Aircraft Technology Research

REDAC Environment & Energy Sub-Committee

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FAA Office of Environment & Energy

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Federal Aviation Administration

Agenda

- **Aircraft Technology Research Programs**
  - Continuous Lower Energy, Emissions & Noise (CLEEN) Program
    - CLEEN Phase II - Complete
    - CLEEN Phase III - *Ongoing*
    - CLEEN Phase IV – Planning
  - Aviation Sustainability Center of Excellence (ASCENT)
  - Fueling Aviation's Sustainable Transition (FAST) Tech
- **Interagency Coordination**
  - Sustainable Flight National Partnership
- **Conclusions**

Continuous Lower Energy, Emissions & Noise (CLEEN) Program

- FAA led public-private partnership with 1:1 cost matching from industry
- Reducing fuel burn, emissions and noise via aircraft and engine technologies and alternative jet fuels
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies

	Phase I	Phase II	Phase III
Time Frame	2010-2015	2016-2020	2021-2026
FAA Budget	~$125M	~$100M	~$125M
Noise Reduction Goal	25 dB cumulative noise reduction cumulative to Stage 5 and/or reduces community noise exposure (new goal for Phase III)		
Fuel Burn Goal	33% reduction	40% reduction	-20% re: CAEP/10 Std.
NO_X Emissions Reduction Goal	60% landing/take-off NO_X emissions (re: CAEP/6)	75% landing/take-off NO_X emissions (-70% re: CAEP/8)	
Particulate Matter Reduction Goal	-	-	Reduction relative to CAEP/11 Std.
Entry into Service	2018	2026	~2031

For more information on CLEEN program: http://www.faa.gov/go/cleen

CLEEN Phase III Technologies

Engine Core

- GE: Compact Core - Low Emissions Combustor
- GE: Advanced Thermal Management
- GE: Hybrid Electric Integrated Generation
- Honeywell: Efficient Green High-Pressure Core
- Honeywell: Compact High-Work High-Lift Low Pressure Turbine
- Pratt & Whitney: TALON X+ Combustor
- Rolls-Royce: Axi-Cf Compressor Technologies

Airframe

- Boeing: Quiet Landing Gear
- Boeing: Quiet High-Lift System

Aircraft Systems

- GE: MESTANG III
- Boeing: Intelligent Operations

Sustainable Aviation Fuels

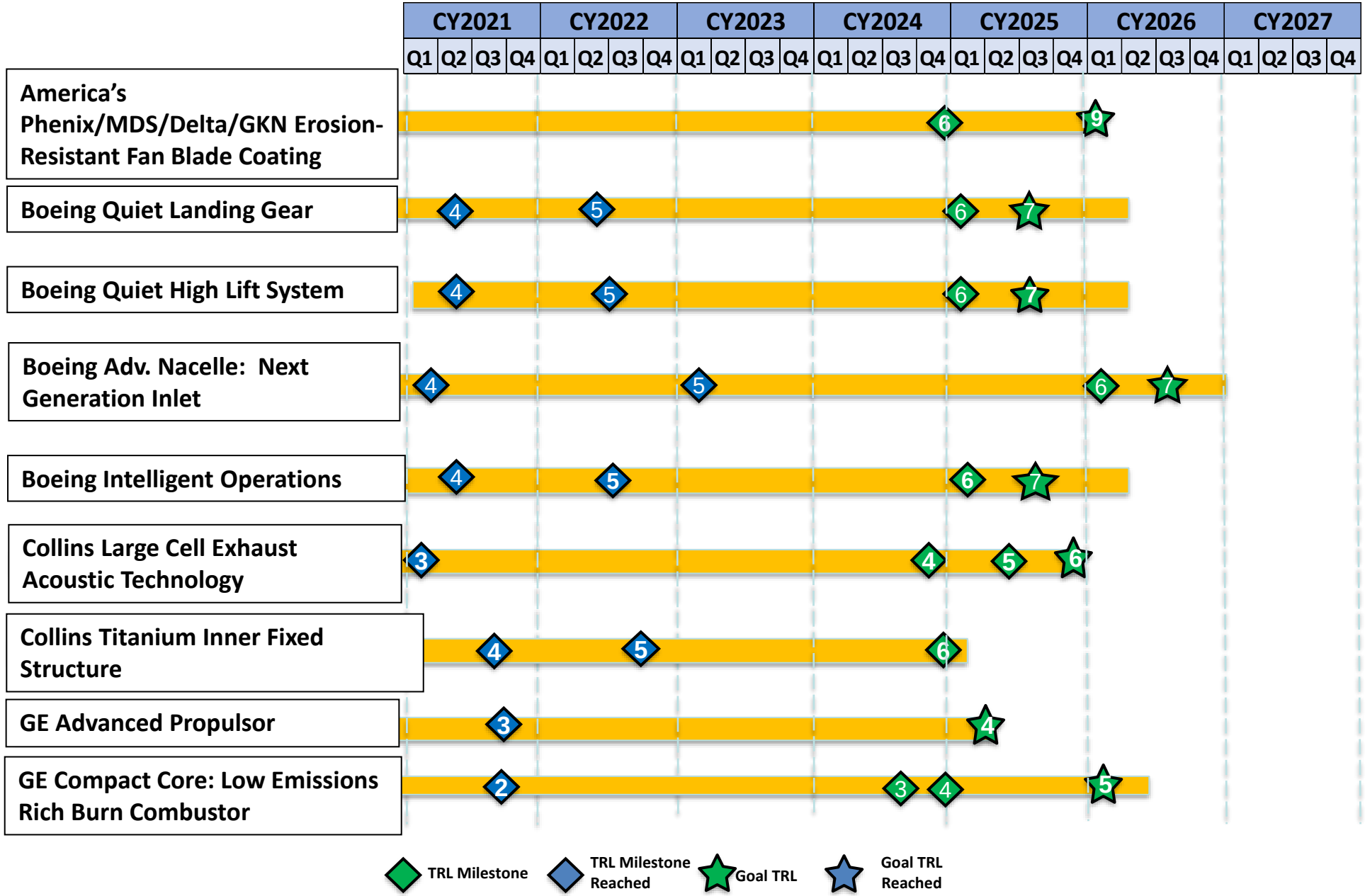
- Boeing: Higher Blend SAF Qualification
- GE: Higher Blend SAF Qualification

