



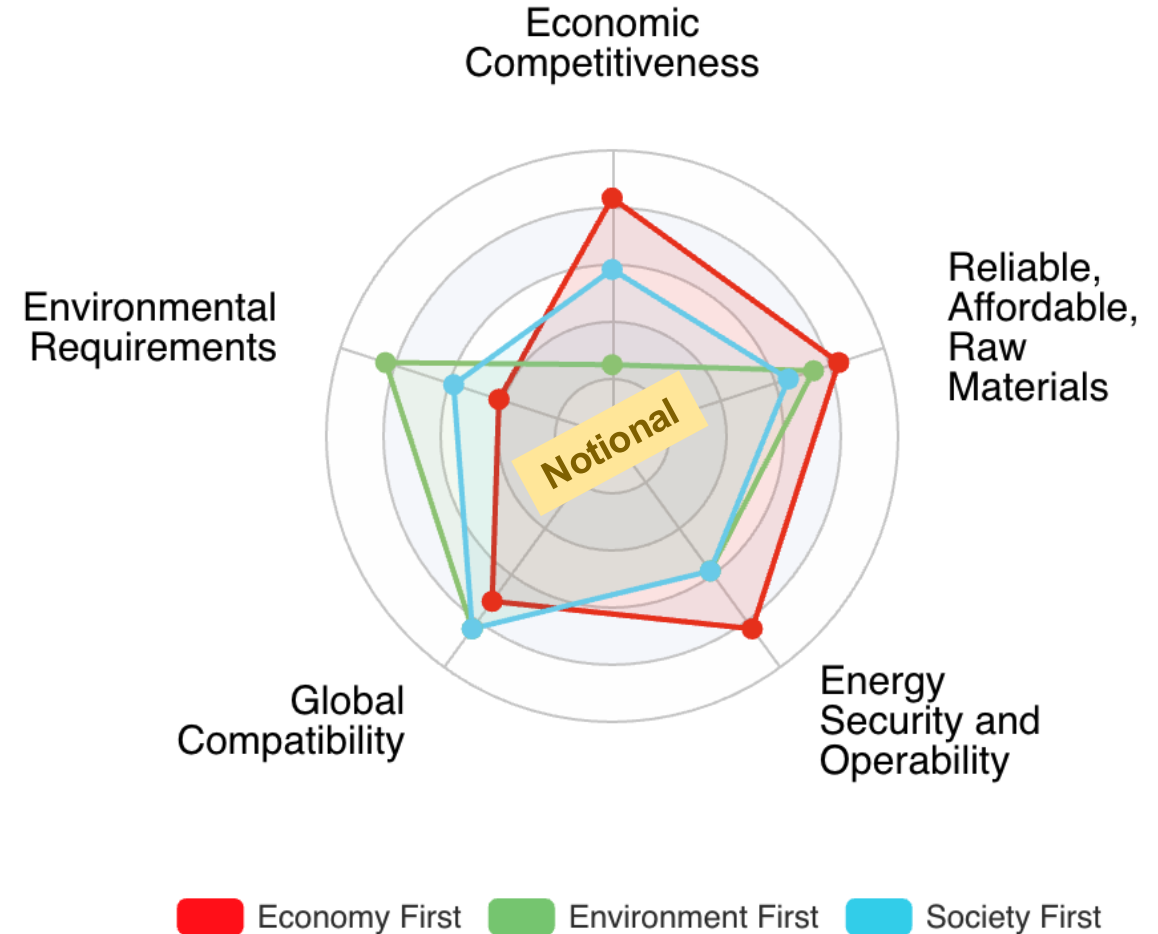
Revolutionizing Future Aerial Mobility through Transformative Air Vehicle Concepts and Technologies



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A Complex, Uncertain Future



Positioning US aviation for success beyond the next frontier will require extraordinary improvements in vehicle technologies, alternative fuels, and transformative levels of system integration.

Aviation emissions are a monumental (and growing) challenge.

