ASCENT Research Update

Prepared for: REDAC E&E Subcommittee

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Office of Environment and Energy
Federal Aviation Administration

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FAA Centers of Excellence (COE)

For 16 years, FAA Office of Environment and Energy has relied on university centers of excellence to:

- Provide knowledge to inform decision making on environment and energy matters;
- Enable the introduction of innovative solutions to cost-effectively mitigate the environmental impacts of aviation; and
- Support the instruction of hundreds of professionals with knowledge of the environmental challenges facing aviation.

Timeline:

- In 2004, FAA established PARTNER Center of Excellence
- In 2013, FAA established Center of Excellence for Alternative Jet Fuels and Environment, a.k.a. Aviation Sustainability Center or ASCENT, that continues work of PARTNER with expanded efforts on alternative jet fuels R&D
- In 2015, FAA sunsets PARTNER Center of Excellence, which had 48 projects (research efforts shifted to ASCENT)
- **Currently standing up new projects that will take us over 80 ASCENT Projects in total**

ASCENT Center of Excellence (COE)

Lead Universities:

Washington State University (WSU)

Massachusetts Institute of Technology (MIT)*

Core Universities:

Boston University (BU)*

Georgia Institute of Technology (Ga Tech)*

Missouri University of Science and Technology (MS&T)*

Oregon State University (OSU)

Pennsylvania State University (PSU)*

Purdue University (PU)*

Stanford University (SU)*

University of Dayton (UD)

University of Hawaii (UH)

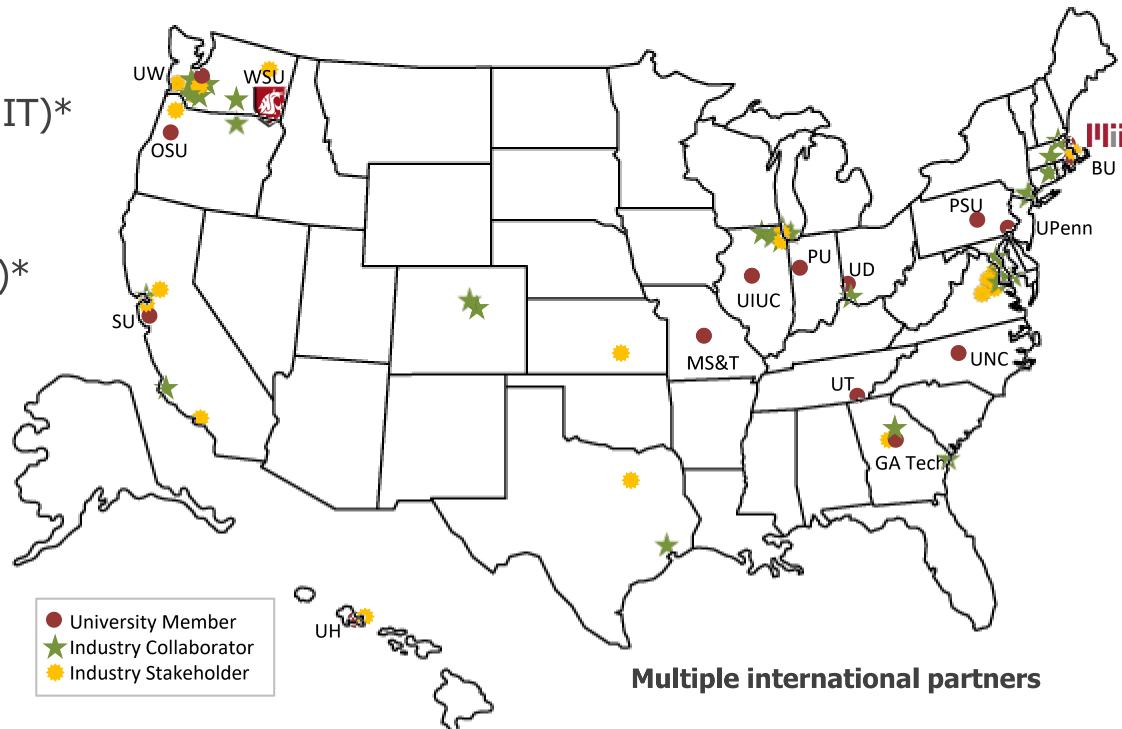
University of Illinois at Urbana-Champaign (UIUC)*