Nacelle, Fan, and Bypass

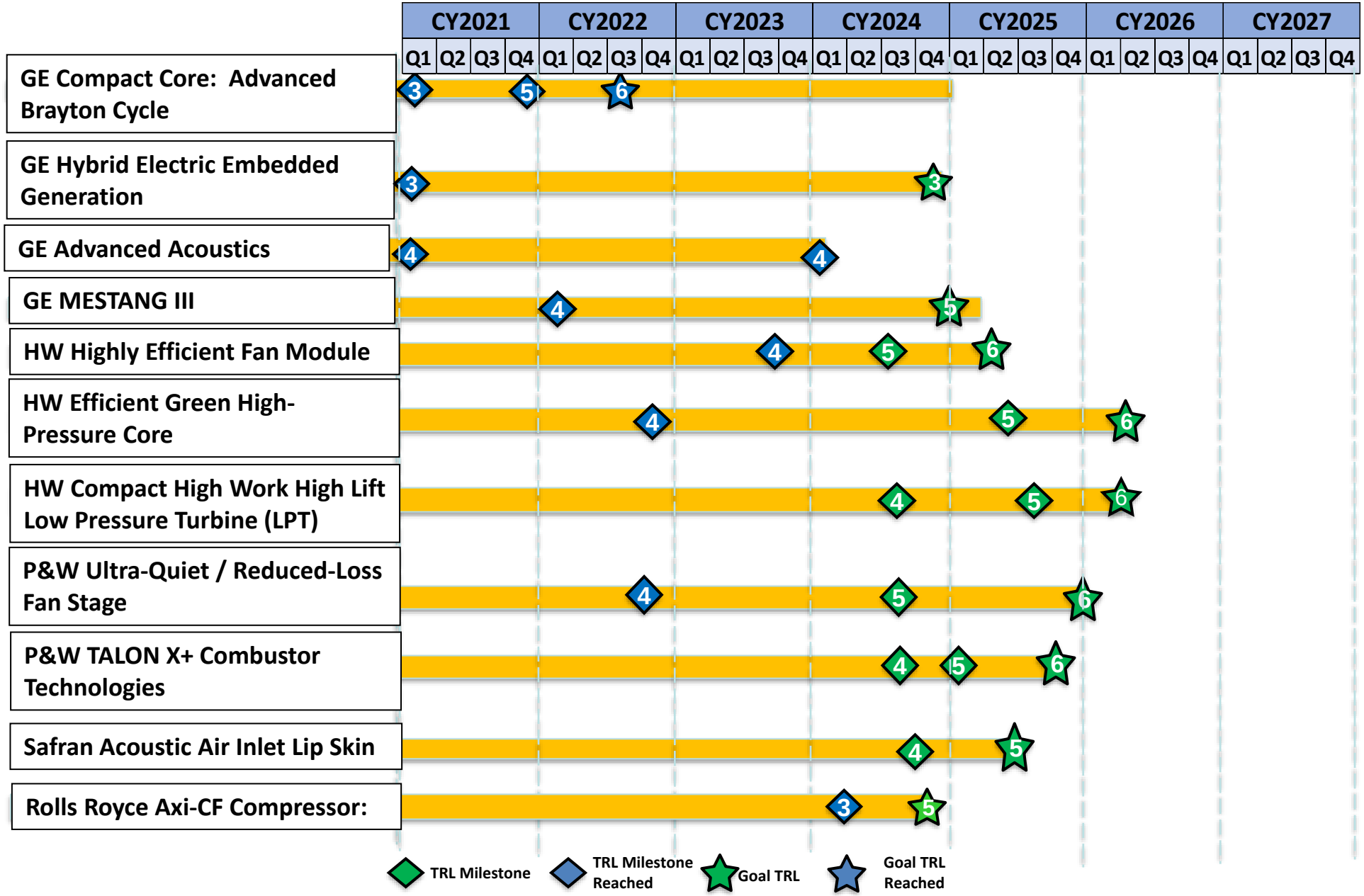
- America's Phenix: Erosion-Resistant Fan Blade Coating
- Boeing: Advanced Nacelle Next Generation Inlet
- Collins: Large Cell Exhaust Acoustic Technology
- Collins: Titanium Inner Fixed Structure
- GE: Open Fan
- GE: Advanced Acoustics
- Honeywell: Highly Efficient Fan Module
- Pratt & Whitney: Ultra-Quiet Reduced-Loss Fan Stage
- Safran: Acoustic Air Inlet Lip Skin