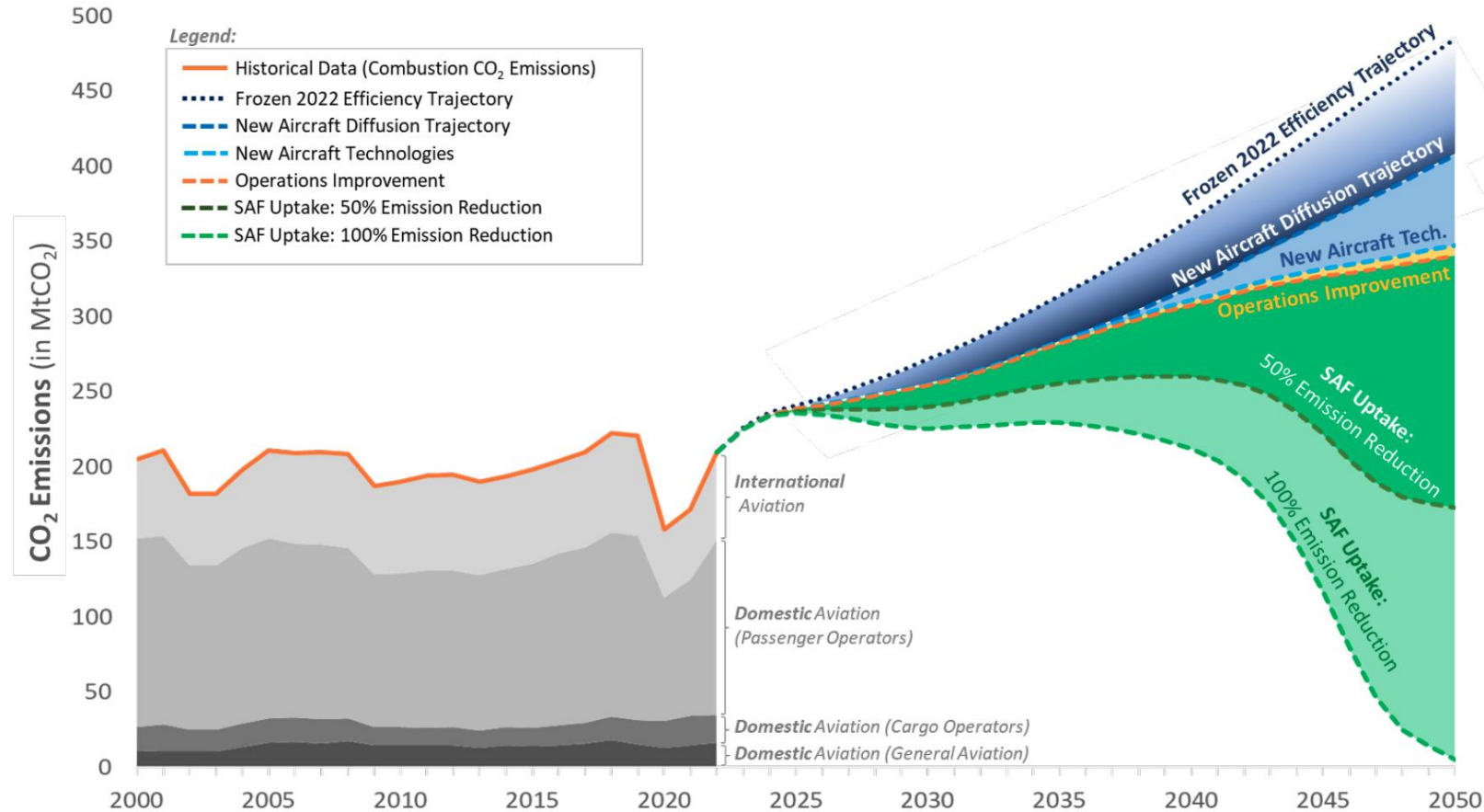


Figure 7. Analysis of Future U.S. Domestic and International Aviation CO₂ Emissions²⁵

