabling an alternative fuels future for aviation.

Questions

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