Fuel
Emissions
Noise

CLEEN III Technologies – TRL Milestones



CLEEN III Technologies Continued – TRL Milestones



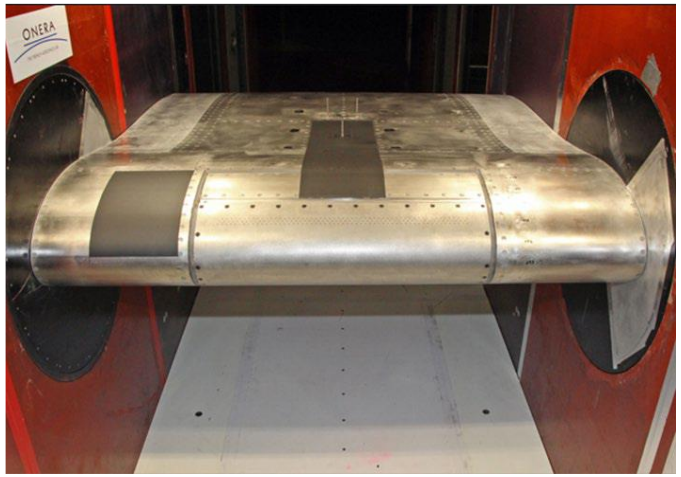
Recent CLEEN Phase III Accomplishments

Overall program milestones:

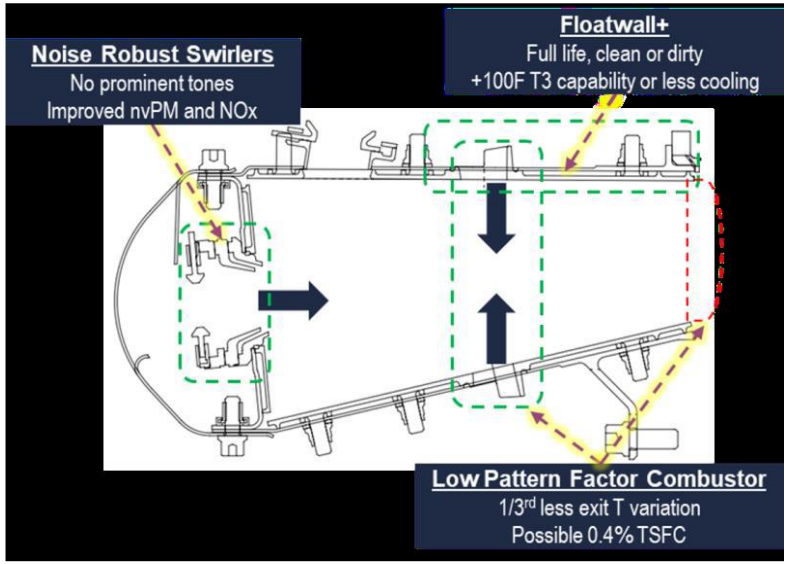
- Completed sixth CLEEN Phase III Consortium Meeting May 6-10, 2024 in Washington, DC

Project technical highlights:

- **America's Phenix:** Continued supplemental CFD analysis with University of Maryland to estimate fuel consumption impact
- **Boeing:** Completed Software Drop 3 for Intelligent Operations project
- **Collins:** Completed preliminary design review for Advanced Acoustic Exhaust technology
- **GE:** Airfoil manufacturing in progress for Open Fan technology
- **Honeywell:** Conducted low emissions combustor rig tests
- **P&W:** Completed preliminary design of TALON X+ combustor configuration for full annular rig test
- **Rolls-Royce:** Completed final build test of compressor technology at Centrifugal Stage for Aerodynamic Research (CSTAR) rig at Purdue University
- **Safran:** Revised architecture of anti-icing acoustic lip technology based on dry wind tunnel test results



