

FAA Continuous Lower Energy, Emissions and Noise (CLEEN) Program

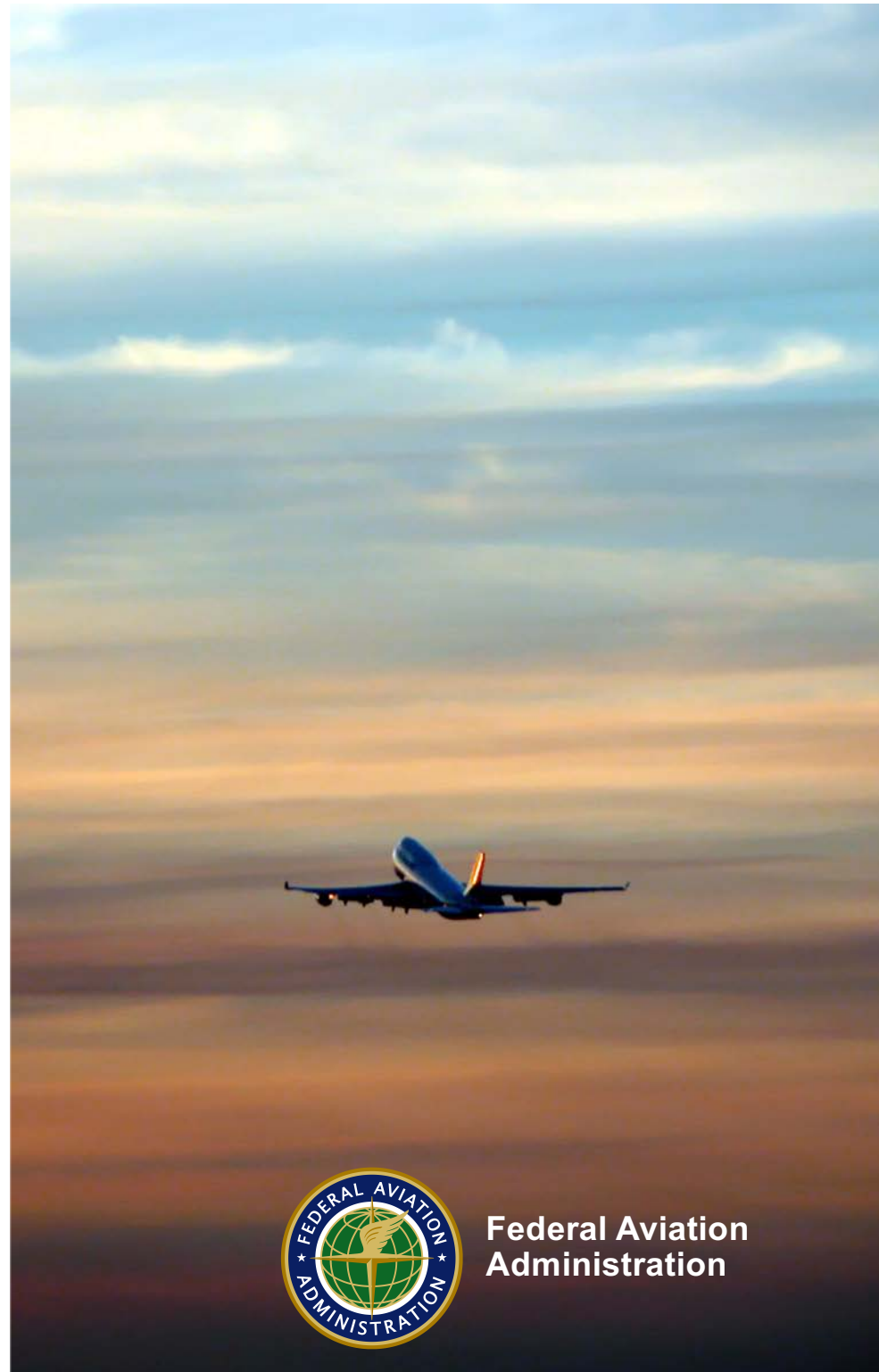
Presented to: ASCENT Advisory Committee

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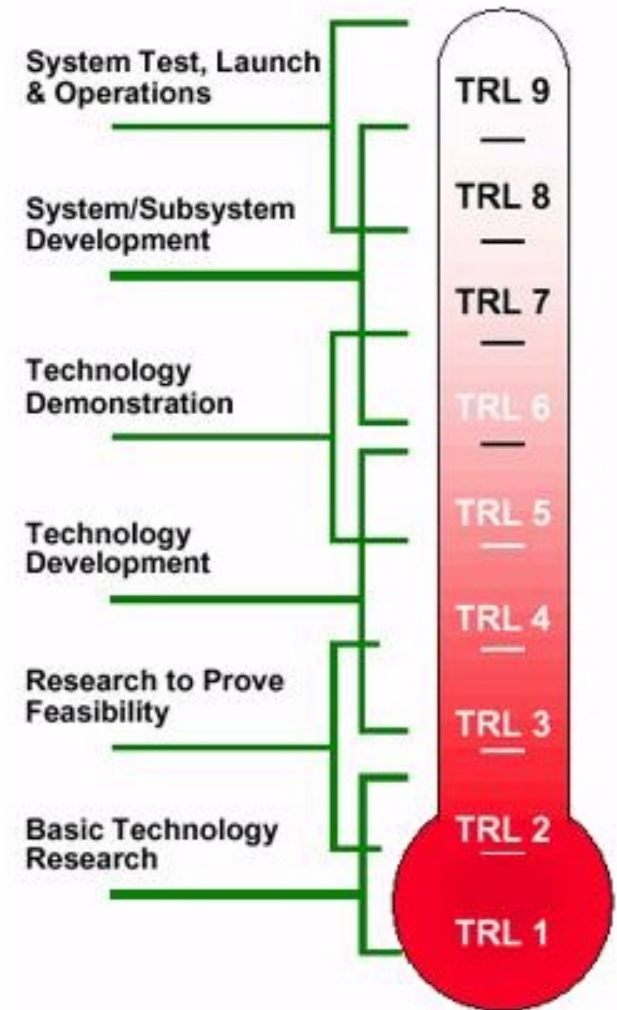


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CLEEN Program Overview

- FAA's principal environmental effort to accelerate development of new aircraft and engine technologies. One of three key programs to advance introduction of alternative jet fuels.
- Objective:
 - Mature previously conceived noise, emissions and fuel burn reduction technologies for civil subsonic airplanes from Technology Readiness Levels (TRL) 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 the benefits and advance the development and introduction of “drop-in” alternative jet fuels, including blends



Continuous Lower Energy, Emissions & Noise (CLEEN)

- FAA led public-private partnership with 50-50 cost share from industry
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies



	Phase I	Phase II
Time Frame	2010-2015	2015-2020
FAA Budget	~\$125M	~\$100M
Noise Reduction Goal	25 dB cumulative noise reduction cumulative to Stage 5	
NO _x Emissions Reduction Goal	60% landing/take-off NO _x emissions	75% landing/take-off NO _x emissions
Fuel Burn Goal	33% reduction	40% reduction
Entry into Service	2018	2026



CLEEN Fact Sheet (updated 7/30/18)