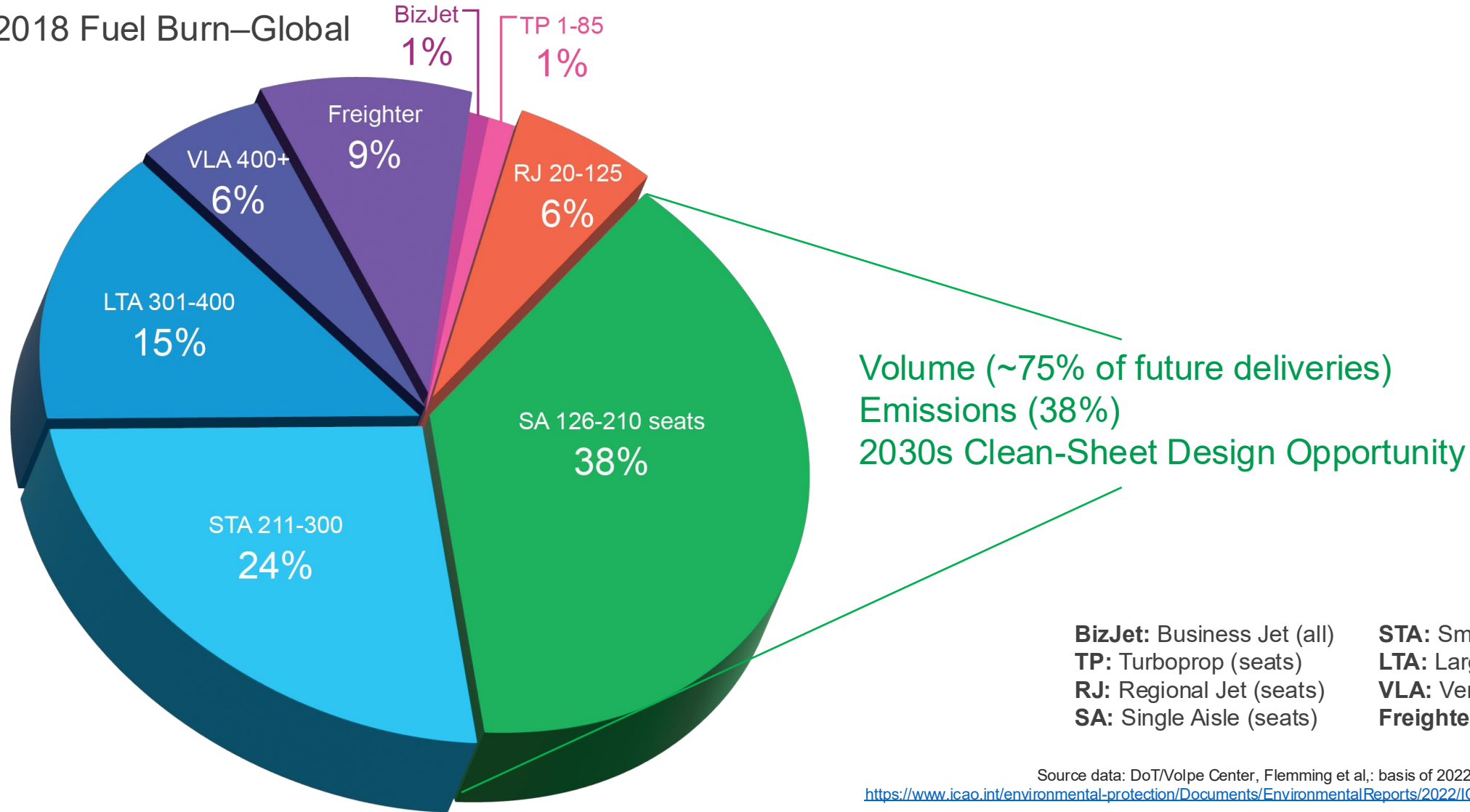
<https://www.epa.gov/system/files/documents/2024-12/us-aviation-state-action-plan-2024-final.pdf>

Reducing environmental emissions and achieving mid-century international emissions goals will require a multi-faceted solution impacting vehicles, operations, and fuels.

Fuel burn is proportional to cost, emissions, and impact.



