

FAA Office of Environment & Energy

CLEEN Program Overview

Presented to: Aviation Noise & Emissions Symposium 2020

By: Chris Dorbian
FAA CLEEN Program Engineer

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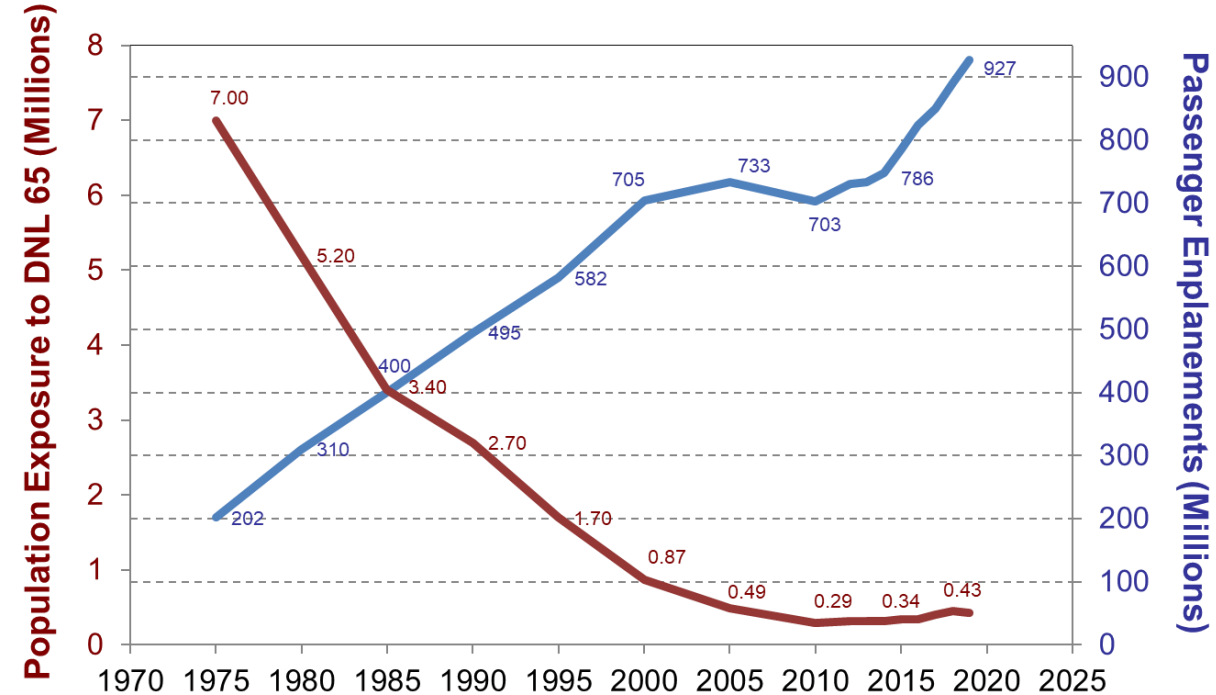
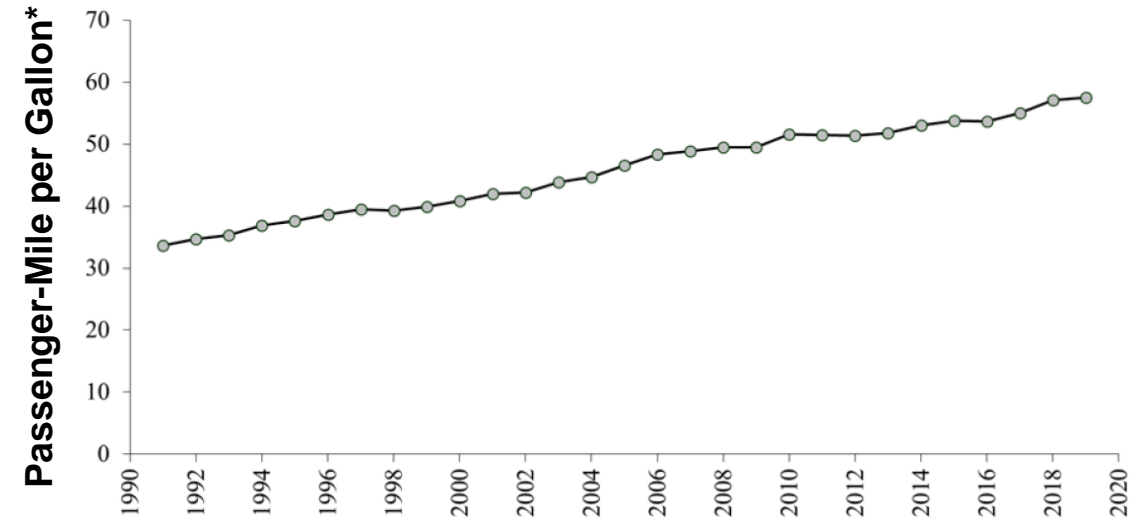