Safran Wind Tunnel Test



Pratt & Whitney Combustor Technology

Upcoming CLEEN Phase III Milestones

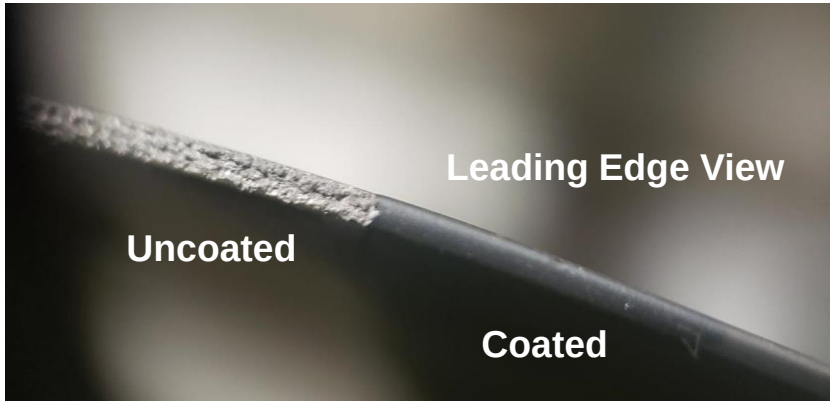
Overall program milestones:

- Seventh CLEEN Phase III Consortium Meeting to be held November 18-22, 2024 in East Hartford, CT

Project technical highlights:

- **America's Phenix:** Deliver full PW2000 coated blade sets
- **Boeing:** Complete fabrication and assembly for Quiet Landing Gear, Quiet High Lift, and Next Generation Inlet technologies in preparation for flight test campaigns
- **Collins:** Complete critical design review of Advanced Acoustic Exhaust technology
- **GE:** Complete Open Fan rig hardware manufacturing
- **Honeywell:** Conduct component rig, development engine, and core engine testing of multiple technologies (fan module, combustor, high pressure compressor/turbine)
- **P&W:** Fabricate, assemble, and test TALON X+ combustor technologies in full annular and multi-sector rigs
- **Rolls-Royce:** Conduct data analysis and modeling comparisons with Purdue University on axi-cf compressor technology
- **Safran:** Initiate representative wind tunnel test campaign of anti-icing acoustic lip technology

Boeing Landing Gear Shields



America’s Phenix Fan Blade Coating

Assessment of CLEEN Technologies' Environmental Benefits

Analytical Evaluation:

- Conducted by Georgia Tech through ASCENT COE Project 37
- Evaluating impact of technology applications through 2050

Fuel Burn Benefit:

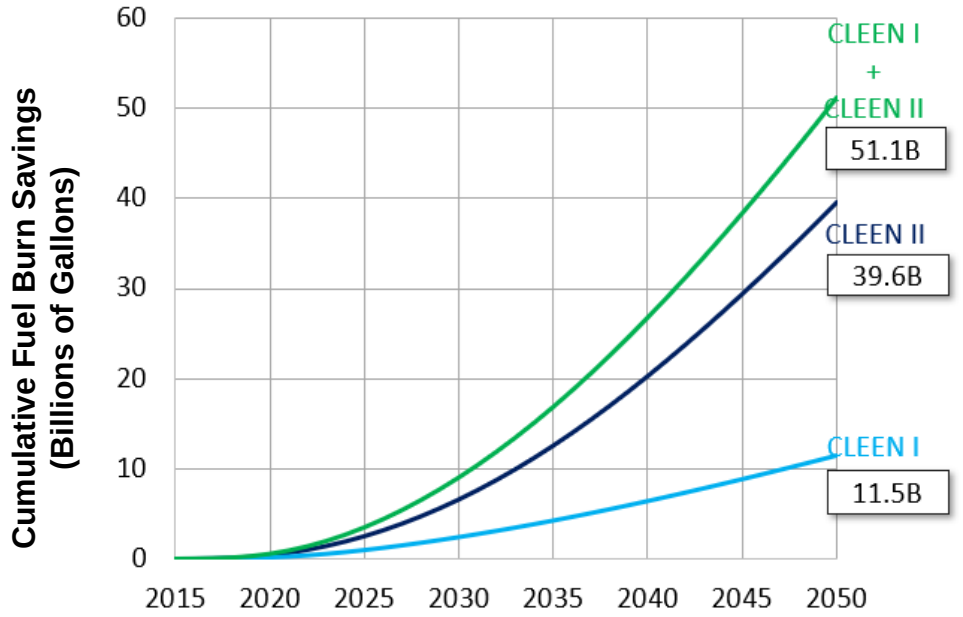
- **51.1 billion gallons of fuel saved cumulative by 2050** from CLEEN Phase I and II
- **CO_2 emissions reduced by 500 million metric tons** over this time period

NOx Benefit:

- CLEEN Phase I and II technology cumulatively **reduce LTO NOx emissions by 2.79 Megatons through 2050**

Noise Benefit:

- The interim assessment indicates that the CLEEN Phase I and II technologies could yield a **10% reduction in 65 DNL noise contour area by 2050** compared to continued evolution of aircraft technologies absent CLEEN's research & development investments.