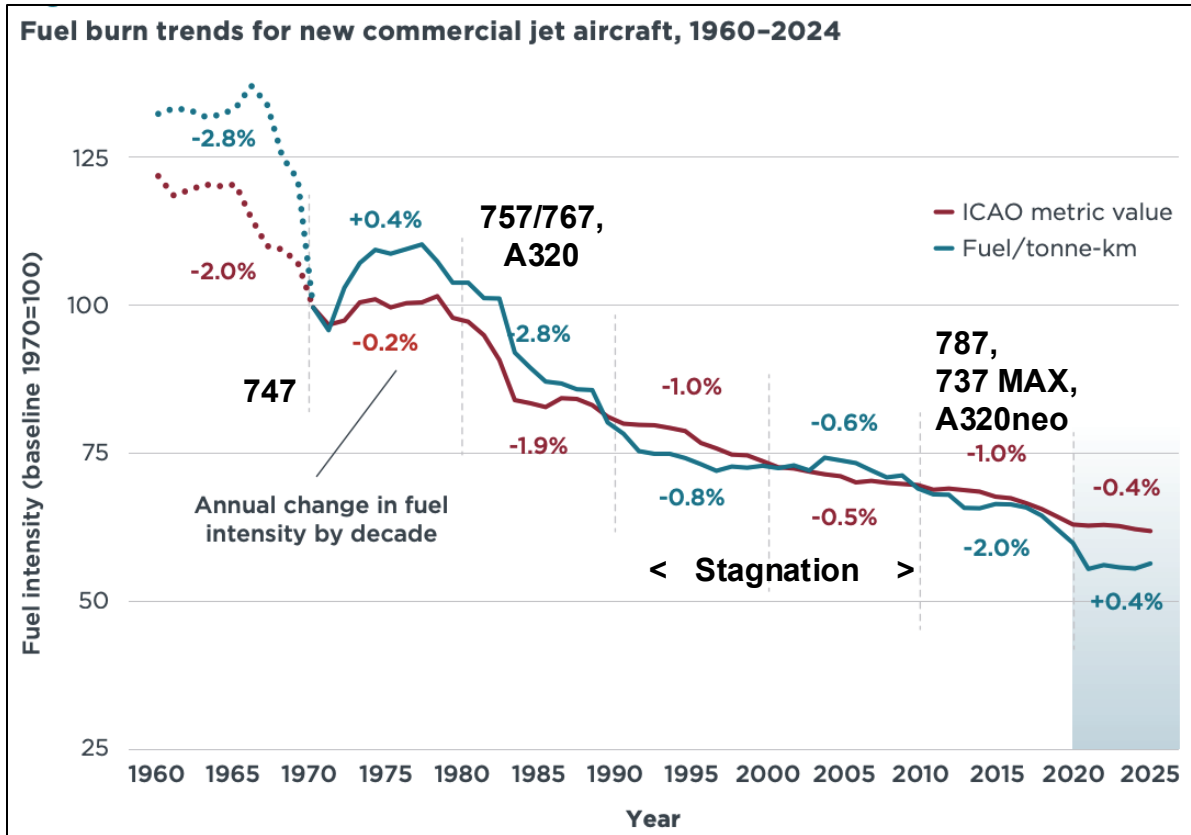
2018 Fuel Burn—Global



Source data: DoT/Volpe Center, Flemming et al.; basis of 2022 ICAO Environmental Report, Chapter 1, p24
<https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2022/ICAO%20ENV%20Report%202022%20F4.pdf>

92% of commercial aviation fuel burn from aircraft larger than 125 seat-class

How long can we lean on evolutionary improvements?



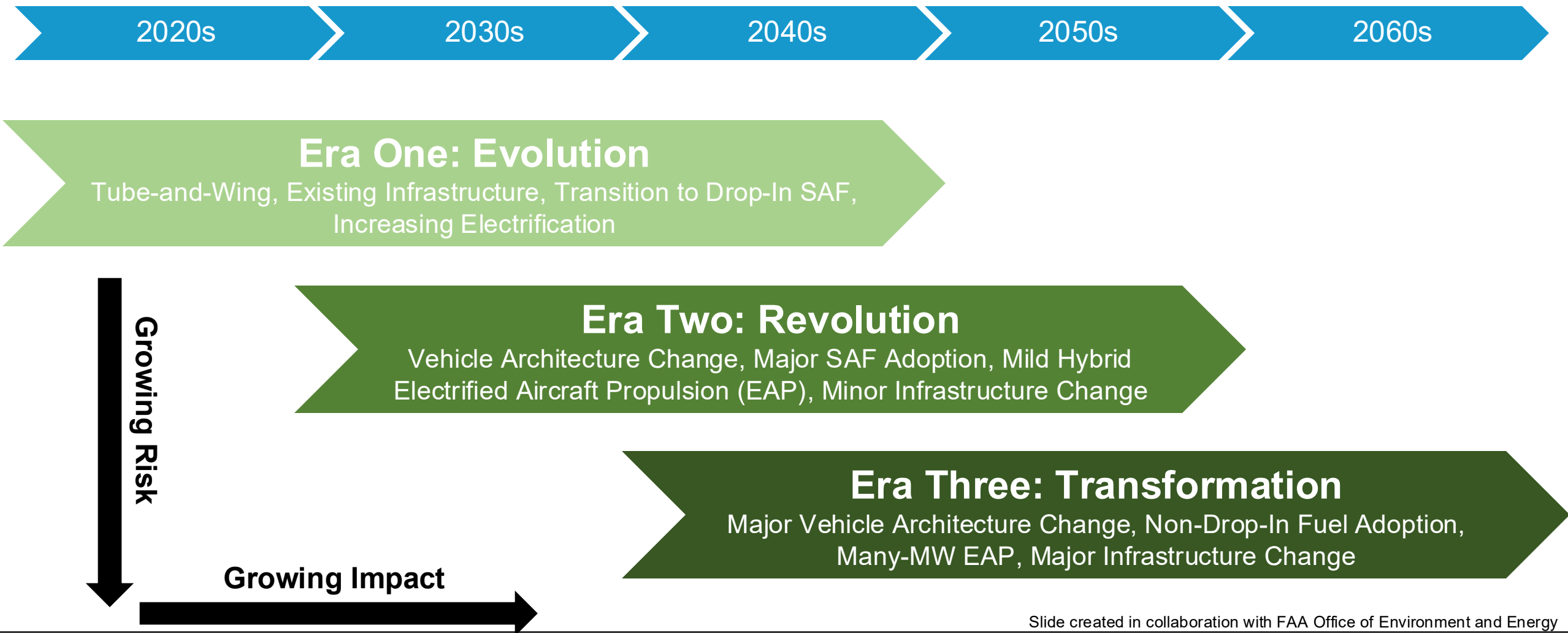
ICCT, 2024.

