ONCC Daytime Noise Subcommittee Meeting

Continuous Lower Energy, Emissions & Noise (CLEEN) Program Overview

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Technology & Operations Division

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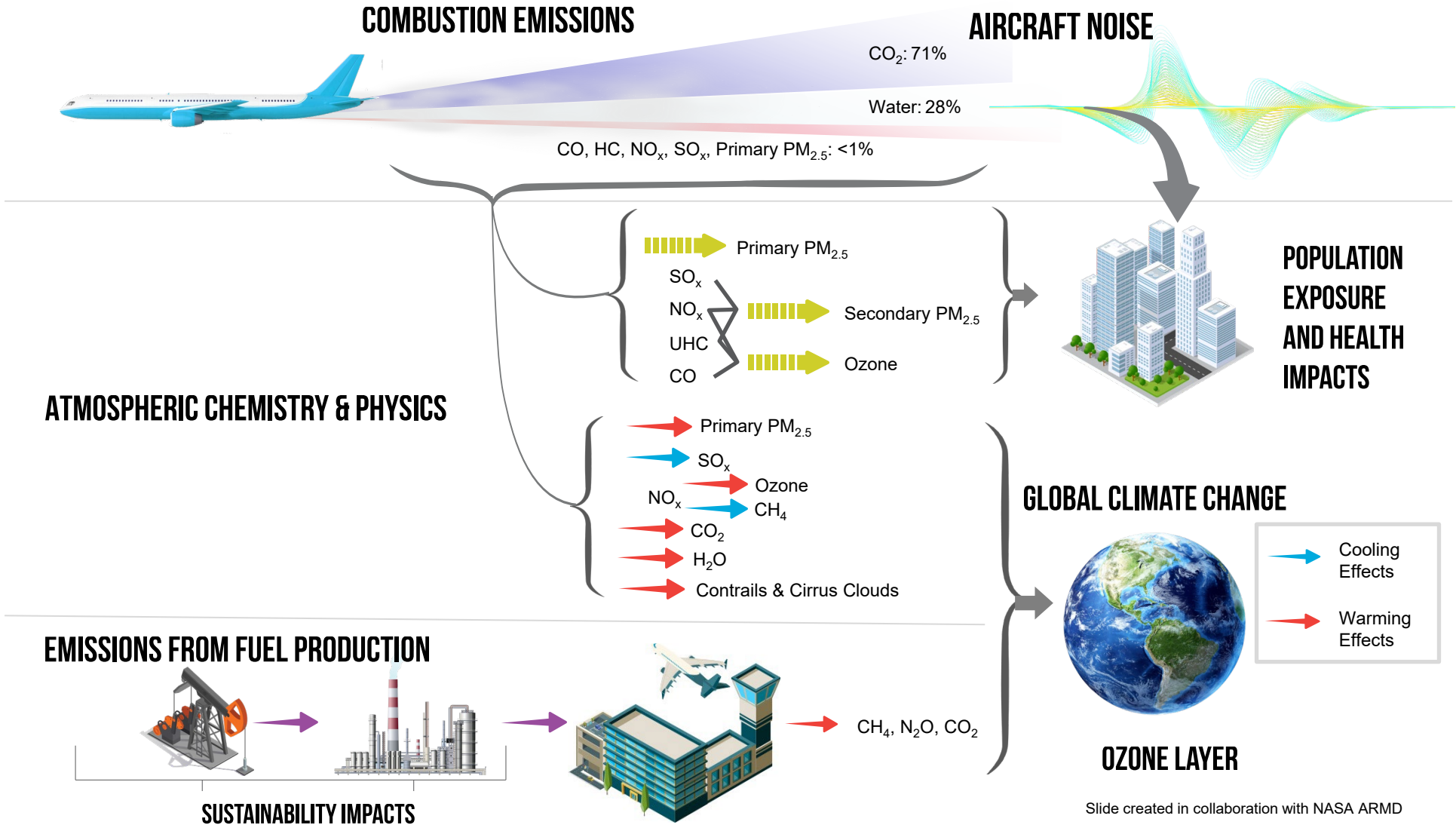
Federal Aviation Administration