University of North Carolina at Chapel Hill (UNC)*

University of Pennsylvania (UPenn)*

University of Tennessee (UT)

University of Washington (UW)



Multiple international partners

Advisory Committee - 57 organizations:

5 airports
4 airlines
9 NGO/advocacy
8 aviation manufacturers
10 feedstock/fuel manufacturers
21 R&D, service to aviation sector

** Indicates university was also a member of PARTNER COE*

For more information: https://ascent.aero/

Federal Aviation Administration

ASCENT COE Update

ASCENT Research Portfolio

Portfolio covers broad range of topics on Alternative Jet Fuels, Emissions, Noise, Operations, and Analytical Tools

Over last few years have stood up many projects to advance aircraft technology innovation and supersonic flight

Projects listed by topic: https://ascent.aero/projects-by-topic/

ASCENT Leadership

- Mike Wolcott of WSU - Director
- John Hansman of MIT - Co-Director
- Carol Sim of WSU - Assistant Director

ASCENT Annual Technical Report Summaries*

* ASCENT Annual Tech Reports available for download at: https://ascent.aero/resources

Federal Aviation Administration

ASCENT / PARTNER Support

Federal Aviation Administration

Transport Canada

NASA

Environmental Protection Agency

Defense Logistics Agency - Energy

U.S. Dep't of Energy

U.S. Dep't of Agriculture

Air Force Research Laboratory

ASCENT COE:

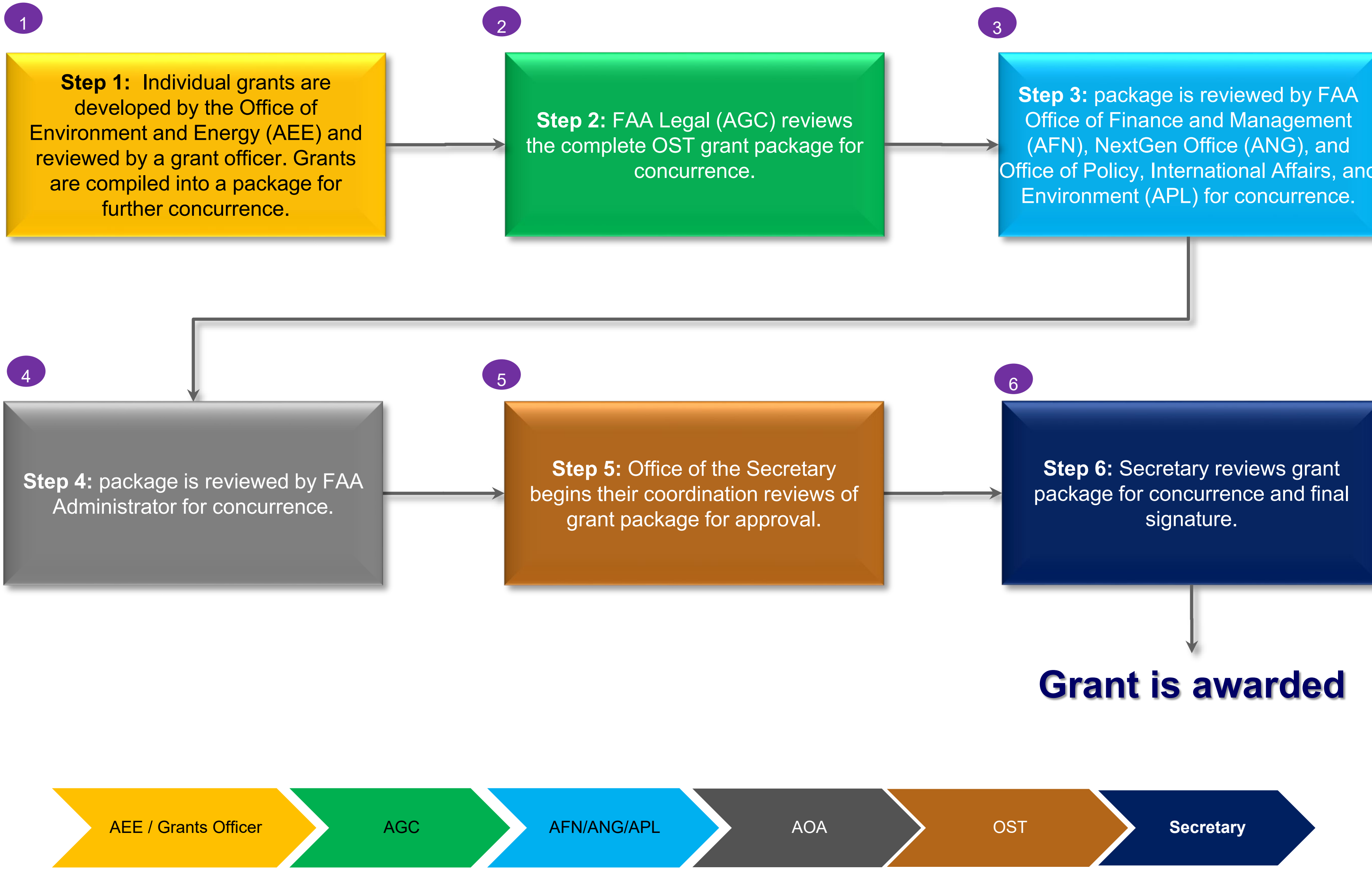
- In operation: 2013 to present
- $15M+ annual funding level
- $81.6M funding to date