https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22534

CLEEN Awardees and Technologies



Awardees:

- Aurora Flight Sciences (Phase II only)
- Boeing
- Delta Tech Ops, America's Phenix, MDS Coating Technologies (Phase II only)
- General Electric (GE) Aviation
- Honeywell Aerospace
- Pratt & Whitney
- Rohr, Inc. / UTC Aerospace Systems (Phase II only)
- Rolls-Royce

Phase I Technologies:

- **9 Technologies focused on**
 - Revolutionary Engine Design
 - Engine redesign
 - Wing technologies
 - Flight Management System Improvements
 - Improved Combustors

Phase II Technologies:

- **14 Technologies focused on**
 - Fuselage redesign
 - Engine redesign
 - Wing technology
 - Flight Management System improvements
 - Improved combustion



CLEEN Phase I Benefits:

Demonstrated technologies that reduce noise, emissions and fuel burn

Boeing

Adaptive Trailing Edge

~ 2% fuel burn reduction

~ 1.7 EPNdB cum in some single and twin aisles

CMC Acoustic Nozzle

~ 1% fuel burn reduction

~2.3 EPNdB cumulative noise margin to Stage 4

Honeywell

Fuel Burn Technologies

CLEEN technologies contributed to ~5% fuel burn reduction as part of a 15.7% fuel burn reduction engine package

Pratt & Whitney

Geared Turbofan Technologies

CLEEN techs expand design space for engine with ~ 20% fuel burn reduction, > 20 EPNdB cumulative noise margin to Stage 4

General Electric

TAPS II Combustor (entered fleet in 2016)