Federal Aviation
Administration



Why do we invest 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
- Government resources help mitigate this risk and incentivize aviation manufacturers to invest in and develop cleaner, quieter technology



* U.S. Department of Transportation – Bureau of Transportation Statistics, Air Carrier Summary Data, Form 41 and 298C Schedule T2 for 1991-2019 (July 29, 2019). Available at: <http://www.transtats.bts.gov/>.



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)
Time Frame	2010-2015	2016-2020
FAA Budget	~\$125M	~\$100M
Noise Reduction Goal	25 dB cumulative noise reduction relative to Stage 5	
Fuel Burn Goal	33% reduction	40% reduction
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)
Target Entry into Service	2018	2026



CLEAN Technologies

Engine Core

- ✓ Boeing: CMC Acoustic Nozzle
- ✓ GE: TAPS II Combustor
- ✓ GE: TAPS III Combustor
- ✓ Honeywell: Engine Core Efficiency Technologies
- Honeywell: Compact Combustor System
- Honeywell: Advanced Turbine Blade Outer Air Seal
- 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
- 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
- Collins Aerospace: Nacelle Technologies
- Delta Tech Ops / MDS Coating Technologies: Leading Edge Protective Blade Coatings
- ✓ GE: Open Rotor
- GE: Low Pressure Ratio Advanced Acoustics
- ✓ Pratt & Whitney: Geared Turbofan Technologies

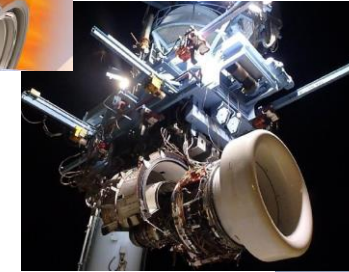
Fuel
NO_x
Noise

- ✓ Completed Effort
- Continues in FY20

CLEEN Highlights

CLEEN Phase I

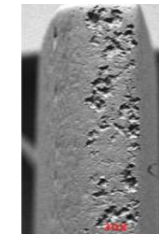
- GE TAPS II Combustor entered fleet in 2016 on LEAP engine; installed on Airbus 320neo, Boeing 737 MAX, and COMAC C919
Exceeds CLEEN Phase I NO_x Reduction Goal
- Pratt & Whitney Gen 2 geared turbofan propulsor technology successfully engine tested
Enables engine designs that provide 20% fuel burn reduction and 20 dB noise reduction
- Boeing CMC Nozzle flight tested on a 787 aircraft
Up to 1% fuel burn reduction and 2.3 dB noise reduction



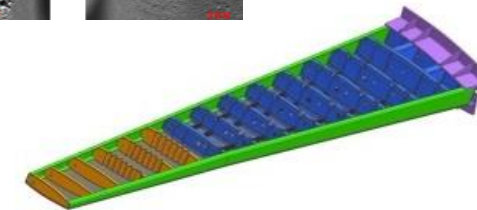
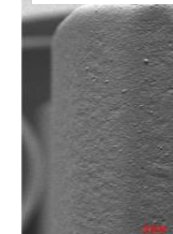
CLEEN Phase II

- Delta TechOps/MCT conducting in-service flight evaluation of fan blade leading edge protective coating
Retained efficiency equating to 0.4% to 1% fuel burn savings
- Boeing completed full scale ground test of Structurally Efficient Wing
3.5% fuel savings through weight reduction
- Boeing completed ground engine test of Compact Nacelle technology
1% fuel burn reduction; enables more efficient engine designs and improved acoustic treatments
- GE TAPS III combustion system will be implemented in the GE9X-powered Boeing 777X
Enables NO_x emissions 30% below CAEP/8
- GE completed TRL 6 demonstration of Flight Management System optimization algorithms, including electronic flight bag prototype
1% fleet-wide average improvement in fuel burn
- P&W high pressure compressor completed ground and flight tests—learnings integrated into GTF product line
0.8-1.0% fuel burn reduction relative to a state-of-the-art engine