PARTNER COE:

- In operation: 2004 to 2015
- $62.8M over 10 years

FAA COE research requires 100% cost share. This has led to significant collaboration among universities, industry, and international research programs

COE Grant Approval Process



ASCENT COE

Aircraft Technology Innovation Portfolio

https://ascent.aero/topic/Aircraft-Technology/

ASCENT's aircraft technology innovation research advances the industry state-of-the-art and expands the technical knowledge base.

ASCENT Aircraft Technology Innovation Projects

- 010- Aircraft Technology Modeling and Assessment
- 037 - CLEEN II System Level Assessment
- 047 - Clean Sheet Supersonic Aircraft Engine Design and Performance
- 050 - Over-Wing Engine Placement Evaluation
- 051 - Combustion concepts for next-generation aircraft engines to reduce fuel burn and emissions
- 052 - Comparative Assessment of Electrification Strategies for Aviation
- 055 - Noise Generation and Propagation from Advanced Combustors
- 056 - Turbine Cooling Through Additive Manufacturing
- 059 - Jet Noise Modeling to Support Low Noise Supersonic Aircraft Technology Development
- 063 - Parametric Noise Modeling For Boundary Layer Ingesting Propulsors
- 064 - Alternative Design Configurations to Meet Future Demand
- 066 - Evaluation of High Thermal Stability Fuels
- 067 - Impact of Fuel Heating on Combustion and Emissions
- 068 - Combustor Wall Cooling Concepts for Dirt Mitigation
- 070 - Reduction of nvPM emissions via innovation in aero-engine fuel injector design
- 071 - Predictive Simulation of Soot Emission in Aircraft combustors
- 074 - Low Emissions Pre-Mixed Combustion Technology for Supersonic Civil Transport
- 075 - Improved Engine Fan Broadband Noise Prediction Capabilities
- 076 - Improved Open Rotor Noise Prediction Capabilities
- 077 - Noise Measurements for UAS/UAM Vehicles and Identify Noise Reduction Opportunities
- 079 (IN DEVELOPMENT) - Novel Noise Liner Development Enabled by Advanced Manufacturing

ASCENT Alternative Jet Fuels Research Portfolio

https://ascent.aero/topic/alternative-fuels/

Alternative jet fuels have the potential to provide benefits to the aviation industry in terms of energy security and reduction in greenhouse gases. Their production can support rural economic growth and job creation through the development of economically valuable feedstocks and fuel processing facilities.