> 60% margin to CAEP/6 LTO NOx was achieved

FMS/Engine and FMS/ATM Integration (Entered into service - LEAP engine on B737MAX, Airbus A320 Neo aircraft, and GE9X engine on 777X)

0.7-1.0% fuel burn reduction

Open Rotor

~26% reduction in fuel burn (re: 737-800)

~15-17EPNdB cumulative noise margin to Stage 4

Rolls Royce

Ceramic Matrix Composite Turbine Blade Track

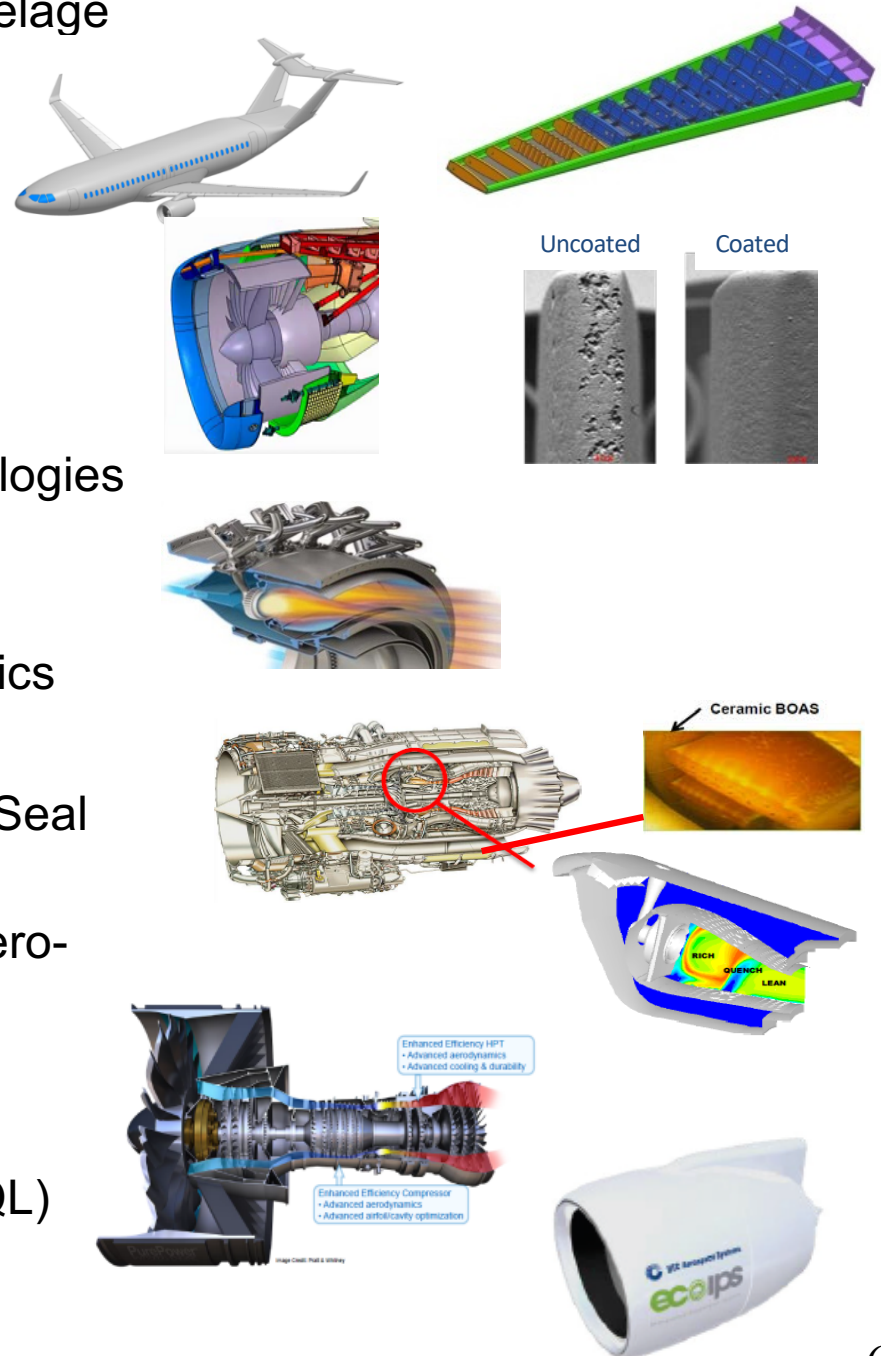
CMC blade tracks offer > 50% reduction in cooling flow and component weight.