Updated 04/2024. Includes domestic operations and international departures of U.S. commercial and foreign flag carriers

CLEEN Phase IV

- Plan to continue FAA's programmatic model of public-private partnership with 1:1 cost matching from industry to develop new environmentally beneficial aircraft technologies

- Solicitation planned in calendar year 2024

	Phase I	Phase II	Phase III	Phase IV (DRAFT)
Time Frame	2010-2015	2016-2020	2021-2026	2025-2029
FAA Budget	~$125M	~$100M	~$125M	~$190M
Energy Efficiency / Fuel Burn Reduction Goal	33% reduction re: year 2000 baseline	40% reduction re: year 2000 baseline	-20% re: CAEP/10 Std.	-35% re: CAEP/10 Std., and/or reduces aviation's climate impacts
Noise Reduction Goal	25 dB cumulative noise reduction cumulative to Stage 5 and/or reduces community noise exposure (new goal for Phase III)			
NO_X Emissions Reduction Goal	60% landing/take-off NO_X emissions re: CAEP/6	-70% landing/take-off NO_X emissions re: CAEP/8 (-75% re: CAEP/6)		-70% landing/take-off NO_X emissions re: CAEP/8 and/or reduces absolute NOx over the aircraft's mission
Particulate Matter Reduction Goal	-	-	Reduction relative to CAEP/11 Std.	-50% landing/take-off nvPM number and mass re: CAEP/11
Entry into Service	2018	2026	~2031	~2035

For more information on CLEEN program: http://www.faa.gov/go/cleen

ASCENT Technology Projects

- **Complementary venue for university-led research on aircraft technology research and development**
- **Advances the industry state-of-the-art and expands the technical knowledge base**
- **Cuts across development of individual technologies and models**
- **Technical Themes:**
  - Noise reduction technology modeling and development
  - System-level modeling and design considerations
  - Propulsion-airframe integration
  - Combustion
  - Turbomachinery
  - Supersonics
- **Overview of projects available on ASCENT website:**

  https://ascent.aero/topic/Aircraft-Technology/

ASCENT Aircraft Technology Innovation Portfolio

Noise reduction technology modeling and development

- 075 - Improved Engine Fan Broadband Noise Prediction Capabilities
- 076 - Improved Open Rotor Noise Prediction Capabilities
- 079 - Novel Noise Liner Development Enabled by Advanced Manufacturing

System-level modeling and design considerations

- 010 - Aircraft Technology Modeling and Assessment
- 037 - CLEEN II System Level Assessment
- 052 - Comparative Assessment of Electrification Strategies for Aviation
- 064 - Alternative Design Configurations to Meet Future Demand
- 095 – Assessment of Fuel Cells for Powering Modern Business Jets
- 096 – Future Transportation System Opportunities and Constraints
- 097 – FAST-Tech System Level Assessment

Propulsion-airframe integration

- 050 - Over-Wing Engine Placement Evaluation
- 063 - Parametric Noise Modeling For Boundary Layer Ingesting Propulsors

Supersonics

- 047 - Clean Sheet Supersonic Aircraft Engine Design and Performance
- 059 - Jet Noise Modeling to Support Low Noise Supersonic Aircraft Technology Development

Combustion

- 051 - Combustion concepts for next-generation aircraft engines to reduce fuel burn and emissions
- 055 - Noise Generation and Propagation from Advanced Combustors
- 066 - Evaluation of High Thermal Stability Fuels
- 067 - Impact of Fuel Heating on Combustion and Emissions
- 068 - Combustor Wall Cooling Concepts for Dirt Mitigation
- 070 - Reduction of nvPM emissions via innovation in aero-engine fuel injector design
- 071 - Predictive Simulation of Soot Emission in Aircraft combustors
- 074 - Low Emissions Pre-Mixed Combustion Technology for Supersonic Civil Transport
- 098 – Low Emissions Lean Pre-Mixed Pre-Vaporized Combustion Technology for Subsonic Civil Transport

Turbomachinery

- 056 - Turbine Cooling Through Additive Manufacturing
- 092 – Advanced Two-Stage Turbine Rig Development

Blue = ended or ending after this period of performance

ASCENT Aircraft Technology Innovation Portfolio

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n Combustion and Emissions
Concepts for Dirt Mitigation
ions via innovation in aero-
oot Emission in Aircraft
d Combustion Technology
-Mixed Pre-Vaporized
bsonic Civil Transport
Additive Manufacturing

Request for feedback:

- As we look to future planning, are there gaps in our ASCENT aircraft tech portfolio that we should be working?