ASCENT Alternative Jet Fuels Projects

- 001 - Alternative Jet Fuel Supply Chain Analysis
- 025-030 & 034 - National Jet Fuel Combustion Program
- 031 - Alternative Jet Fuels Test and Evaluation
- 032 (COMPLETE) - Worldwide LCA of GHG Emissions from Petroleum Jet Fuel
- 033 - Alternative Fuels Test Database Library
- 052 - Comparative Assessment of Electrification Strategies for Aviation
- 065 - Fuel Testing Approaches for Rapid Jet Fuel Prescreening
- 066 - Evaluation of High Thermal Stability Fuels
- 067 - Impact of Fuel Heating on Combustion and Emissions
- 073 - Combustor Durability with Alternative Fuel Use
- 080 (IN DEVELOPMENT) - Hydrogen Production Alternatives for Sustainable Aviation Fuel (SAF) Production

ASCENT Emissions Research Portfolio

https://ascent.aero/topic/emissions/

Demand for air transportation, both for passenger and cargo service, has been increasing and airports are expanding to accommodate it. This growth is accompanied by an increase of emissions from aircraft, ground services equipment and vehicle traffic on and near airports. All this activity impacts the local air quality around airports and human health.

ASCENT Emissions Projects

- 002 - Ambient Conditions Corrections for Non-Volatile PM Emissions Measurements
- 013 (COMPLETE) - Micro-Physical Modeling & Analysis of ACCESS 2 Aviation Exhaust Observations
- 014 (COMPLETE) - Analysis to Support the Development of an Aircraft CO2 Standard
- 018 - Community Measurement of Aviation Emission Contribution of Ambient Air Quality
- 019 - Development of Improved Aviation Emissions Dispersion Capabilities for AEDT
- 020 (COMPLETE) - Development of NAS wide and Global Rapid Aviation Air Quality
- 021 (COMPLETE) - Improving Climate Policy Analysis Tools
- 024 (COMPLETE) - Emissions Data Analysis for CLEEN, ACCESS, and Other Recent Tests
- 022 - Evaluation of FAA Climate Tools
- 039 - Naphthalene Removal Assessment
- 047 - Clean Sheet Supersonic Aircraft Engine Design and Performance
- 048 - Analysis to Support the Development of an Engine nvPM Emissions Standard
- 051 - Combustion concepts for next-generation aircraft engines to reduce fuel burn and emissions
- 052 - Comparative Assessment of Electrification Strategies for Aviation
- 058 - Improving Policy Analysis Tools to Evaluate Aircraft Operations in the Stratosphere
- 064 - Alternative Design Configurations to Meet Future Demand
- 067 - Impact of Fuel Heating on Combustion and Emissions
- 068 - Combustor Wall Cooling Concepts for Dirt Mitigation
- 069 - Transitioning a research nvPM mass calibration procedure to operations
- 070 - Reduction of nvPM emissions via innovation in aero-engine fuel injector design
- 071 - Predictive Simulation of Soot Emission in Aircraft combustors
- 074 - Low Emissions Pre-Mixed Combustion Technology for Supersonic Civil Transport
- 078 (IN DEVELOPMENT) - Contrail Avoidance Decision Support and Evaluation

ASCENT Noise Research Portfolio

https://ascent.aero/topic/noise/

The growth in demand for passenger and cargo air transportation has pushed operators to increase the number and frequency of their scheduled flights. The expansion in operations and the changes to the airspace aimed at accommodating it have resulted in renewed public concern.