https://theicct.org/wp-content/uploads/2025/02/ID-287-%E2%80%9393-Jet-aircraft_working-paper_final.pdf

- Since 1970, commercial aviation's fuel burn reductions have averaged ~1%/year, for a combined reduction of 43%
- Assuming the same annual rate of evolutionary improvements, it will take 130 years to achieve what we've achieved in absolute terms in the past 50 years
- Widespread technology adoption could double the annual reduction of fuel burn and bring the time-to-realize the next 43% reduction in fuel burn down to 50 years again

Efficiency always helps; but evolutionary improvements and re-engining aircraft may yield smaller future returns. New aviation technology frontiers must be established and overcome to sustain long term progress.

Aviation Eras on the Path Toward Transformation



Slide created in collaboration with FAA Office of Environment and Energy

Transformation doesn't happen overnight; the U.S. is making deliberate, long-term investment in broad-ranging technologies beyond industry's risk tolerance

Aspirational Goals to Drive Technology Development



SUBSONIC AIRCRAFT TECHNOLOGY BENEFITS ¹	TECHNOLOGY GENERATIONS (Technology Readiness Level = 5-6)	
	Mid Term By 2030	Far Term By 2040-2045
Energy Consumption ^{2,3} (below CAEP 10)	35%	50%
		35% w/ zero operational GHG emissions
LTO NO _x Emissions ^{3,4} (below CAEP 8)	75%	>75%
LTO nvPM Emissions (below CAEP 11)	50%	75%
Noise (cum below Stage 5)	25 dB	35 dB
1) Aircraft operations improvements may yield significant system-level efficiencies and reduced atmospheric impacts in time at the fleet and vehicle levels 2) CAEP 10 CO ₂ metric is energy-use based; energy use per available seat-mile also tracked 3) 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 4) CAEP standards for Cruise NO _x are not yet established		

NASA continues to play a unique role in the community through setting far term, aggressive goals for driving technology progress and innovation beyond state-of-the-art.

Sustainable Flight National Partnership

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

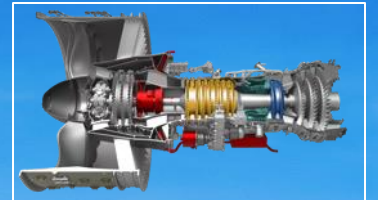
High-Rate Composites
(4-6x manufacturing increase)