Blue = ended or ending after this period of performance

FAST Program Overview

FAST Grants

The new **Fueling Aviation's Sustainable Transition (FAST)** discretionary grant program will make investments to accelerate production and use of **sustainable aviation fuels** and the development of **low-emission aviation technologies** to support the U.S. aviation climate goal to achieve net zero greenhouse gas emissions by 2050. (Legislative Authority: Section 40007 of the Inflation Reduction Act of 2022)

- Grants will carry out projects located in the United States that:
  - Produce, transport, blend or store sustainable aviation fuel (FAST-SAF) - $244,530,000
  - Develop, demonstrate, and apply low-emission aviation technologies (FAST-Tech) - $46,530,000

- Eligible entities include: state and local governments, airports, air carriers, academic and research institutions, other aviation industry, and nonprofits
- Federal cost-share is 75% of project cost (90% for small or non-hub airport awardees)

- Notice of Funding Opportunity (NOFO) released on Sept 25, 2023; closed on Dec 4, 2023
- FAA anticipates announcing awards in Summer 2024

FAST Status / Next Steps

FAST Grants

- **Notice of Funding Opportunity opened 9/25/23 and closed 12/4/23**
- **Significant response**
  - More than 120 applications
- **In the process of evaluating applications, developing recommended award package, and gaining departmental concurrence**
  - Enlisted support from DOE, NASA, Volpe, DOT, and AEE-400
- **Targeting announcing awards in Summer 2024**

Types of Interagency Coordination

- **Engaging in multiple forums to coordinate aircraft technology development activities, plans, and strategy:**
  - NASA Aeronautics Independent Review Panels
  - Advanced Turbine Technology for Affordable Mission Capability (ATTAM) Steering Committee
  - Propulsion Power Systems Alliance (PPSA) leadership team
  - Continuous ad hoc engagement
- **Mutual regular engagement in technology development technical reviews**
  - Particularly with the programs under the NASA Sustainable Flight National Partnership (SFNP) umbrella
- **Always looking for ways to leverage and complement each other's programs and projects**
- **NASA involvement in technical evaluations of AEE R&D solicitations, and vice versa**

Summarizing FAA Environmental Aircraft Technology Programs

- **CLEEN**
  - Industry partnership with 50/50 cost share via cooperative agreements
  - Focused on taking TRL 3-5 technologies through TRL 6-7 to reduce technical risk and put technologies on a path for entry into service ~5 years after conclusion of R&D
  - Focused technology development with additional benefits to enhancing analysis and design tools
- **Aviation Sustainability Center of Excellence (ASCENT)**
  - Academic partnership with 50/50 cost share via grants
  - Focused on applied R&D at any TRL
  - Advances state of the art of knowledge broadly in the industry
  - Covers: new discrete technologies, enhanced analysis and design tools, and improved physics modeling
- **Fueling Aviation's Sustainable Transition via Technology (FAST-Tech)**
  - Industry and/or academia partnership with 75% FAA cost share via grants
  - Explicitly focused on low-emissions technologies
  - *Potential focus areas:*
    - *Designing, prototyping, and testing of discrete low-emission aviation technologies, and*
    - *Enhancing aircraft and engine technology testing and demonstration capabilities to accelerate development and demonstration of a broad range of low-emission aircraft technologies.*

