Continuous Lower Energy, Emissions and Noise (CLEEN) Program

Program Update

Presented to: REDAC E&E Subcommittee
By: Levent Ileri, CLEEN Program Manager
Date: March 26, 2014
Outline

• Aviation Environmental Goals
• CLEEN Overview and Goals
• Completed Technology Demonstrations
• CLEEN Technologies Updates
• CLEEN II Update
• Summary
Aviation Environmental Goals and Solutions

NextGen Environmental Goals

- Absolute reduction of significant community noise and air quality emissions impacts
- Improve NAS energy efficiency and supply of and access to alternative fuel sources
- Limit or reduce the impact of aviation Greenhouse Gas (GHG) emissions on the global climate
- Reduce significant aviation impacts associated with water quality

NextGen 5 Pillar Env. Approach

P1: Improved Scientific Knowledge and Integrated Modeling
P2: New Aircraft Technologies
P3: Sustainable Alternative Aviation Fuels
P4: Air Traffic Management Modernization and Operational Improvements
P5: Policies, Environmental Standards, and Market Based Measures
Continuous Lower Energy, Emissions and Noise (CLEEN)

- 5 yr effort to accelerate technology commercialization
- Reduces aircraft fuel burn, emissions and noise
- Renewable alt fuels, and alt fuel engine tests
- 50% cost share; total FAA budget: ~$125M

**Boeing**
- Ceramic Matrix Composite (CMC) Nozzle
- Adaptive Trailing Edge

**Honeywell**
- Increase engine efficiency, reduce engine weight, higher temp engine, improved higher turbine cooling

**Pratt & Whitney**
- Ultra-high Bypass Ratio Geared Turbofan

**General Electric**
- Twin Annular Pre-mixing Swirler (TAPS) II Low NOx Combustor
- Open Rotor
- Flight Management System / Air Traffic Integration
- Flight Management System / Engine Integration
CLEEN Program Goals

Develop and demonstrate (TRL 6-7) certifiable aircraft technology

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<tr>
<td>Noise (cum below Stage 4)</td>
<td>-32 dB</td>
<td>-42 dB</td>
<td>-52 dB</td>
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<tr>
<td>LTO NO$_x$ Emissions (Below CAEP 6)</td>
<td>-60%</td>
<td>-75%</td>
<td>better than -75%</td>
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<td>Aircraft Fuel Burn</td>
<td>-33%</td>
<td>-50%</td>
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* Technology Readiness Level (TRL) for key technologies = 4-6

Advance use of “drop-in” renewable alternative fuels

Bio feedstock → Fuel Production → Jet fuel
Completed Technology Demos

**Met CLEEN Goal**
Landing and Takeoff NOx reduced 60% re CAEP 6

- TAPS II Core Engine Test (TRL 6)
- Open Rotor Wind Tunnel Tests (TRL 5)
- Adaptive Trailing Edge Flight Demonstration (TRL 7)
- Ceramic Matrix Composite Nozzle Ground Test (TRL 6)
- Dynamic Synchronization Simulation (TRL 6)

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<th>2011</th>
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Federal Aviation Administration
CLEEN Technology Assessment Criteria

- Vetted tools compatible w/ AEDT
- Environmental perf & benefits at aircraft & fleet level
- Can identify synergistic technologies
- Can refine models with proprietary data

Subsystem Technology Impacts

Technology Effects on Vehicle

Fleet Level Implications

Regional Jet
Single-Aisle
Small Twin-Aisle
Large Twin-Aisle
Very Large Aircraft
Role of Technology Assessment

• Develop tools for effective technology assessment
• Assess suitability, environmental benefits and impact of aircraft technologies & alternative fuels on
  – Aircraft performance
  – Fleet operations
  – Environmental and economic policy
  – Global climate change
• Evaluate production costs & timeframes for new aircraft designs
• Compare tool results with CLEEN company estimates
• Foster collaboration and consensus among academic, commercial and governmental institutions
GE CLEEN Technologies Updates

TAPS II Combustor
- Completed design, manufacture, lab rig, sector, full combustor rig, and engine core test (TRL 6)
- Demonstrated in rig and core engine test > 60% NOx margin to CAEP/6, exceeding CLEEN goal.