Environmental Impacts of Aviation

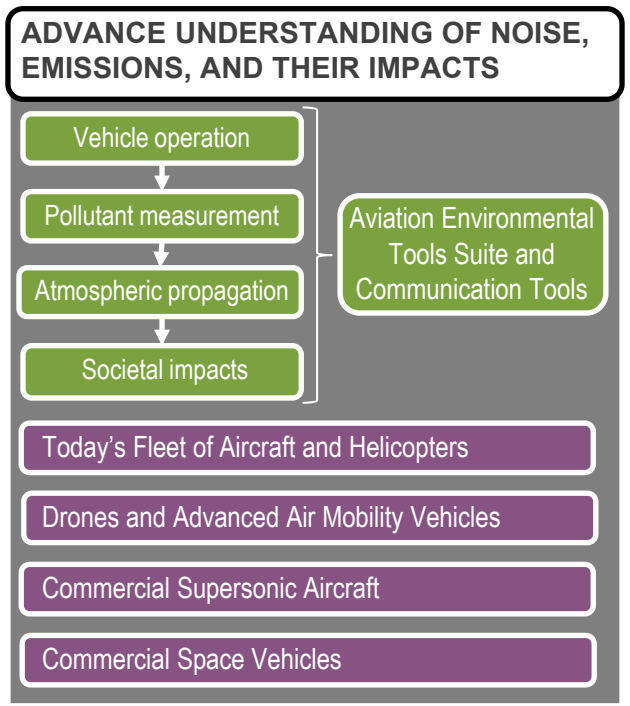


Slide created in collaboration with NASA ARMD

FAA Environmental & Energy (E&E) Strategy

E&E Mission: *To understand, manage, and reduce the environmental impacts of global aviation through research, technological innovation, policy, and outreach to benefit the public*
E&E Vision: *Remove environmental constraints on aviation growth by achieving quiet, clean, and efficient air transportation*

E&E R&D Portfolio Activities & Programs:



ASCENT AVIATION SUSTAINABILITY CENTER
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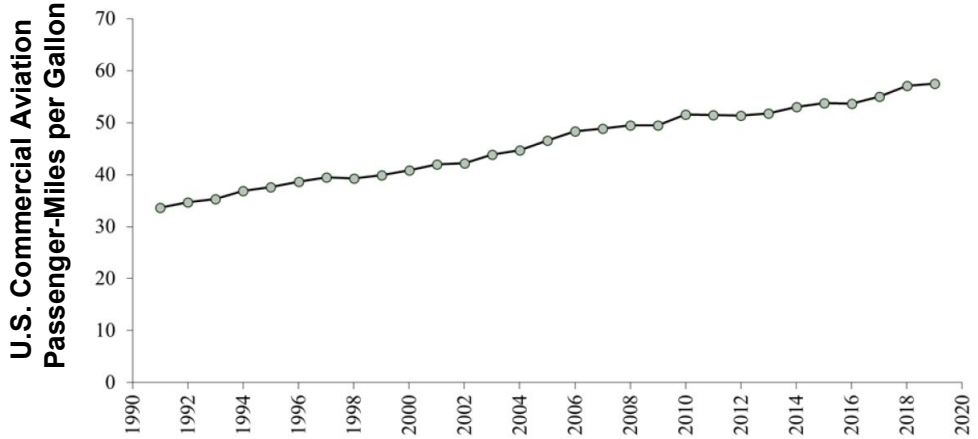
CAAFI®
www.caafi.org/