Uncoated



Coated



Assessment of CLEEN Technologies

Analytical Evaluation:

- Conducted by Georgia Tech (through ASCENT and PARTNER COEs)
- Evaluating impact on fuel burn and noise out to 2050
- Modeled most, but not all, Phase I and II CLEEN Technologies
- Evaluation of Phase I captured in two technical reports

Key Results:

- 22 billion gallons of cumulative jet fuel saved – equivalent to 1.7 million cars taken off road – between 2025 and 2050
- Contributes to 14% decrease in the land area exposed to DNL 65 dB and greater

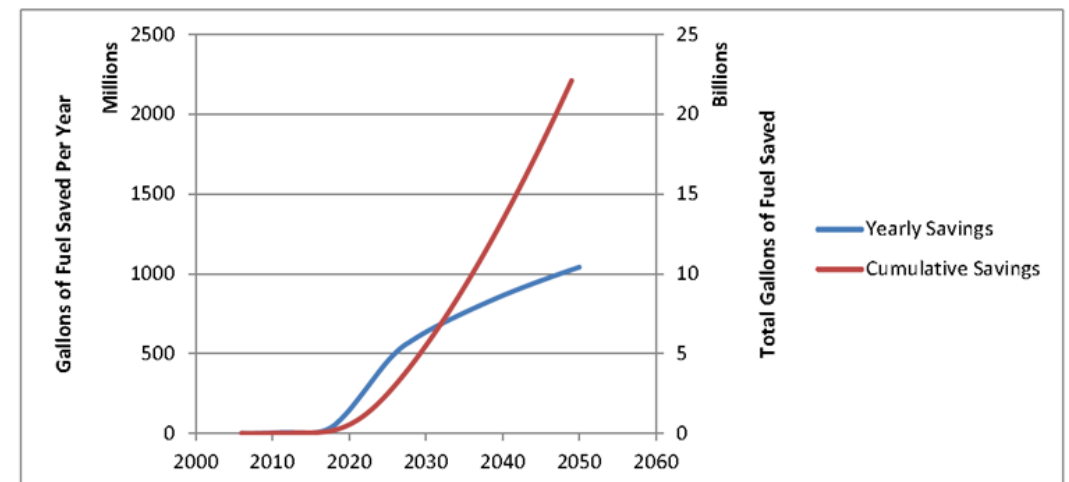


FIGURE 40: POTENTIAL FUEL BURN SAVINGS PROVIDED BY CLEEN TECHNOLOGIES MODELED IN THIS STUDY

CLEEN Phase III Overview – 1 of 2

	Phase III*	
Time Frame	2021-2025	
Entry into Service	2031	
FAA Budget	TBD	
Vehicle Type	Subsonic	Supersonic
Noise Goal	25 dB cumulative noise reduction cumulative to Stage 5 and/or reduces community noise exposure	Reduction during landing and takeoff cycle (LTO)
Fuel Burn Goal	-20% re: CAEP/10 Std	-
NO _x Goal	-70% re: CAEP/8 Std (LTO)	Reduction in absolute NO _x emissions
Particulate Matter Goal	Reduction rel: CAEP/11 Std (LTO)	-

- **CLEEN Phase III: Follow-on to CLEEN Phase I and Phase II Programs focusing on aircraft noise, emissions and energy**
- **Purpose:**
 - Mature previously conceived noise, emissions and fuel burn reduction technologies for civil subsonic and supersonic airplanes from TRLs of 3-5 to TRLs of 6-7 to enable industry to expedite introduction of these technologies into current and future aircraft and engines
 - Assess jet fuels that could provide reductions in emissions or improvements in efficiency, including fuels that enable advancements in aircraft and engine design. This includes both conventional and alternative fuels.

