Project 037 Continuous Lower Energy, Emissions, and Noise (CLEEN) II System-Level Assessment

Georgia Institute of Technology

Project Lead Investigator

Dimitri Mavris (PI)
Regents Professor
School of Aerospace Engineering
Georgia Institute of Technology
Mail Stop 0150
Atlanta, GA 30332-0150
Phone: 404-894-1557
Email: dimitri.mavris@ae.gatech.edu

University Participants

Georgia Institute of Technology

- PI(s): Dr. Dimitri Mavris (PI), Dr. Jimmy Tai (Co-PI)
- FAA Award Number: 13-C-AJFE-GIT-013
- Period of Performance: August 31, 2018 to August 31, 2019
- Task(s): Technology Modeling and Assessment

Project Funding Level

FAA funding was distributed at the following levels.

- Georgia Institute of Technology ($170,000)

The Georgia Institute of Technology (GT) has agreed to a total of $170,000 in matching funds. This total includes salaries for the project director, research engineers, and graduate research assistants and computing, financial, and administrative support, including meeting arrangements. The institute has also agreed to provide tuition remission for any students whose tuition is paid via state funds.

Investigation Team

- Dimitri Mavris, Principal Investigator, Georgia Institute of Technology
- Jimmy Tai, Co-Investigator, Georgia Institute of Technology
- Holger Pfaender, Technology Modeling and Assessment, Georgia Institute of Technology
- Chris Perullo, Technology Modeling and Assessment, Georgia Institute of Technology

Project Overview

The objective of this research project is to support the FAA by independently modeling and assessing the technologies that are being advanced under the Continuous Lower Energy, Emissions, and Noise (CLEEN) II program. This task involves direct coordination and data sharing in order to accurately model the environmental benefits of their developments at the vehicle and fleet levels. The long-term goals of this project include vehicle- and fleet-level assessments of fuel burn, emission, and noise benefits for CLEEN II aircraft and engine advancements. GT will create vehicle- and fleet-level Environmental Design Space (EDS) models using a combination of both CLEEN II and other public domain N+1 (next generation) and N+2 (two generations out) technologies. The outcomes of the technology and fleet assumptions from workshops conducted under the previous ASCENT Project 10 will be heavily leveraged for this effort. The ASCENT Project 10 was conducted in conjunction with industry, government, and academia to establish a standardized set of scenarios and assumptions regarding future demand and operations growth. These scenarios can be used to assess the impact of advanced technologies, such as those being developed under CLEEN II, on aviation-related fuel burn, emissions, and noise generation. Other technologies expected to enter service in the analysis time period will also be included to ensure that the predicted impacts are relevant and accurate.

Task 1 – Technology Modeling and Assessments

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Objective

The objective of this task is to support the FAA by independently modeling and assessing the technologies that are being developed under the CLEEN II program. This task will involve direct coordination and data sharing with CLEEN II companies in order to accurately model the environmental benefits of these technologies at the vehicle and fleet levels.

Research Approach

The objective of this research project is to support the FAA by independently modeling and assessing technologies developed under the CLEEN II program. This effort involves direct coordination and data sharing with companies developing technologies under CLEEN II, with the aim of accurately modeling the environmental benefits of these technologies at the vehicle and fleet levels.

GT was previously selected to perform all system-level assessments for the CLEEN program under PARTNER Project 36 and ASCENT Project 10. As a result, GT has a unique position from both a technical and programmatic standpoint to continue system-level assessments for CLEEN II. From a technical perspective, GT has significantly enhanced the EDS over the last five years to incorporate advanced, adaptive, and operational technologies targeting fuel burn, noise, and emissions. The EDS was successfully applied to all CLEEN I contractor technologies, including GE open rotors, twin-annular premixing swirler (TAPS) II combustors, flight management system (FMS) engines and airframes, Pratt & Whitney geared fans, Boeing adaptive trailing edge and ceramic matrix composite (CMC) nozzles, Honeywell hot section cooling and materials, and Rolls-Royce turbine cooling technologies. GT also gained significant experience in communicating system-level modeling requirements to industry engineers and translating the impacts to fleet-level fuel burn, noise, and emission assessments. This broad technical knowledge base covering both detailed aircraft and engine design and high-level benefit assessments puts GT in a unique position to assess CLEEN II technologies.

As the ultimate goal of this work is to conduct fleet-level assessments for aircraft representatives of future “in-service” systems, GT must create system-level EDS models using a combination of both CLEEN II and other public domain N+1 and N+2 technologies. The outcomes of technology and fleet assumption-setting workshops conducted under ASCENT Project 10 will be heavily leveraged for this effort. The consideration of non-CLEEN II technologies and potential future fleet scenarios will help to bound the impact of CLEEN II on future fleet fuel burn, emissions, and noise. During our first year, nondisclosure agreements were signed with all CLEEN II contractors.

Because the FAA will also be performing a portion of the EDS technology modeling work, EDS training was provided to the FAA in 2016 under ASCENT Project 10. This training provided the FAA with the skill set required to use EDS.

In the previous year of this project, GT initiated modeling activities with Aurora, Pratt & Whitney, and GE. This modeling process included validations of underlying EDS models, the information and data exchange necessary to model the individual technologies, and related EDS modeling activities. In addition, GT has assisted the FAA with in-house modeling of Delta/MDS and GE combustion technologies. This process has increased the FAA’s use of FAA personnel for EDS system-level assessment modeling.

