FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

CLEEN II System Level Assessment Project 37

Lead investigator: Dimitri Mavris (PI), Jimmy Tai (Co-I) Project manager: Roxanna Moores, FAA

> September 26 & 27, 2017 Alexandria, VA

Opinions, findings, conclusions and recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of ASCENT sponsor organizations.



CLEEN Program Overview



CLEEN Program (2010-2015)

- Industry partners: Boeing, General Electric, Honeywell, Pratt & Whitney, Rolls-Royce
- CLEEN Fact Sheet http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20454

CLEEN II Program (2015-2020)

- Industry partners: Aurora Flight Sciences, Boeing, Delta/MDS/America's Phenix, General Electric, Honeywell, Pratt & Whitney, Rohr/UTC Aerospace Systems, and Rolls-Royce
- CLEEN II Fact Sheet http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20994

CLEEN II Overview



• Purpose:

- Mature previously conceived noise, emissions and fuel burn reduction technologies for <u>civil subsonic airplanes</u> 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
- CLEEN II technologies expected to be on a path for introduction into commercial aircraft by 2026

CLEEN II Program Goals



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

	CLEEN I	C	
Noise (cum below Stage 4)	-32 dB	-32 dB	and/or reduces the noise contour area in absolute terms
LTO NOx Emissions (below CAEP 6)	-60%	-75% (-70% vs. CAEP/8)	and/or reduces absolute NOx production over the aircraft's mission
Aircraft Fuel Burn	-33%	-40%	and/or supports the FAA's goal to achieve a net reduction in climate impact from aviation

Advance use of "drop-in" renewable alternative fuels







Aurora CLEEN II Technologies



Technology	Goal Impact	Benefits and Application
<text></text>	Fuel burn, enables NOx and noise reduction	 Wing-Mounted engine <i>configuration</i> benefit: ~16% fuel burn reduction when compared to 737-8 Enables ~16 EPNdB cumulative noise reduction and ~21% LTO NOx reduction With current technology and <i>integrated engines</i>, configuration provides: Up to 49% fuel burn reduction 40 EPNdB noise reduction 52% reduction in LTO NO_x emissions (re: CAEP/6) Additional technologies' benefits may stack on top of configuration benefit.

Boeing CLEEN II Technologies



Structurally Efficient Fuel Burn Lower weight, higher performance wing, reducing fuel burn by 3.5%	Technology	Goal Impact	Benefits and Application	
advanced manufacturing and composites technologies	Structurally Efficient Wing - enabled by advanced manufacturing and composites technologies	Fuel Burn	Lower weight, higher performance wing, reducing fuel burn by 3.5%	



Delta/MDS/America's Phenix CLEEN II Technologies



Technology	Goal Impact	Benefits and Application
Leading Edge Protective Coating for Turbofan Blades	Fuel Burn & Emissions	Up to 1% fuel savings at cruise Up to 2% fuel savings at max power
	PHANELAR REAL REAL RANGE OF THE RANGE OF THE REAL RANGE OF THE REAL RANGE OF THE RANGE OF THE REAL RANGE OF THE RANGE OF	Application: 1 st stage turbofan blades on a breadth of engines
	and the second second	200 per dille

GE CLEEN II Technologies (1 of 2)



Technology	Goal Impact	Benefits and Application
TAPS III Low-NOx Combustor Development	Emissions	35% margin to CAEP/8 NOx @ 55 OPR – large twin aisle class aircraft
More Electric Systems and Technologies for Aircraft in the Next Generation (MESTANG)	Fuel burn	Up to 3% fuel burn reduction for single-aisle aircraft



GE CLEEN II Technologies (2 of 2)



Technology	Goal Impact	Benefits and Application
Flight Management System (FMS) – Engine Integration	Fuel burn	Up to 1% fuel burn reduction
Alternative Jet Fuel Test and Evaluation	Alternative Fuels	Testing of drop-in alternative jet fuels to support ASTM International approval



Honeywell CLEEN II Technologies



Technology	Goal Impact	Benefits and Application
Compact Combustor System	Emissions, fuel burn	53% margin to ICAO CAEP/8 NOx
		Reduced weight, emissions
Advanced Turbine Blade Outer Air Seal (BOAS)	Fuel burn	Contributes to package that delivers 27% fuel burn reduction vs. in service baseline

Pratt & Whitney CLEEN II Technologies



Technology	Goal Impact	Benefits and Application
Compressor Aero- Efficiency Technologies	Fuel burn	0.8-1.0% fuel burn reduction
Turbine Aero- Efficiency and Durability Technologies	Fuel burn	0.8-1.0% fuel burn reduction



Rolls-Royce CLEEN II Technologies



Technology	Goal Impact	Benefits and Application
Advanced Rich Quench Lean (RQL) Low NOx Combustion System	NOx Reduction, Fuel burn	65% margin to ICAO CAEP/8 NOx
Alternative Jet Fuel Test and Evaluation (Area A)	Alternative Fuels	Testing of drop-in alternative jet fuels to support ASTM International approval



Rohr / UTAS CLEEN II Technologies



Technology	Goal Impact	Benefits and Application
Short, Integrated Fan Duct Thrust Reverser	Fuel burn	~1.0% fuel burn reduction
Advanced Acoustics	Noise	~2.5 EPNdB noise reduction*

* to offset short fan duct





Legacy Thrust Reverser Fan Duct



CLEEN II Thrust Reverser Fan Duct

High Level Objectives



- GA Tech integrates NASA design & analysis tools
- Assess technology combinations
- Identify synergistic technologies
- Conduct Fleet Level Assessment



ASCENT 37 – CLEEN II Assessment



- Following similar model to CLEEN I:
 - Exchange of proprietary data with CLEEN II companies to accurately represent their technologies at the subsystem and vehicle level
 - Vehicle and fleet-level assessment of CLEEN II and other complementary technologies impacts to fuel burn, emissions, and noise
 - More involvement by FAA with in-house use of tools. Divide and conquer modeling with GT to cover 8 companies
- Progress:
 - Georgia Tech has established necessary NDAs with companies for data exchange
 - Georgia Tech has led initial modeling discussions with each CLEEN II company, planning types of data to be exchanged, availability, timeline
 - Results have been-used to map out the next 4 years of effort
 - Assessment underway with a few of you

CLEEN II Assessment Flow





Modeling and Assessment Process





Fleet Fuel Burn Results – CLEEN I





Fleet Noise Results - 2050 65 DNL Contour – CLEEN I





Shared Modeling Responsibilities



- In CLEEN II, FAA and GT have split the system modeling roles to take advantage of FAA personnel modeling expertise
 - Both teams are using GT tools (EDS) to perform a portion of the technology modeling
- FAA Technology Modeling Responsibilities

 Delta/MDS; GE TAPS III; GE-FMS; PW
- GT Technology Modeling Responsibilities
 - Aurora; Boeing; GE-MESTANG; Honeywell; PW; Rolls-Royce; UTAS
- The final fleet assessments will include all CLEEN II
 technologies
 - GT to perform final fleet assessments

Summary



- Modeling work underway
 - Have completed first round of assessments (Delta & Aurora)
 - Ongoing modeling discussions with GE, PW, Honeywell, UTAS
- Expect initial round of fleet assessments late next year
- Questions?