Electrified Aircraft Propulsion

~5% fuel burn and
maintenance benefit

Engine Efficiency

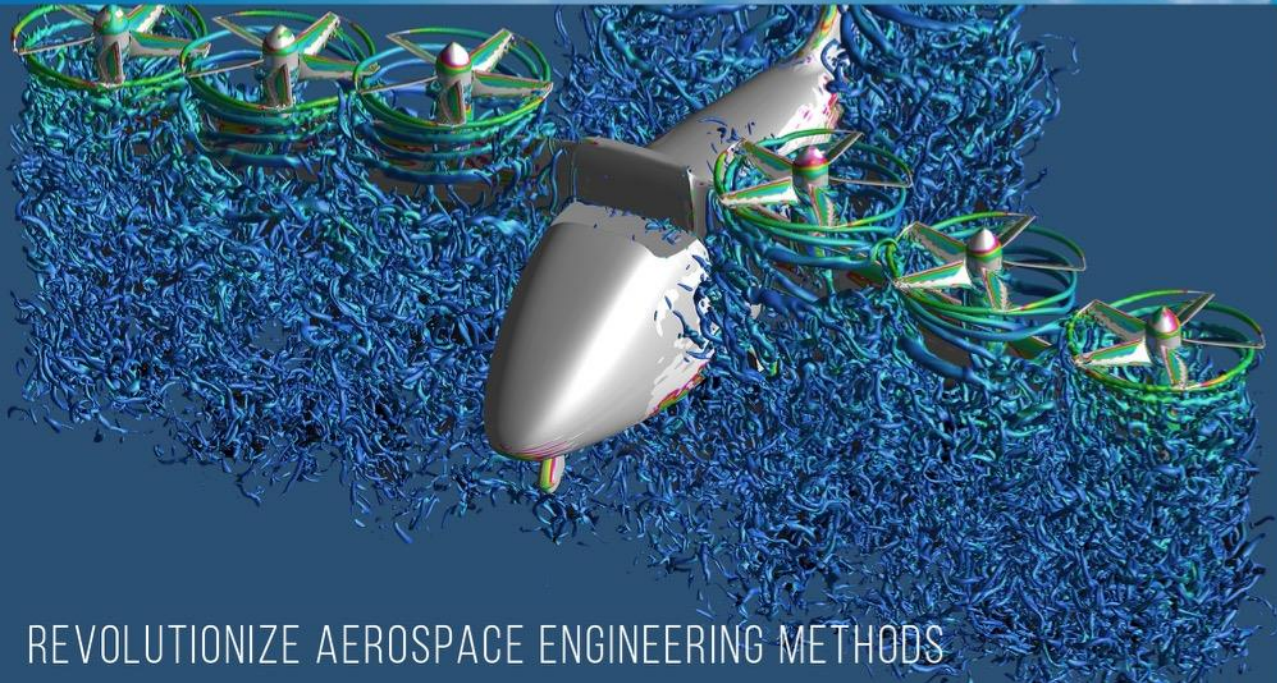
Small Core Gas Turbine
(5-10% fuel burn benefit)





Bottom Right Aircraft Image Credit: University of Illinois / Philip Areall

TRANSFORM AIRFRAMES AND PROPULSION



REVOLUTIONIZE AEROSPACE ENGINEERING METHODS



PIONEER HIGH-SPEED FLIGHT

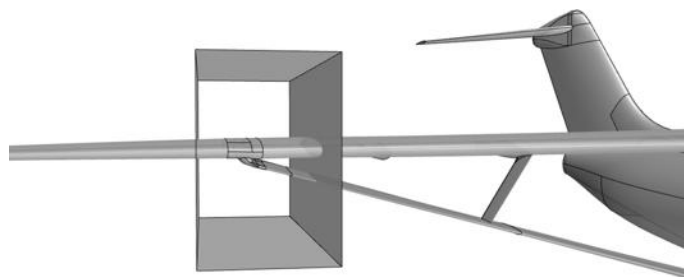
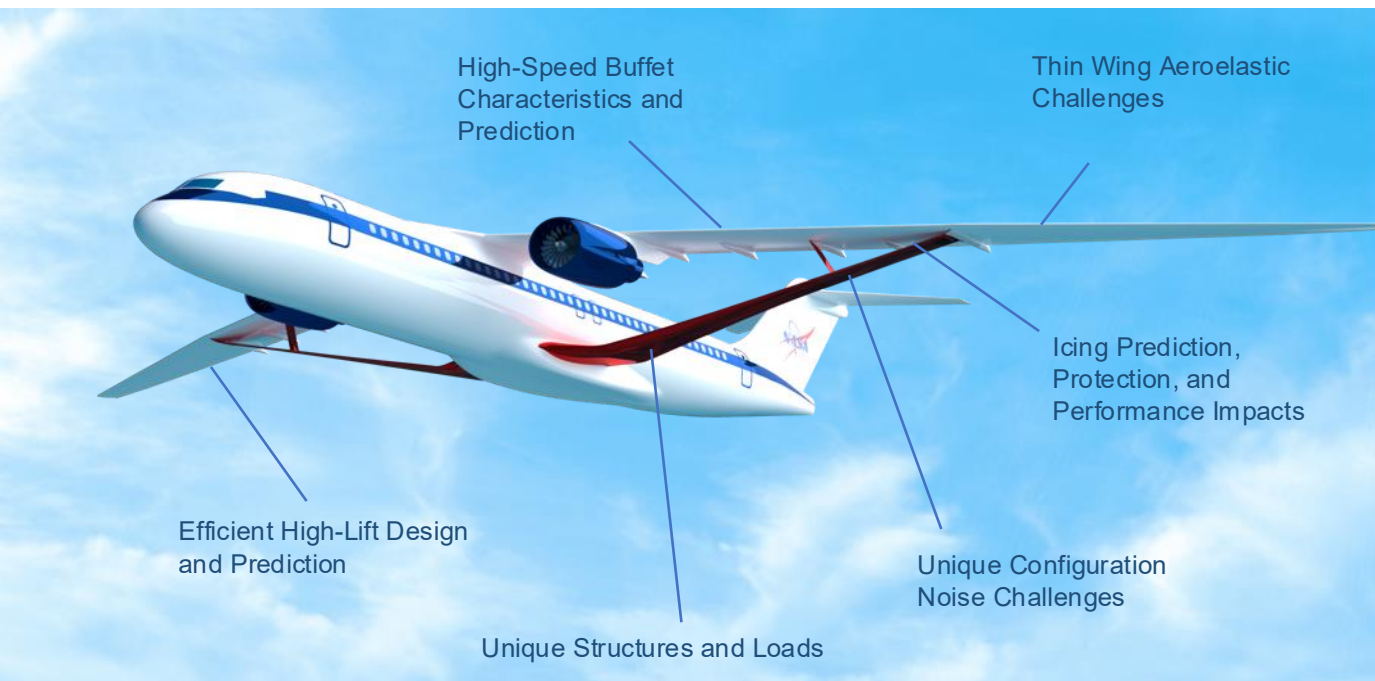