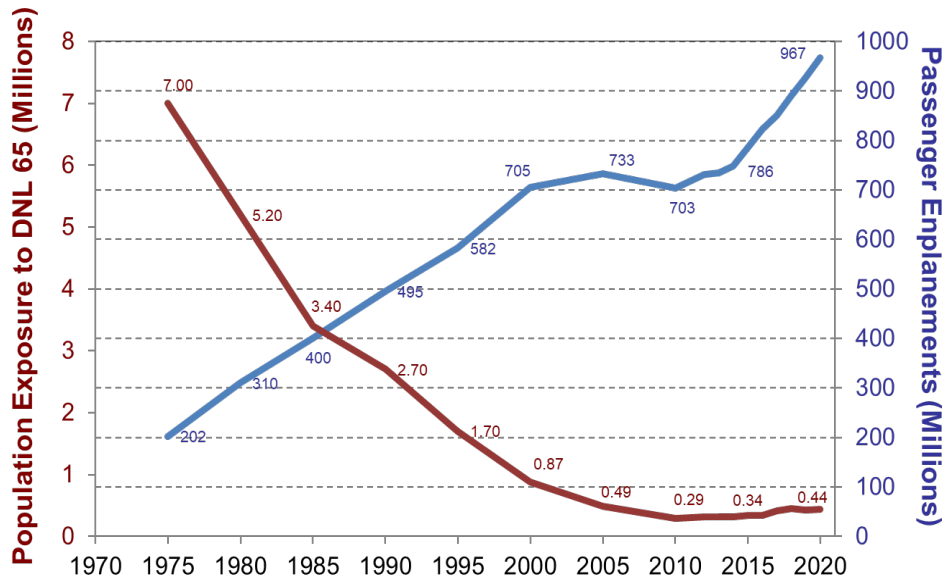
Continuous Lower Energy, Emissions & Noise
CLEEN
Federal Aviation Administration
www.faa.gov/go/cleen/

the VOLPE center

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
- COVID-19 pandemic has hit the aerospace sector particularly hard and the industry has considerably reduced ability to undertake research to advance new technologies
- Manufacturers have limited financial resources to develop technologies to reduce noise and emissions
- Government resources help mitigate technological risk and incentivize aviation manufacturers to invest in and develop cleaner, quieter technology





How Does Technology Reduce Environmental Impacts?

- **Noise:**
  - Reduce the source noise from the airframe and engine
    - Lower jet noise through higher bypass ratio engines (more air moved slower to gain the same thrust)
    - Advanced aerodynamic designs for jet engine components
    - Lower noise high lift devices: innovative flaps, slats, winglets
    - Landing gear noise reduction technologies and designs
  - Improve noise absorption
    - More effective light weight compact acoustic liners
- **Local air quality:**
  - Innovative low emissions (e.g., NO_x , nvPM etc.) combustor designs and technologies
    - Combustion physics changes enabled by high temperature materials and cooling technologies
- **Climate (CO_2):**
  - Novel technologies and designs to reduce drag and weight , increase lift, improve engine efficiency, thereby reducing the amount of fuel burned and CO_2 emitted (1 kg jet fuel = 3.16 kg CO2 when burned)
    - Increased efficiency engine designs
    - Lighter and stronger materials enabled by new manufacturing processes
    - Higher lift and lower drag wing designs
    - Reduced installed drag and weight through integrated propulsion systems
    - Model Based Systems Engineering – Digital simulations to optimize designs and minimize “re-do’s”

Continuous Lower Energy, Emissions & Noise (CLEEN) Program

- FAA led public-private partnership with 100% cost share 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

Success Stories from CLEEN Phase I & II

Pratt & Whitney fan system technologies successfully tested in an engine, contributing to overall benefits of a new geared turbofan design
Enables engine designs that provide 20% fuel burn reduction and 20 dB noise reduction

GE low-emission combustor entered fleet in 2016 on LEAP engine; installed on Airbus 320neo, Boeing 737 MAX, and COMAC C919. Further advanced combustion technology will be implemented in the GE9X-powered Boeing 777X.
Exceeds CLEEN NO_X emissions reduction goal

Delta TechOps/MCT completed in-service flight evaluation of engine fan blade coating that protects against erosion
Retained efficiency equating to 0.4% to 1% fuel burn savings

Boeing completed a noise flyover test of fan duct acoustic technology
Supported 1.5 to 2.4 EPNdB cumulative benefit for compact nacelle architectures

GE completed high fidelity demonstration of Flight Management System algorithms that enable optimized flight paths
1% fleet-wide average improvement in fuel burn

Boeing completed full scale ground test of a wing section built with advanced materials and manufacturing techniques
3.5% fuel savings through weight reduction

See CLEEN Program Summary and Status Report for more information

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 (LPT)
- 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
- 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

Assessment of CLEEN Technologies

Analytical Evaluation:

- Conducted by Georgia Tech through ASCENT COE Project 37
- Evaluating impact on fuel burn and noise out to 2050
- Have completed modeling of CLEEN Phase I technologies and all CLEEN Phase II fuel burn reduction technologies
- Have begun coordinating with companies on CLEEN III technologies

