FAA Office of Environment & Energy

CLEEN Program Overview

Presented to: Aviation Noise & Emissions Symposium 2021

By: Chris Dorbian
FAA CLEEN Program Engineer

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Federal Aviation Administration

FAA Efforts Relating to Aircraft Emissions

Understanding Emissions

- Conducting particulate matter (PM) measurements
- Improving atmospheric modeling capabilities for regulatory tools
- Assessing impacts on air quality, climate change, and ozone layer
- Evaluating current aircraft, commercial supersonic aircraft, unmanned aerial systems, and commercial space vehicles

Reducing Emissions at the Source

- Aircraft technologies and architecture
- Modifications to fuel composition
- Vehicle operations
- Aircraft/engine standards (NO_X, CO_2, and PM standards)
- Future trends analysis

Focus of presentation

Mitigation

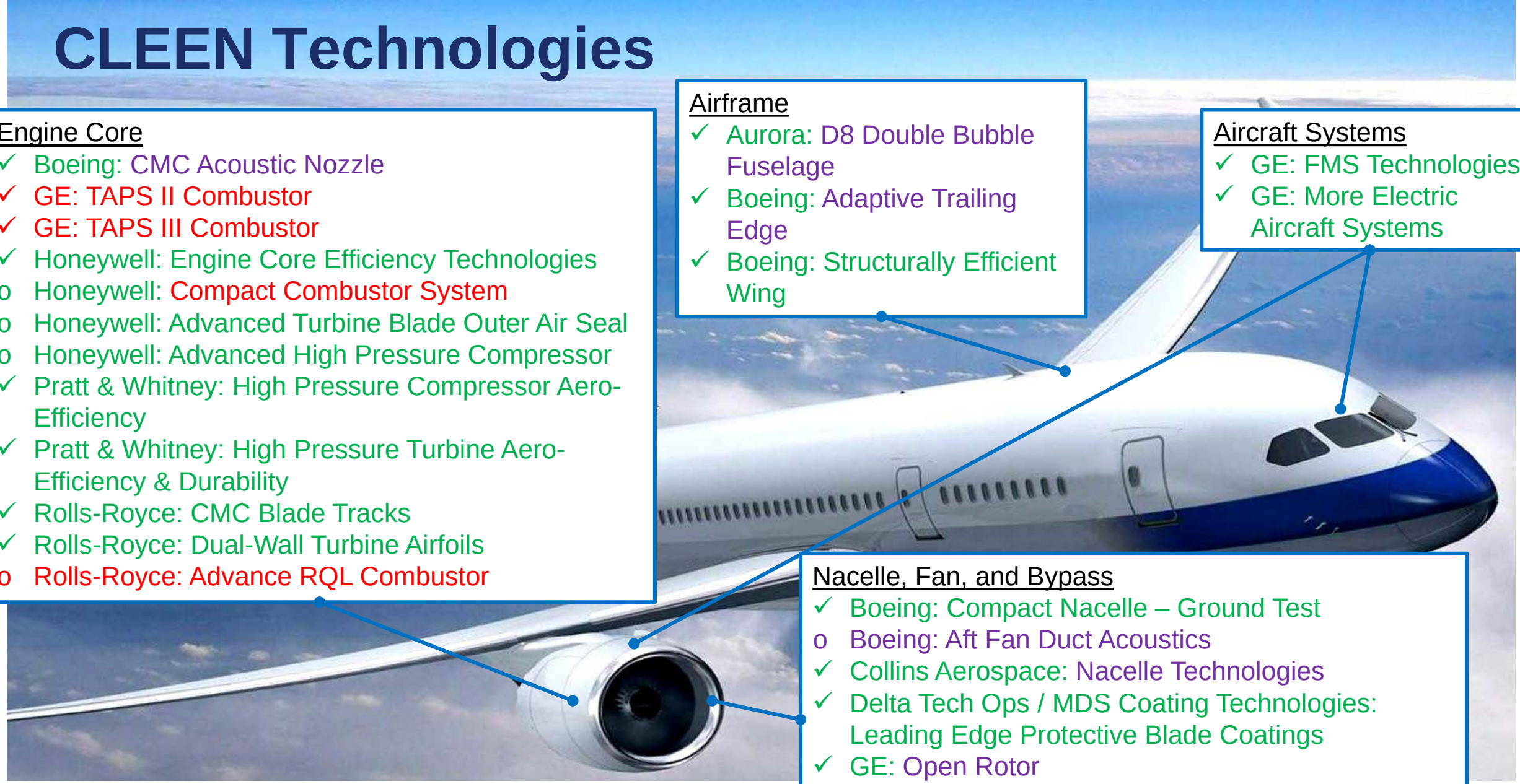
- Alternative fuel sources
- Policy measures (CORSIA)