AUTOMATE AIRSPACE AND SAFETY MANAGEMENT CAPABILITIES



TRANSFORM AIRFRAMES AND PROPULSION

Demonstrate Advanced Configurations for Next Generation Aircraft



Research Focus

- Develop and test an advanced airframe configuration and related technologies to dramatically reduce aircraft fuel burn to help enable next-generation single-aisle aircraft in the 2030s

Thin Wing Technology

- Conduct ground-based demonstration of thin wing architecture and associated technologies
- Assess icing effects on thin wing design

Truss-Braced Wing Studies

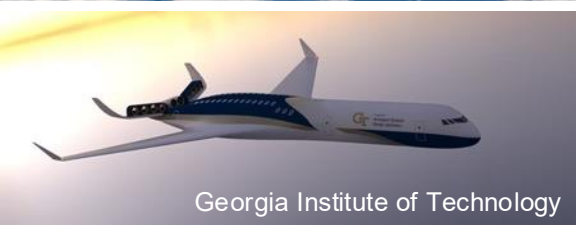
- Conduct ground-based tests of truss-braced wing configurations and explore methods for integrating propulsion technologies with the new design
- Assess progress to inform the X-66 flight demonstrator test campaign

Solving risks associated with thin wing and truss-braced design can yield 5-10% reduction in fuel burn