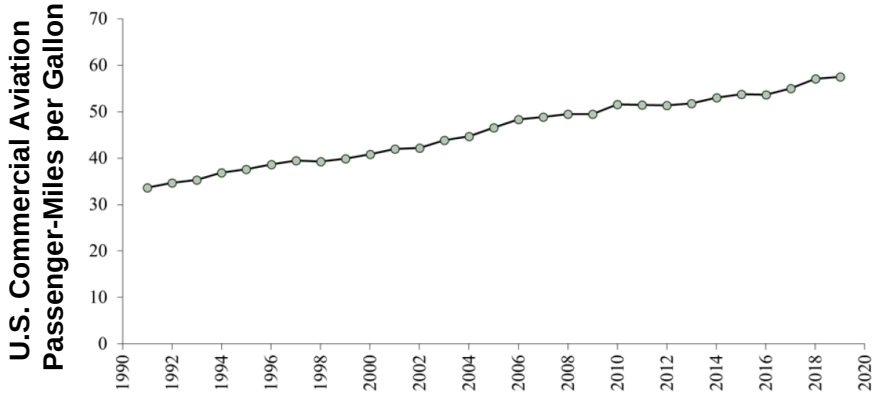
Conclusions

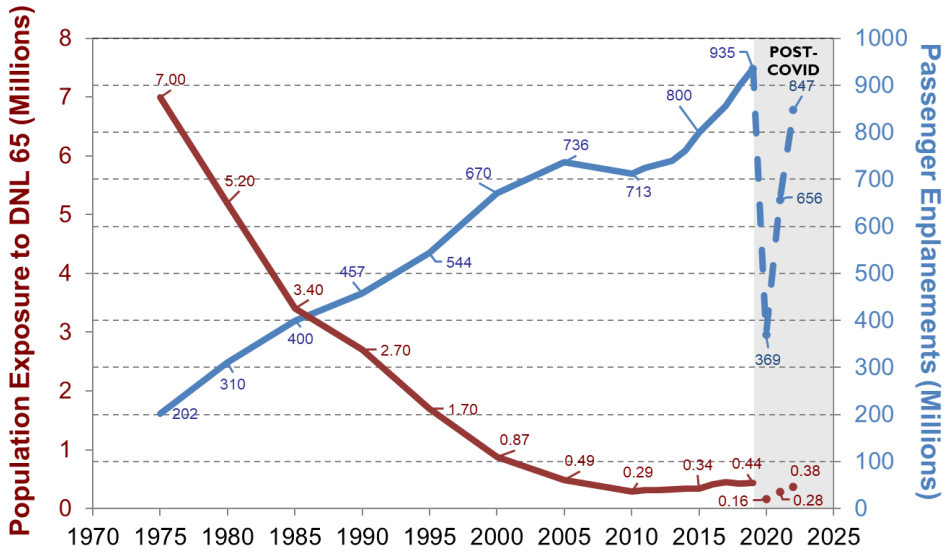
- **CLEEN Phase III continues our efforts to accelerate maturation of environmental aircraft technologies into the fleet (2021-2026)**
  - Many major demonstrations this year and next
- **CLEEN Phase IV Planning**
  - Continue internal development/approval process of solicitation
- **Next CLEEN Consortium Meeting:**
  - November 8-22, 2024 in East Hartford, CT (Pratt & Whitney)
- **ASCENT aircraft technology development continues to complement CLEEN's industry focus in our portfolio**
- **FAST-Tech presents an exciting opportunity to further expand our portfolio into complementary areas**
  - Currently reviewing submissions and developing recommended award package
  - Targeting Summer 2024 awards

Backup Slides

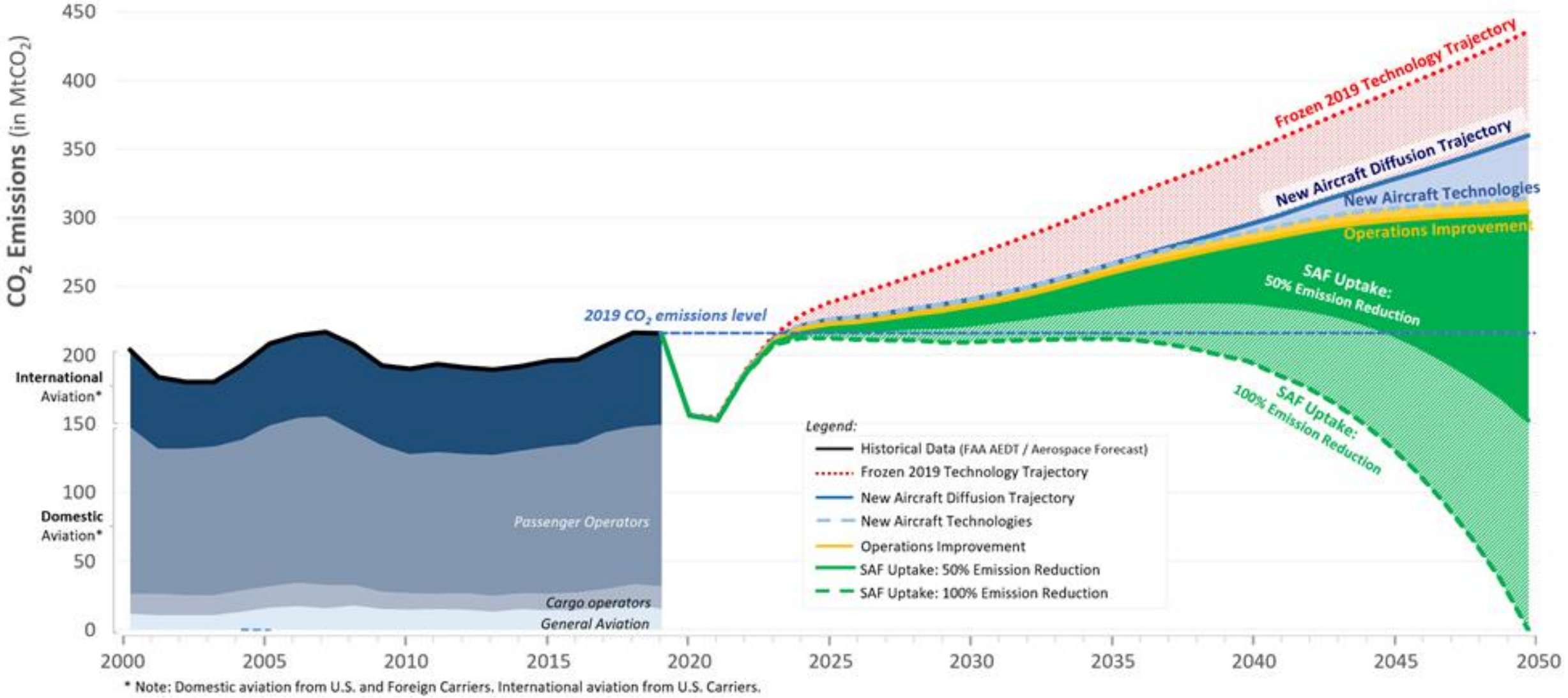
Rationale for Investing in Aircraft Technology