Open Rotor
- Completed design, fabrication, and wind tunnel testing of modern scaled blades in partnership w/ NASA
- Fuel burn & noise significantly reduced for M=0.8 flight quieter than current single aisle aircraft

Targeted fuel burn, emissions, and noise reductions

Images courtesy of GE Aviation
GE CLEEN Technologies Updates

FMS/ATM Integration
- Completed Dynamic Quiet Climb & Wind Input Optimization
- Completed Trajectory Sync Simulation (TRL 6)

2014 Activities:
- Trajectory optimization

FMS/Engine Integration
- Adaptive engine control
- Vehicle health management
- Flight-propulsion control

2014 Activities:
- Further development, preparation for engine testing

Targeted fuel burn and noise reductions

Images courtesy of GE Aviation and Aviation Systems
Boeing CLEEN Technologies Updates

Accomplishments:
• Adaptive trailing edge project complete (TRL 7), including flight demo
• CMC nozzle ground test complete (TRL 6)
• Alternative fuel material compatibility testing complete

2014 Activities:
• CMC exhaust nozzle flight test (TRL 7)
• CMC exhaust nozzle second design cycle and fabrication trials

Targeted fuel burn and noise reductions

Images courtesy of Boeing
Ultra High Bypass Geared Turbofan with Advanced Fan System
• Completed technology and demonstrator engine detailed design

2014 Activities:
• Hardware fabrication, test planning for demonstrator engine
• Fan rig test preparation

Alternative Jet Fuels
• Engine and combustor testing of alternative jet fuels from multiple production pathways

Ultra High Bypass Geared Turbofan (GTF)

Wind Tunnel Tests
Targeted fuel burn and noise reductions

Ground Test
Honeywell CLEEN Technologies Updates

Fuel Burn Reduction Technologies
• Achieved TRL 6 for alloy 10 turbine disk material

2014 Activities:
• Core and engine tests to bring other technologies to TRL 6
  • Alt fuel testing

Alternative Jet Fuels
• Completed study on impact of aromatics on materials
• Completed biofuel Life Cycle Analyses (LCA) with MIT

Targeted fuel burn reduction

High T3 Impeller
• Low leakage air-air seals
• Advanced materials

Images courtesy of Honeywell
Rolls-Royce CLEEN Technologies Updates

**Dual Wall Turbine Airfoils**
- Completed casting trials
- Completed preliminary design

2014 Activities:
- Detailed design
- Initial hardware delivery

**CMC Blade Tracks**
- First ground engine test complete

2014 Activities:
- Further testing

**Novel Alternative Fuels Project**
- Lab, rig, and APU testing complete

Targeted fuel burn reductions
CLEEN and Next Steps

• CLEEN has already successfully accelerated environmentally beneficial technology development
  – TRL 5 wind tunnel tests demonstrated open rotor significantly reduces fuel burn and noise without reducing cruise speed
  – TRL 6 engine demo shows TAPS II combustor meets NOx reduction goal and is expected to enter service in 2016 (LEAP-X)
  – TRL 6 engine demo of CMC exhaust nozzle showed good structural performance (i.e., RR blade tracks)
  – TRL 6 simulation of flight management system / air traffic system trajectory synchronization was a success
  – TRL 7 flight test shows ATE improved aero performance & drag

• Based on success FAA plans to pursue CLEEN II

• CLEEN II could provide additional interagency collaboration opportunities
CLEEN vs CLEEN II Program Goals

Develop and demonstrate (TRL 6-7) certifiable aircraft technology

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<th>CORNERS OF THE TRADE SPACE</th>
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<th>CLEEN II 2015-2020</th>
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Advance use of “drop-in” renewable alternative fuels

- Bio feedstock
- Fuel Production
- Jet fuel
CLEEN II

• Program model based on successful CLEEN I
  – Requires cost share and tech maturation from TRL 3-5 to demonstration at TRL 6-7
  – Program work conducted 2015-2020
  – Requires industry to show path to commercial product so tech realizes benefits in the fleet with EIS 2020-2025

• Milestones:
  ✔ Market survey conducted May-July 2013
  ✔ Draft solicitation released publicly November 2013
  ✔ Industry day held in Washington D.C. December 2013
  – Obtaining internal approvals for planned release of solicitation early summer 2014
  – Contract award and work planned to begin May 2015
Questions