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 sustainable aviation fuels
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies

	Phase I (Completed)	Phase II (Ongoing)	Phase III (Coming Soon)
Time Frame	2010-2015	2016-2020	2021-2025
FAA Budget	~$125M	~$100M	TBD
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	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

CLEEN Technologies



Engine Core
- ✓ Boeing: CMC Acoustic Nozzle
- ✓ GE: TAPS II Combustor
- ✓ GE: TAPS III Combustor
- ✓ Honeywell: Engine Core Efficiency Technologies
- o Honeywell: Compact Combustor System
- o Honeywell: Advanced Turbine Blade Outer Air Seal
- o Honeywell: Advanced High Pressure Compressor
- ✓ Pratt & Whitney: High Pressure Compressor Aero-Efficiency
- ✓ Pratt & Whitney: High Pressure Turbine Aero-Efficiency & Durability
- ✓ Rolls-Royce: CMC Blade Tracks
- ✓ Rolls-Royce: Dual-Wall Turbine Airfoils
- o Rolls-Royce: Advance RQL Combustor

Airframe
- ✓ Aurora: D8 Double Bubble Fuselage
- ✓ Boeing: Adaptive Trailing Edge
- ✓ Boeing: Structurally Efficient Wing

Aircraft Systems
- ✓ GE: FMS Technologies
- ✓ GE: More Electric Aircraft Systems

Nacelle, Fan, and Bypass
- ✓ Boeing: Compact Nacelle – Ground Test
- o Boeing: Aft Fan Duct Acoustics
- ✓ Collins Aerospace: Nacelle Technologies
- ✓ Delta Tech Ops / MDS Coating Technologies: Leading Edge Protective Blade Coatings
- ✓ GE: Open Rotor
- o GE: Low Pressure Ratio Advanced Acoustics
- o Honeywell: Advanced Acoustic Fan and Liners
- ✓ Pratt & Whitney: Geared Turbofan Technologies

Fuel
NO_x
Noise

✓ Completed Effort
o Continues in FY21

CLEEN Technologies that have already entered into the fleet:

Boeing

Adaptive Trailing Edge
~ 2% fuel burn reduction
~ 1.7 EPNdB cum noise reduction in some single and twin aisles

- **Boeing has adopted technologies from this project for use in commercial and defense products.**

Delta/MDS/America's Phenix

Leading Edge Protective Coating for Turbofan Blades
~1% fuel savings for Mainline and Regional Commercial carriers

- **Currently in service in the Delta fleet for operational evaluation.**

General Electric

TAPS II Combustor
> 60% margin to CAEP/6 LTO NOx achieved.

- **CLEEN Phase I NOx goal met.**
- **Entered fleet in 2016 on all LEAP engines for Airbus A320 Neo and Boeing 737MAX**

FMS/Engine and FMS/ATM Integration
0.7-1.0% fuel burn reduction

- **Entered into service on the LEAP engine on Boeing 737MAX, Airbus A320 Neo aircraft, and soon on the GE9X engine on Boeing 777X**