Rolls-Royce – Dual Wall Turbine Airfoil

Dual Wall turbine airfoils provide > 20% reduction in cooling flow and increased operating temperature capability. CLEEN tech will provide ~1% fuel burn reduction

CLEEN Phase II Technologies

- Aurora Flight Sciences: D8 Double Bubble Fuselage
- Boeing: Structurally Efficient Wing (SEW)
- Boeing: Compact Nacelle – Short Inlet
- Delta Tech Ops/MDS Coating Technologies/America's Phenix: Leading Edge Protective Blade Coatings
- GE: TAPS III Combustor
- GE: Flight Management System (FMS) Technologies
- GE: More Electric Systems and Technologies for Aircraft in the Next Generation (MESTANG)
- GE: Low Pressure Ratio Fan Advanced Acoustics
- Honeywell: Compact Combustor System
- Honeywell: Advanced Turbine Blade Outer Air Seal (BOAS) System
- Pratt & Whitney: High Pressure Compressor Aero-Efficiency Techs
- Pratt & Whitney: High Pressure Turbine Aero-Efficiency & Durability Techs
- Rolls Royce: Advanced Rich Quench Lean (RQL) Low NOx Combustion System
- UTAS: Nacelle Technologies



CLEEN I - AJF Accomplishments

CLEEN program was instrumental in approval of alternative jet fuels, and supported:

- Approval of Hydroprocessed Esters and Fatty Acids (HEFA) fuel from renewable oils and fats in 2011 with crucial testing by Honeywell (ASTM D7566 Annex A2)
- Approval of Synthesized Iso-Paraffinic (SIP) for fuel from sugars in 2014 with performance testing by Pratt & Whitney (Annex A4)
- Testing and development of Alcohol to Jet (ATJ) fuels with testing of Byogy by Rolls-Royce and with funding of Lanzatech for process development via a Broad Agency Announcement (BAA) (Annex A5)
 - Later ATJ was approved under CLEEN II
- Obtained data for ASTM research reports for seven novel fuels that will be used in upcoming fuel approvals.
- Support for ongoing industry evaluation and review of data and expansion of the ASTM fuel specification to include more fuels.