Moving towards the end of the project, this year’s work will focus on completing vehicle- and fleet-level assessments for CLEEN II. This step includes final technology modeling details for each vehicle-level assessment of fuel burn, emissions, and noise generated by CLEEN II industry contractors in comparison to current best-in-class results, along with fleet-level estimates of fuel burn, emissions, and noise, including community noise impact estimates for multiple relevant airports. By quantifying this impact, we will quantify the number of increased operations per day that CLEEN II technologies can enable without increasing noise exposure to the surrounding community. While airports in the U.S. are generally not noise-constrained, some European airports have limited capacities to meet noise constraints. Understanding the impact of technologies on the future U.S. fleet is critical to quantifying interactions between economic growth (i.e., increased flight operations at a given airport) and community noise impacts.

GT has completed most of the technology modeling thus far. Remaining items include updates of technology models using the most recent data from contractors and a final fleet assessment. The table in the next section shows the current status of technology modeling. Where work remains, a brief description is provided after the table.

Milestone(s)

Milestone	Planned Due Date
Complete Modeling of Chosen Contractor's Technologies	08/2018
Preliminary Fleet Assessment	02/2019

Major Accomplishments

- GT has signed nondisclosure agreements with all CLEEN II contractors.
- The Delta/MDS modeling is complete.
- The Aurora modeling is complete.
- Modeling for GE FMS is complete, pending further updates to technology.
- Modeling for GE TAPS III is complete.
- The modeling framework for GE MESTANG is complete.
- Modeling for the Boeing compact nacelle is complete.
- Data exchange and assumptions for the Honeywell blade outer air seal and combustor have been defined.
- Modeling for the Boeing structurally efficient wing is complete.
- Modeling for the GE FMS is 80% complete, and the approach has been finalized.
- The modeling approach for the Collins slim nacelle has been finalized, and data and assumptions are being reviewed with Collins and PW.
- Ongoing efforts are being made to model UTAS zoned liner technology.
- The fleet analysis for CLEEN I is currently being repeated with the updated EDS version and preliminary CLEEN II estimates.
- An approach for modeling Pratt & Whitney technologies has been determined, and the modeling is 75% complete.

Contractor	Technology / Model Impact Area	Initial Modeling Discussions Held with Contractor	Modeling Underway	Percentage Complete	May Require Update
Aurora (technologies listed are subparts of double-bubble fuselage)	D8 Configuration	✓	✓	100%	No
Boeing	Structurally Efficient Wing	✓	✓	100%	No
	Compact Nacelle	✓	✓	100%	No
Delta/MDS/America's Phenix	Leading Edge Protective Fan Blade Coating	✓	✓	100%	No

Contractor	Technology / Model Impact Area	Initial Modeling Discussions Held with Contractor	Modeling Underway	Percentage Complete	May Require Update
GE	Twin-Annular Premixing Swirler (TAPS) III Low NOx Combustor	✓	✓	100%	No
	More Electric Systems and Technologies for Aircraft in the Next Generation (MESTANG)	✓	✓	90%	Yes
	Flight Management System (FMS)	✓	✓	100%	Yes
	Low-Pressure-Ratio Advanced Acoustic	✓		0%	
Honeywell	Compact Combustor	✓	✓	75%	Yes
	Turbine Blade Outer Air Seal	✓	✓	75%	No
Pratt & Whitney	Compressor and Turbine Aeroefficiency Technologies	✓	✓	65%	Yes
Collins/Rohr/UTAS	Slim Nacelle	✓	✓	75%	Yes
	Noise Liner Technologies	✓	✓	50%	Yes
Rolls-Royce	Advanced Rich Quench Lean Low NOx Combustor	✓		25%	

Remaining modeling work

- GE MESTANG
  - Received revised flight profiles from GE for baselining technology benefit; need to update EDS model and reconfirm benefit numbers with GE
- GE Low-Pressure-Ratio Advanced Acoustic
  - Waiting on information from GE; modeling not yet started
- Honeywell Compact Combustor
  - Received preliminary combustor correlation estimates from Honeywell
  - Will update correlations and finalize model when Honeywell completes high-pressure testing at NASA facility; only minor modeling changes required
- Honeywell Turbine Blade Outer Air Seal
  - Have received modeling impacts from Honeywell; have modeled similar technology for CLEEN I from Honeywell; will implement and confirm at the same time as the compact combustor validation

- Pratt & Whitney Compressor and Turbine Aeroefficiency Technologies
  - Have held several working meetings with Pratt & Whitney; have agreed upon a modeling approach; have received the required modeling data from Pratt & Whitney; will run sensitivity studies and verify trends with PW
- Collins Slim Nacelle
  - Iteration with PW almost complete (one meeting left) for sensitivity of the low-pressure drop bypass duct to engine performance, based on Collins' request
  - Have determined modeling approach for noise impacts; difficulty in capturing higher-fidelity noise attenuation effects; iterations on approach continuing with Collins
- Rolls-Royce Advanced Rich Quench Lean Low NOx Combustor
  - Will use the same modeling approach applied for Honeywell when Rolls-Royce completes testing, but with an empirical NOx model specific to Rolls-Royce

Publications
N/A

Outreach Efforts
CLEEN Consortium

Awards
None.

Student Involvement
Siyuan Wu is a graduate student who has been assisting with modeling of UTAS noise technologies. Wu has graduated and is currently working in industry.

Plans for Next Period
Future work will focus on completing the technology modeling and conducting fleet analysis assessments for presentation at the May 2020 Consortium.

This work will also support attendance at CLEEN Consortium meetings and preliminary and detailed contractor design reviews to identify any updates required for previously developed technology models.