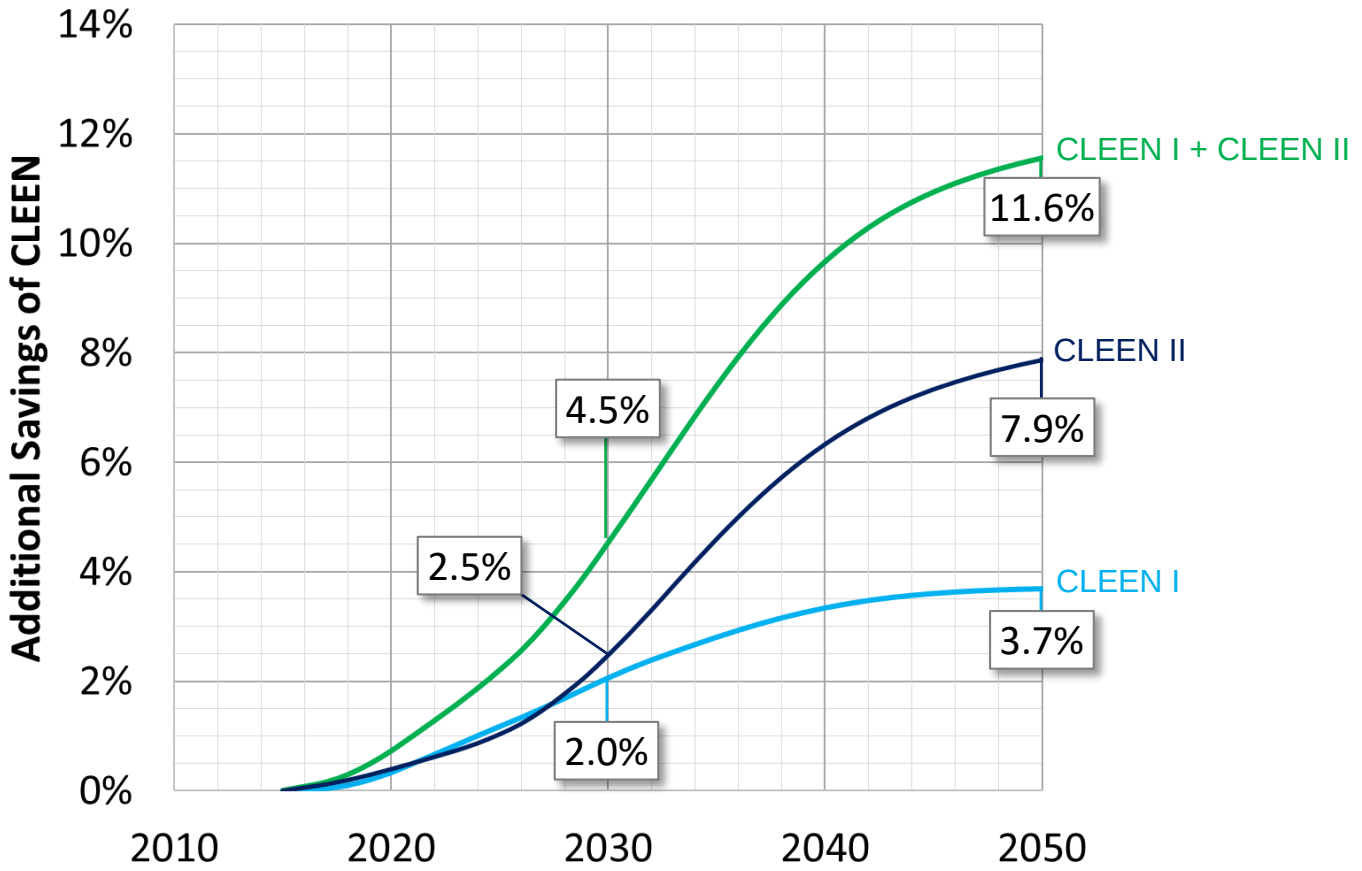
Twin Annular Pre-Swirler (TAPS) III Combustion System
~ 35% margin to the more stringent CAEP/8 (at 55 OPR) LTO NOx achieved.

- **Entering the fleet on the GE9X engine on Boeing 777X**

Improved tools and processes that have resulted from CLEEN technology maturation are leading to lower noise and emissions