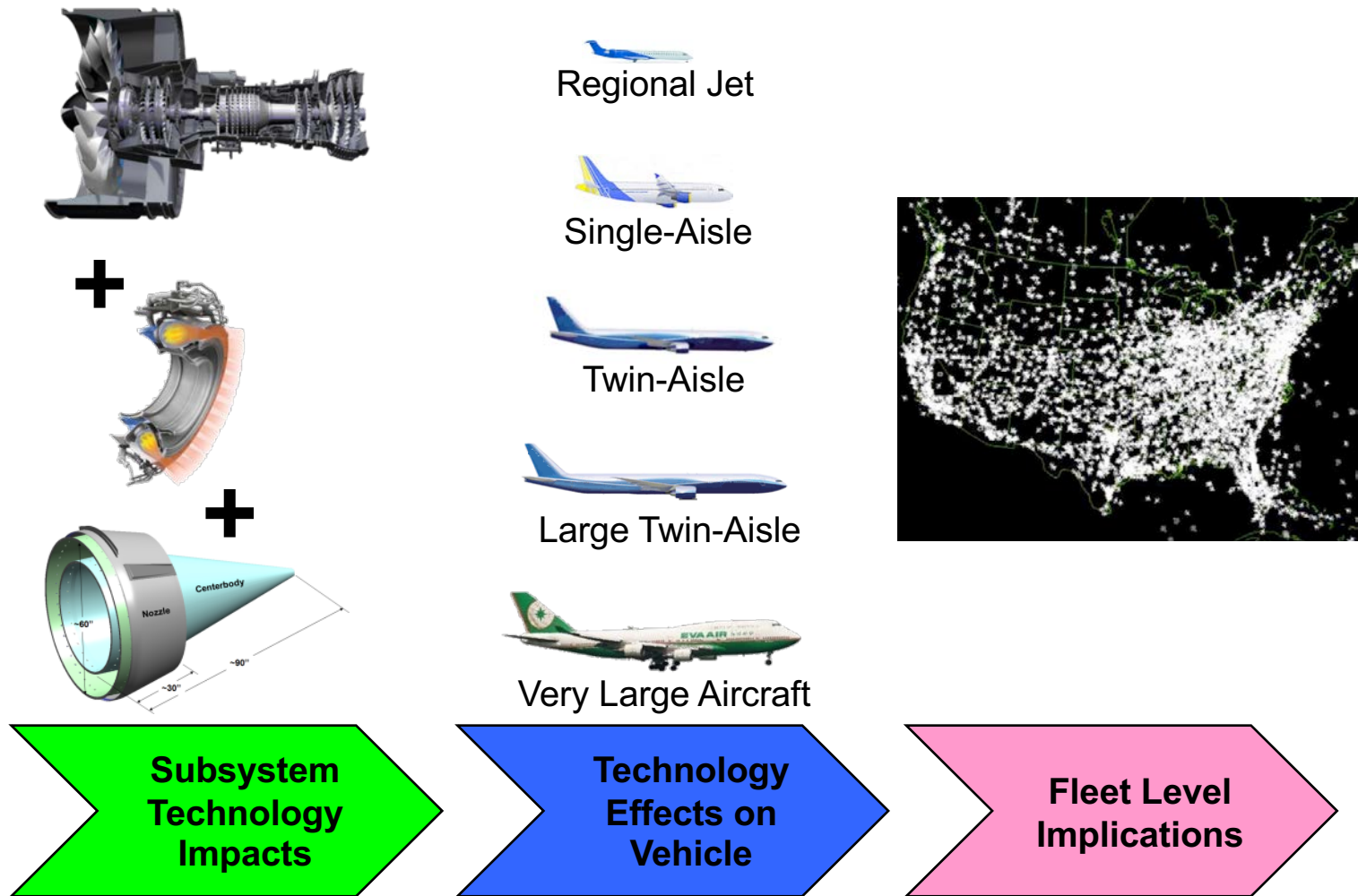
CLEEN II - AJF Testing

Company	Alternative Jet Fuels (AJF) Testing
GE: Alternative Jet Fuels Testing	<ul style="list-style-type: none"> <li>• NJFCP fuel 100% GEVO Alcohol to Jet-Synthetic Paraffinic Kerosene(ATJ-SPK) Complete <li>• 75% Hydroprocessed Esters and Fatty Acids- Synthetic Paraffinic Kerosene (HEFA-SPK) + 25% Hydrodeoxygenated Synthesized Aromatic Kerosene (HDO-SAK) <li>• 75% Jet A + 25% Hydrodeoxygenated Synthesized Aromatic Kerosene (HDO-SAK) <li>• 16% High Freeze Point- Hydroprocessed Esters and Fatty Acids (HFP-HEFA) (Neste Oil)/84% Jet Complete
Rolls Royce: Alternative Jet Fuels Testing	87% LanzaTech ATJ-SPK / 13% Swift non-renewable mesitylene



Aircraft Technology Modeling & Assessment (ASCENT-37)

- Model aircraft technologies at a physics-based level
- Assess technology combinations
- Identify fleet-wide benefits



<https://ascent.aero/project/clean-ii-technology-modeling-and-assessment/>



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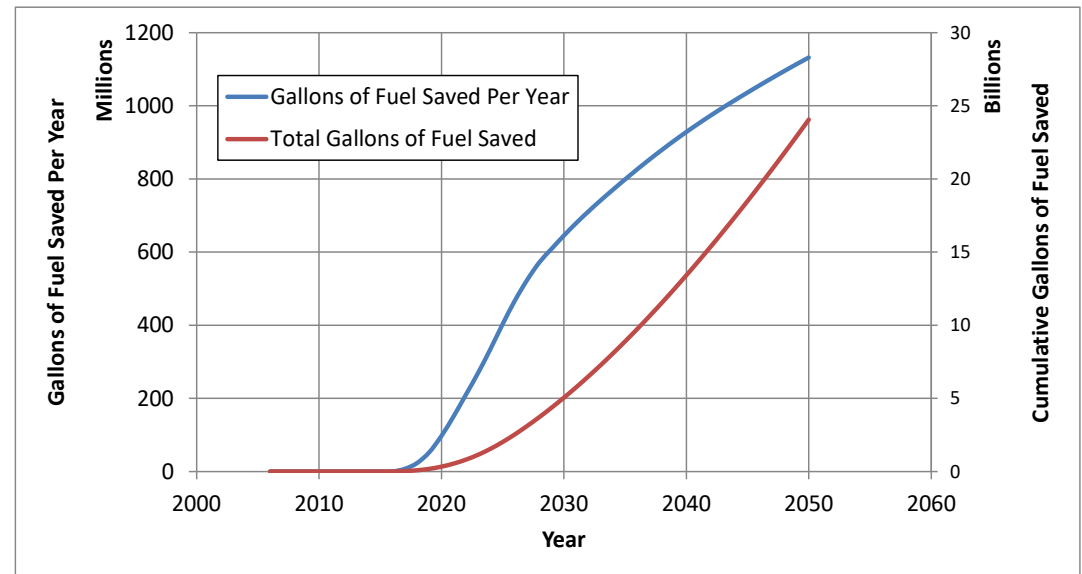
Assessment of CLEEN Technologies