The third phase of the CLEEN Program also aims to advance the development and introduction of hydrocarbon jet fuels for aviation that could enable improvements in fuel efficiency and reductions in emissions. This includes fuel blends. The CLEEN Program is interested in fuels that are drop-in compatible with the existing pipeline and airport fueling infrastructure, but have changes in their composition that could help an aircraft meet these CLEEN Program goals.



CLEEN Phase III Overview – 2 of 2

	Phase III*	
Time Frame	2021-2025	
Entry into Service	2031	
FAA Budget	TBD	
Vehicle Type	Subsonic	Supersonic
Noise Goal	25 dB cumulative noise reduction cumulative to Stage 5 and/or reduces community noise exposure	Reduction during landing and takeoff cycle (LTO)
Fuel Burn Goal	-20% re: CAEP/10 Std	-
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Tier 1

Tier 2

Tier 3

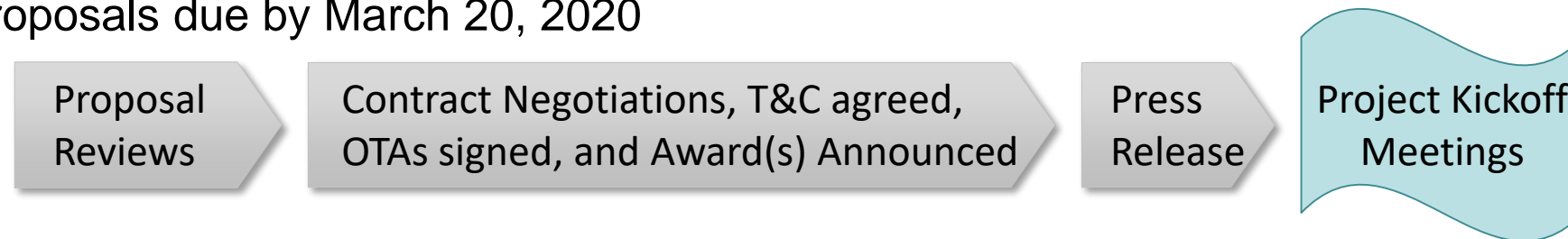
Tier 4

* The information for the third phase of the CLEEN Program is notional as the FAA is in the process of developing the final solicitation.

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CLEEN Schedule

- In the process of initiating CLEEN Phase III (2020-2025)
 - Market Survey was conducted in summer of 2018
 - Industry day took place on December 10, 2018
 - FAA Acquisition Strategy Review Board approval on September 4, 2019
 - FAA CFO approval on January 30, 2020
 - [Final Screening Information Request released February 25, 2020](#)
 - Proposals due by March 20, 2020

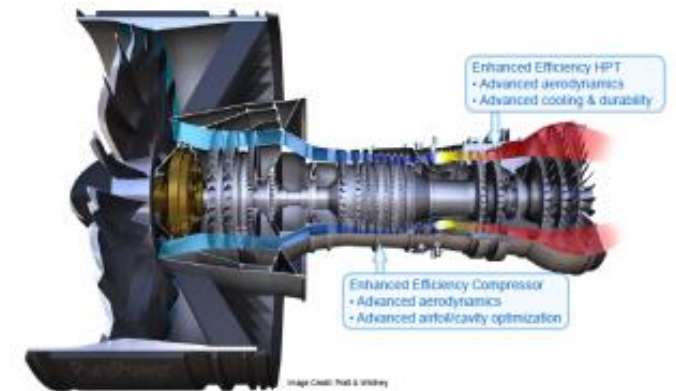


- Next CLEEN II Consortium Meetings (each include one public day):
 - May 5-7, 2020: Phoenix, AZ (Honeywell)
 - Nov 16(7)-19(20), 2020: Washington, DC (location TBD)
 - May 4-6, 2021: (location TBD)
 - Nov 2-4, 2021: Washington, DC (location TBD)



Summary

- Development of ever more efficient airframes and engines has produced the most significant aviation fuel, emissions, and noise reductions.
- The US Government (USG) 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.
- USG actions to improve aircraft and engine technology are carried out by the FAA, the National Aeronautics and Space Administration (NASA), and the Department of Defense (DoD), among others.





Chris Dorbian
CLEEN Program Engineer
Federal Aviation Administration
Office of Environment and Energy
Email: christopher.dorbian@faa.gov