Fuel Burn Benefit:

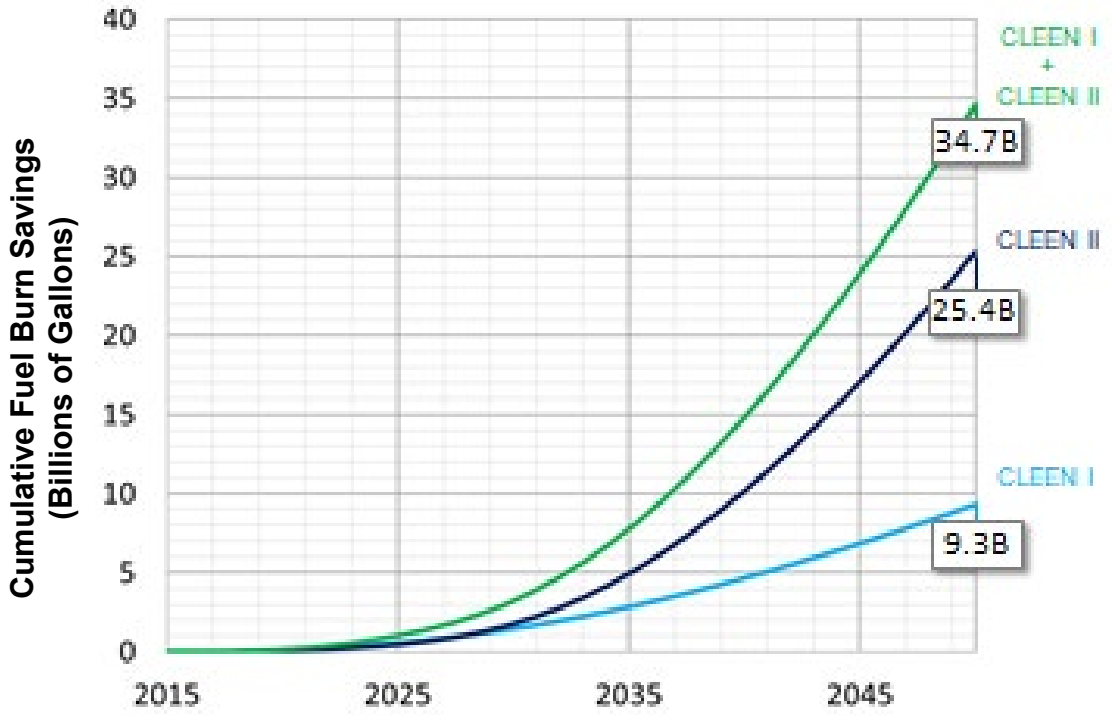
- 34.7 billion gallons of fuel saved cumulative by 2050 from CLEEN Phase I and II
- CO_2 emissions reduced by 404 million metric tons over this time period – the equivalent to removing 2.9 million cars from the road from 2020 to 2050

Noise Benefit:

- CLEEN Phase I Contributes to 14% decrease in the land area exposed to DNL 65 dB and greater
- CLEEN Phase II noise benefits assessment expected by November 2022 CLEEN Consortium Meeting

NOx Benefit:

- CLEEN Phase I and II technology cumulatively reduce LTO Nox emissions by over 1.3M metric tons through 2050 (preliminary)



Updated 1/4/2022

ASCENT Center of Excellence

For 18 years, FAA Office of Environment and Energy has relied on university centers of excellence to:

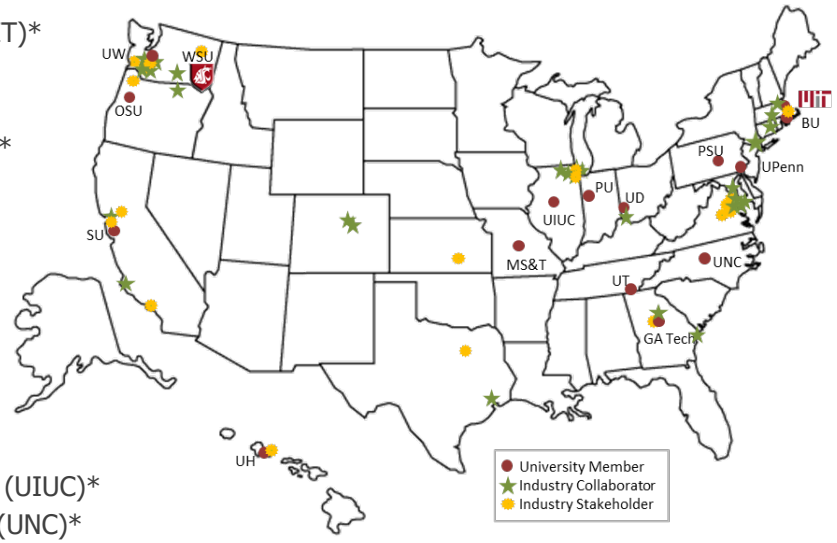
- Provide knowledge to inform decision making on environment and energy matters;
- Enable the introduction of innovative solutions to cost-effectively mitigate the environmental impacts of aviation; and
- Support the instruction of hundreds of professionals with knowledge of the environmental challenges facing aviation

ASCENT Research Portfolio

- In 2013, FAA established ASCENT to conduct research on environment and alternative jet fuels
- Portfolio covers broad range of topics on Alternative Jet Fuels, Emissions, Noise, Operations, and Analytical Tools
- Currently overseeing a large increase in the COE portfolio

Lead Universities:
Washington State University (WSU)
Massachusetts Institute of Technology (MIT)*

Core Universities:
Boston University (BU)*
Georgia Institute of Technology (Ga Tech)*
Missouri University of Science and Technology (MS&T)*
Oregon State University (OSU)
Pennsylvania State University (PSU)*
Purdue University (PU)*
Stanford University (SU)*
University of Dayton (UD)
University of Hawaii (UH)
University of Illinois at Urbana-Champaign (UIUC)*
University of North Carolina at Chapel Hill (UNC)*
University of Pennsylvania (UPenn)*
University of Tennessee (UT)
University of Washington (UW)



Multiple international partners

Advisory Committee (57 orgs)
5 airports
4 airlines
9 NGO/advocacy
8 aviation manufacturers
10 feedstock/fuel manufacturers
21 R&D, service to aviation sector

ASCENT Support

Federal Aviation Administration
Transport Canada
NASA
Environmental Protection Agency
Defense Logistics Agency - Energy
U.S. Dep't of Energy
U.S. Dep't of Agriculture
Air Force Research Laboratory

For more information: https://ascent.aero/

ASCENT Aircraft Technology Innovation 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

- **Overview of projects now available on ASCENT website:**
  https://ascent.aero/topic/Aircraft-Technology/

Sustainable Flight National Partnership

A sustained major technology development initiative, under which NASA and the FAA will work with industry, to accelerate the maturation of aircraft and engine technologies that enable a step-change reduction in fuel burn, emissions, and noise, (i.e., 25-30% lower fuel burn and 10-15 decibel noise reduction relative to best-in-class aircraft today).

SNFP will build upon successful cooperation among FAA, NASA, and industry:

- NASA's investments under the SFNP include a suite of integrated, large-scale aircraft and propulsion flight and ground technology demonstrations, including ultra-efficient wings (such as transonic truss-braced wings), small-core gas turbines, electrified and hybrid electric aircraft propulsion system(s), and new manufacturing techniques such as high-rate composite manufacturing to enable rapid production of such new aircraft.
- FAA R&D is focused on engine technologies, low-emissions combustion, and aircraft technologies that enable future operational concepts. At the FAA, these technology development efforts will be executed primarily under the CLEEN Program and the ASCENT Center of Excellence.

Summary

- Development of more efficient airframes and engines has resulted in significant aviation fuel, emissions, and noise reductions
- The US Government is leading a number of efforts and collaborating with the aviation industry to mature new technology that results in increased fuel efficiency and reduced noise and emissions
- Most of the CLEEN Phase II technology projects have concluded and CLEEN Phase III is underway
- New ASCENT projects continue to expand our aircraft technology research portfolio
- Collaboration with NASA Aeronautics via the Sustainable Flight National Partnership is key to providing the aircraft technology benefits needed to realize the U.S. Aviation Climate Action Plan goals