- Historically, advances in aircraft technology have been the main factor in reducing aviation's environmental impact
- Continued improvements come with large technological risk
- Small profit margins, competitive/cost pressures, and supply chain disruptions have considerably reduced industry's ability to undertake research to advance new technologies to reduce noise and emissions
  - **However**, industry has also set ambitious net zero targets
- SAF scale-up has challenges and cannot be the only solution
  - Technology improvements can make SAF go farther
- Government resources help mitigate technological risk and incentivize aviation manufacturers to invest in and develop cleaner, quieter technology



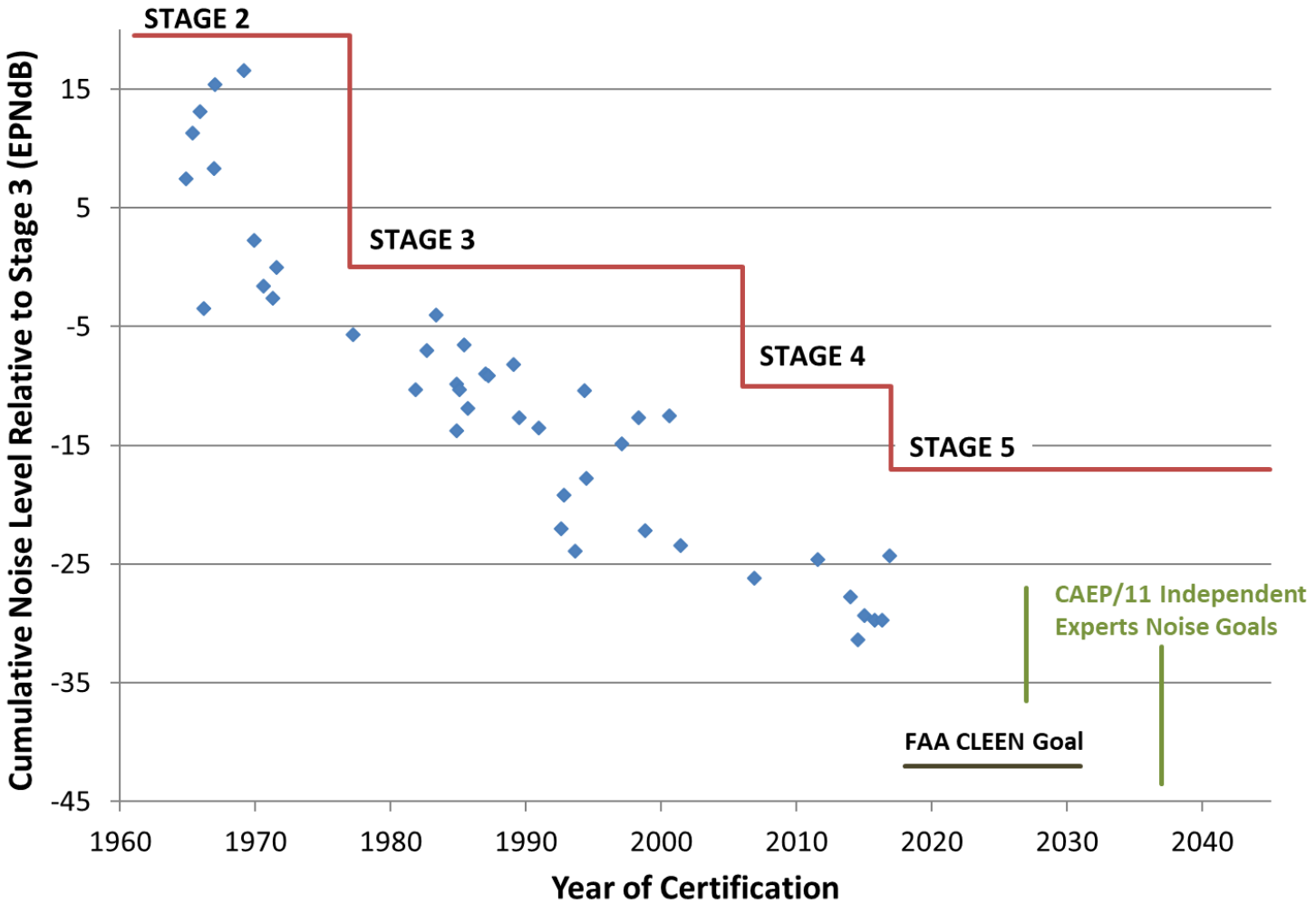


Domestic and International Aviation CO_2 Emissions



NOTE: Analysis conducted by BlueSky leveraging FAA Aerospace Forecast and R&D efforts from the FAA Office of Environment & Energy (AEE) regarding CO2 emissions contributions from aircraft technology, operational improvements, and SAF

CLEEN Noise Goal in Context



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