Analytical Evaluation:

- Conducted by Georgia Tech
- Evaluating impact on fuel burn and noise out to 2050
- Modeled all Phase I CLEEN Technologies
- Evaluation of Phase I captured in two technical reports

Key Results:

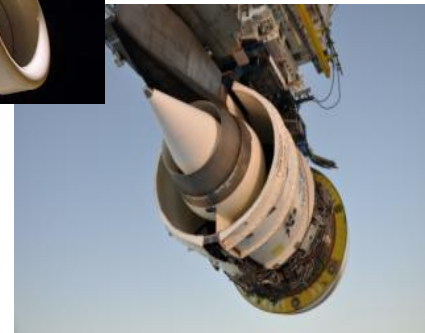
- 22 billion gallons of cumulative jet fuel saved
 - Equivalent to 1.7 million cars off road between 2025 and 2050
- Contribute to a 14% decrease in the land area exposed to DNL 65 dB and greater
 - Could enable 1.4 x increase in operations at same noise levels



CLEEN Highlights

CLEEN Phase I

- GE TAPS II Combustor entered fleet in 2016 on LEAP engine
- Pratt & Whitney Gen 2 geared turbofan propulsor technology successfully engine tested
- Boeing ceramic matrix composite nozzle flight tested on a 787 aircraft



CLEEN Phase II

- Aurora Flight Sciences tested key structural subcomponent that enables mass-efficient double bubble fuselage
- America's Phenix/Delta TechOps/MDS Coating Technologies currently conducting in-service flight evaluation of fan blade leading edge protective coating
- Boeing completed ground engine test of compact nacelle technology
- Rolls-Royce conducting full annular rig test for RQL low NOx combustion system
- Pratt & Whitney completed rig testing of advanced high pressure compressor technologies



FAA Reauthorization (signed 10/05/18)

SEC. 743. CLEEN AIRCRAFT AND ENGINE TECHNOLOGY PARTNERSHIP.

(a) COOPERATIVE AGREEMENT.—Subchapter I of chapter 475 of title 49, United States Code, is amended by adding at the end the following:

“§ 47511. CLEEN engine and airframe technology partnership

“(a) IN GENERAL.—The Administrator of the Federal Aviation Administration shall enter into a cost-sharing cooperative agreement, using a competitive process, with institutions, entities, or consortiums to carry out a program for the development, maturation, and testing of certifiable CLEEN aircraft, engine technologies, and jet fuels for civil subsonic airplanes.

“(b) CLEEN ENGINE AND AIRFRAME TECHNOLOGY DEFINED.—In this section, the term ‘CLEEN aircraft and engine technology’ means continuous lower energy, emissions, and noise aircraft and engine technology.

“(c) PERFORMANCE OBJECTIVE.—The Administrator shall establish the performance objectives for the program in terms of the specific objectives to reduce fuel burn, emissions and noise.”

(b) TECHNICAL AND CONFORMING AMENDMENT.— The table of contents of subchapter I of chapter 475 is amended by inserting after the item relating to section 47510 the following:

“47511. CLEEN engine and airframe technology partnership.”.

This language will be added to the US Law to give specific authority to FAA for the CLEEN Program



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CLEEN Phase III Outlook

- Notional CLEEN Phase III timeline (actual timeline in flux due to budget uncertainty)
- Market Survey: <https://faaco.faa.gov/index.cfm/announcement/view/31002>



In Summary

- CLEEN technology development and alternative fuels projects are progressing under CLEEN Phase II
- Next CLEEN II Consortium Meeting:
Nov 6-8; Washington, DC
- In the process of initiating CLEEN Phase III (2020-2025)
- For more on CLEEN <https://www.faa.gov/go/cleen>





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