Fleet-Level Fuel Burn Reduction

CLEEN Fuel Savings relative to Evolutionary Scenario

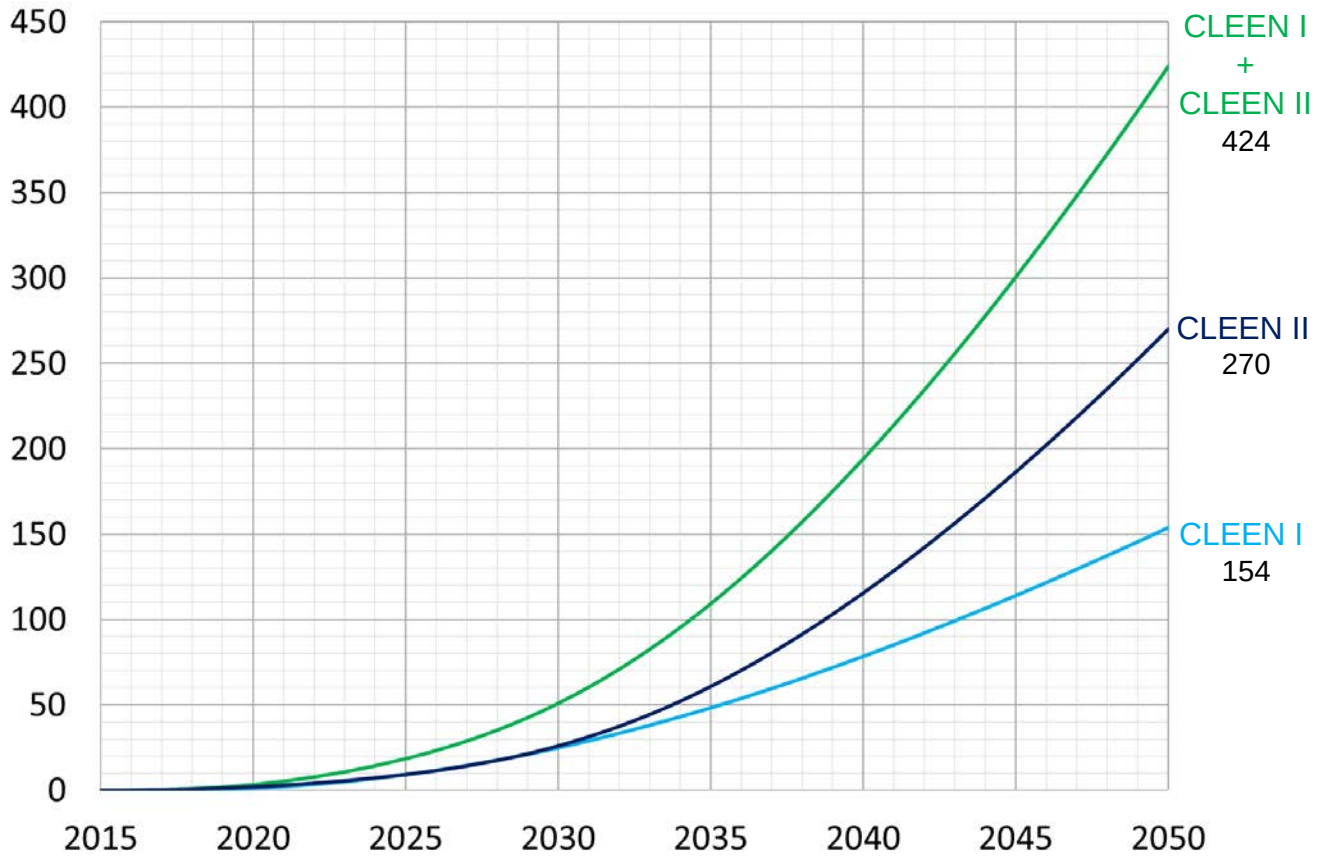


Note: Fuel burn savings are shown for a given year (not cumulative).

Analysis includes CLEEN Phase II fuel burn technologies modeled to date.

Fleet-Level Cumulative CO_2 Reduction

Cumulative CLEEN CO_2 Savings relative to Evolutionary Scenario (Million Metric Tonnes)



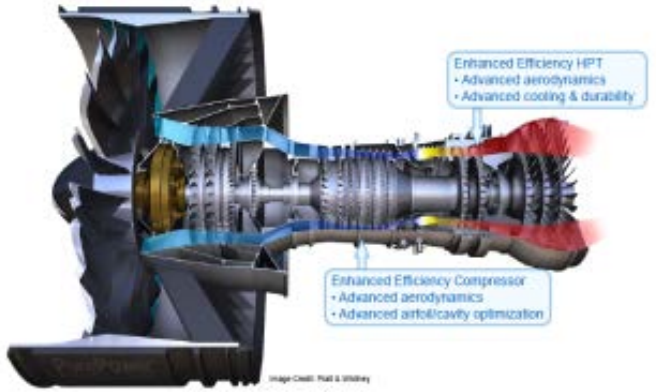
Note: Results assume a CO_2 production rate of 3.15 kg CO_2 / kg Fuel.
Analysis includes CLEEN Phase II fuel burn technologies modeled to date.

ASCENT Technology Projects

- **Expansion of environmental technology research portfolio into FAA's Center of Excellence for Alternative Jet Fuels and Environment**
- **Provides complementary venue for University-led research to advance industry state-of-the-art and expand knowledge broadly**
- **Themes:**
  - Improved technology noise modeling
  - System-level modeling and design considerations
  - Propulsion-airframe integration
  - Combustion
  - Turbomachinery
  - Supersonics
- **Overview of projects now available on ASCENT website:** https://ascent.aero/topic/Aircraft-Technology/

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 reached their maturation goals, with more expected in the next year, despite COVID impacts
- CLEEN Phase III will continue FAA efforts to accelerate maturation of environmental aircraft technologies into the fleet
- New ASCENT projects continue to expand our aircraft technology research portfolio



Chris Dorbian

CLEEN Program Engineer

Federal Aviation Administration
Office of Environment and Energy

Email: christopher.dorbian@faa.gov