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\textsubscript{X}, CO\textsubscript{2}, and PM standards)
- Future trends analysis

Mitigation
- Alternative fuel sources
- Policy measures (CORSIA)

Focus of presentation

For more information:
ASCENT: www.ascent.aero/
CAAFI: www.caafi.org/
CLEEN: www.faa.gov/go/cleen/
Volpe: www.volpe.dot.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

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Phase I (Completed)</th>
<th>Phase II (Ongoing)</th>
<th>Phase III (Coming Soon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Reduction Goal</td>
<td>25 dB cumulative noise reduction cumulative to Stage 5 and/or reduces community noise exposure (new goal for Phase III)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Burn Goal</td>
<td>33% reduction</td>
<td>40% reduction</td>
<td>-20% re: CAEP/10 Std.</td>
</tr>
<tr>
<td>NO(_X) Emissions Reduction Goal</td>
<td>60% landing/take-off NO(_X) emissions</td>
<td>75% landing/take-off NO(_X) emissions (-70% re: CAEP/8)</td>
<td></td>
</tr>
<tr>
<td>Particulate Matter Reduction Goal</td>
<td></td>
<td></td>
<td>Reduction relative to CAEP/11 Std</td>
</tr>
<tr>
<td>Entry into Service</td>
<td>2018</td>
<td>2026</td>
<td>2031</td>
</tr>
</tbody>
</table>

Federal Aviation Administration
CLEEN 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
  - 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
  - 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
  - Boeing: Aft Fan Duct Acoustics
- Collins Aerospace: Nacelle Technologies
- Delta Tech Ops / MDS Coating Technologies:
  - Leading Edge Protective Blade Coatings
- GE: Open Rotor
  - GE: Low Pressure Ratio Advanced Acoustics
  - Honeywell: Advanced Acoustic Fan and Liners
- Pratt & Whitney: Geared Turbofan Technologies

**Fuel NOx Noise**
- Completed Effort
  - 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