Pursue Transformative Propulsion Options for 2040+



Electra



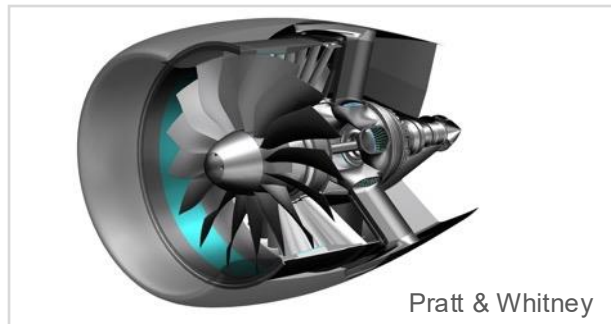
Georgia Institute of Technology



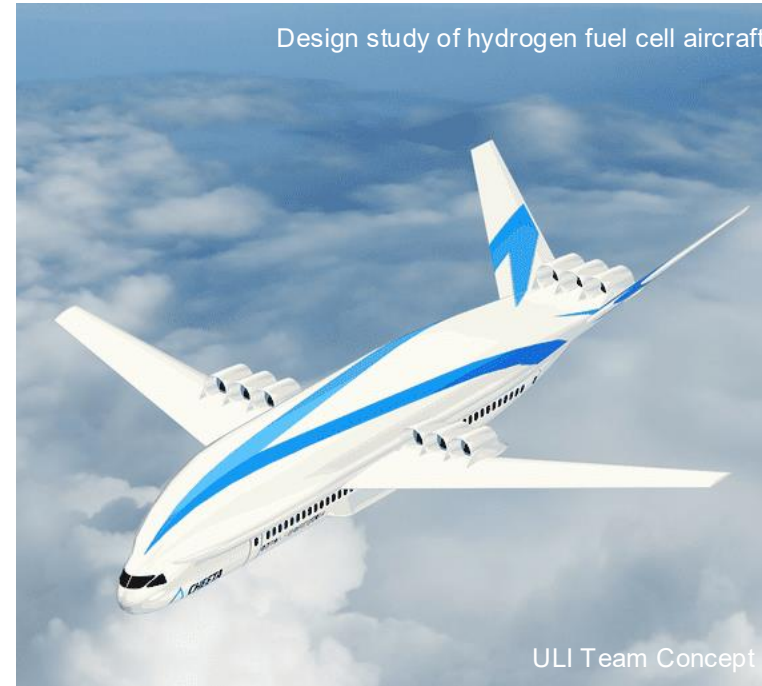
Boeing



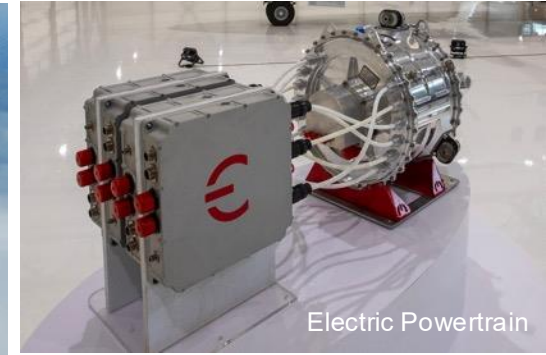
JetZero



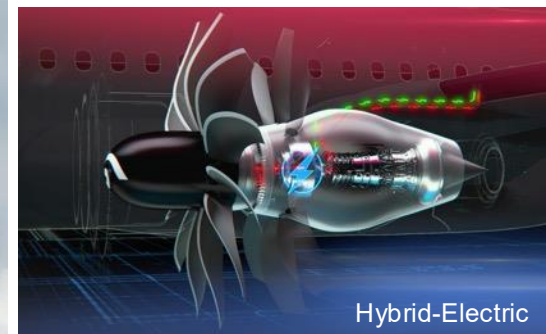
Pratt & Whitney



ULI Team Concept



Electric Powertrain



Hybrid-Electric

Design: Bring Together the Best Ideas

- Studies on advanced concept designs delivered to NASA for potential investment
- Results inform promising technologies and architectures
- Opportunities for new industry partnerships

Energy Innovation: Lower Cost Propulsion Cycles

- Jet fuel is the biggest cost to airlines, and new, potentially lower-cost energy sources are available to supplement or replace it
- NASA tests/evaluates the overlap of technology and energy
- Accelerate research into hybrid-electric, hydrogen fuel cells, cryogenic fuels, methane combustion

Protecting the future of aerial mobility requires a long view.



A long term solution will involve many potential elements:

- Revolutionary propulsion cycles and technologies (cryogenics, fuel cell, water injection, etc)
- Digital engineering and MDAO for reduced design cycle time and cost
- Harnessing of transformative propulsion-airframe-integration schemes
- Revamped operations in the national airspace for contrail mitigation and fuel use optimization
- Completely new ways to think about underutilized airports as hubs for energy production, distribution, and regional air mobility
- Cross-sector systems analysis and modeling to forecast aviation technology requirements considering energy carrier availability and pricing, infrastructural CapEx, regulatory and certification developments, and much more beyond the vehicle outer moldline
- + and more...

Success will require pushing beyond long held assumptions of design, operations, and fuels.

Government is likely to play an increasing role in lower technology readiness level, explorative R&D endeavors, working closely with academia, to equip industry for transformative technology adoption in the far term

Sustainability may be the challenge of the century for aviation,
requiring truly innovative, transformative technology development across the aviation system.

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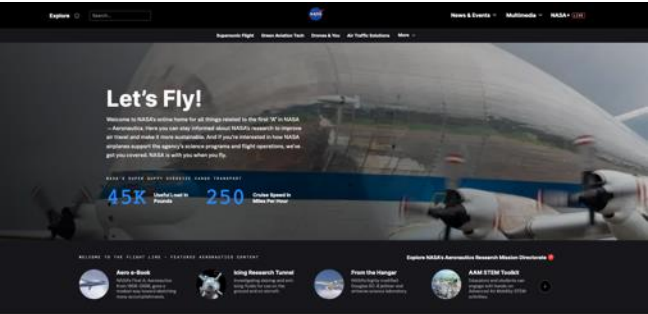
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