## 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

#### DE divergent trailing edge Figiet Figiet Core-to of Under side of outboard poton of wing MIST-5813

-Adaptive Trailing Edge

#### **Rolls-Royce**

-Ceramic Matrix Composite (CMC) Blade Tracks

-Dual-Walled Turbine Airfoils

#### 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

CORNERS OF THE TRADE SPACE	CLEEN (N+1) (EIS 2015-18) Ref: B737/CFM56-7B	N+2 (2020)* Ref: B777-200/GE-90	N+3 (2025)*
Noise (cum below Stage 4)	-32 dB	-42 dB	-52 dB
LTO NO <sub>x</sub> Emissions (Below CAEP 6)	-60%	-75%	better than -75%
Aircraft Fuel Burn	-33%	-50%	better than -70%

\* Technology Readiness Level (TRL) for key technologies = 4-6

#### Advance use of "drop-in" renewable alternative fuels



## **Completed Technology Demos**



### **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





## **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



## **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



## **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



Photo: Bob Ferguson

2014 Activities:

- CMC exhaust nozzle flight test (TRL 7)
- CMC exhaust nozzle second design cycle and fabrication trials



Targeted fuel burn and noise reductions



## **P&W CLEEN Technologies Updates**

#### Ultra High Bypass Geared

Turbofan with Advanced Fan

#### <u>System</u>

 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

**Ground Test** 

Targeted fuel burn and noise reductions



## 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



High T3• Low leakage air-air sealsImpeller• Advanced materials

Targeted fuel burn reduction



## **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

#### Blade tracks/shrouds and dual wall turbine airfoils

- Increased temp
- Reduced weight
- Improved SFC





## **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

CORNERS OF THE TRADE SPACE	CLEEN 2010-2015	CLEEN II 2015-2020
Noise (cum below Stage 4)	-32 dB	-32 dB
LTO NO <sub>x</sub> Emissions (Below CAEP 6)	-60%	-75%
Aircraft Fuel Burn	-33%	-40%

\* Technology Readiness Level (TRL) for key technologies = 4-6

#### Advance use of "drop-in" renewable alternative fuels



## **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