ASCENT Noise Projects

- 003 - Cardiovascular Disease and Aircraft Noise Exposure
- 004 (COMPLETE) - Estimate of Noise Level Reduction
- 005 (COMPLETE) - Noise Emission and Propagation Modeling
- 007 (COMPLETE) - Civil, Supersonic Over Flight, Sonic Boom (Noise) Standards Development
- 008 - Noise Outreach
- 009 (NEW) - Geospatially driven noise estimation module
- 017 - Pilot Study on Aircraft Noise and Sleep Disturbance
- 038 – Rotorcraft Noise Abatement Procedures Development
- 040 (COMPLETE) – Quantifying Uncertainties in Predicting Noise in Real-world Situations
- 041 - Identification of Noise Acceptance Onset for Noise Certification Standards of Supersonic Airplanes
- 042 - Acoustical Model of Mach Cut-off
- 043 – Noise Power Distance Re-Evaluation
- 044 - Aircraft Noise Abatement Procedure Modeling and Validation
- 049 - Urban Air Mobility Noise Reduction Modeling
- 050 - Over-Wing Engine Placement Evaluation
- 053 - Validation of Low-Exposure Noise Modeling by Open-Source Data Mgmt and Visualization Systems Integrated w/ AEDT
- 055 - Noise Generation and Propagation from Advanced Combustors
- 057 - Support for Supersonic Aircraft Noise Efforts in ICAO CAEP
- 059 - Jet Noise Modeling to Support Low Noise Supersonic Aircraft Technology Development
- 061 - Noise Certification Streamlining
- 062 - Noise Model Validation for AEDT
- 063 - Parametric Noise Modeling For Boundary Layer Ingesting Propulsors
- 072 - Aircraft noise exposure and market outcomes in the US
- 075 - Improved Engine Fan Broadband Noise Prediction Capabilities
- 076 - Improved Open Rotor Noise Prediction Capabilities
- 077 - Measurements to Support Noise Certification for UAS/UAM Vehicles and Identify Noise Reduction Opportunities
- 079 (IN DEVELOPMENT) - Novel Noise Liner Development Enabled by Advanced Manufacturing

ASCENT Operations Research Portfolio

https://ascent.aero/topic/operations/

Aviation operations at an airport can affect local communities in ways that are dependent on how and where aircraft are flown. Aviation operations can be optimized to reduce the amount of noise and emissions generated by these operations while still maintaining the efficiency of the airport system.

ASCENT Operations Projects

- 006 (COMPLETE) - Rotorcraft Noise Abatement Operating Conditions Modeling
- 015 (COMPLETE) - Cruise Altitude and Speed Optimization
- 016 (COMPLETE) - Airport Surface Movement Optimization
- 023 - Analytical Approach for Quantifying Noise from Advanced Operational Procedures
- 038 - Rotorcraft Noise Abatement Procedures Development
- 044 - Aircraft Noise Abatement Procedure Modeling and Validation
- 053 - Validation of Low-Exposure Noise Modeling by Open-Source Data Management and Visualization Systems Integrated with AEDT
- 078 (IN DEVELOPMENT) - Contrail Avoidance Decision Support and Evaluation

ASCENT Tools Research Portfolio

https://ascent.aero/topic/tools/

The aviation system operation involves the complex interactions between many different components and understanding how to optimize its activities requires advanced modeling tools. The FAA suite of tools has been developed to provide the ability to characterize and quantify the interdependences of aviation-related noise and emissions, impacts on health and welfare, and industry and consumer costs under different policy, technology, operational and market scenarios.

ASCENT Tools Projects

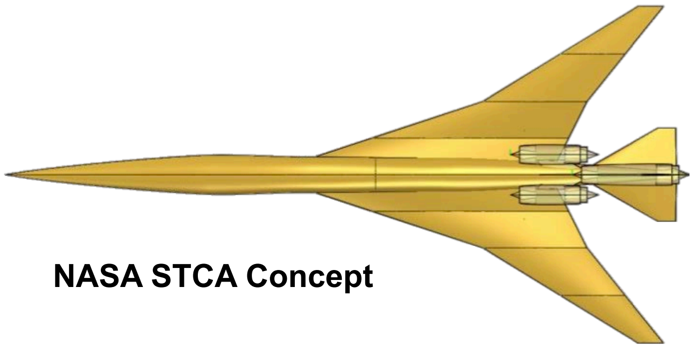
- 009 - Geospatially driven noise estimation module
- 010 - Aircraft Technology Modeling and Assessment
- 011 (COMPLETE) - Rapid Fleet-wide Environmental Assessment Capability
- 012 (COMPLETE) - Aircraft Design and Performance Assessment Tool Enhancement
- 035 (COMPLETE) - Airline Flight Data Examination to Improve flight Performance Modeling
- 036 (COMPLETE) - Parametric Uncertainty Assessment for AEDT2b
- 037 - CLEEN II System Level Assessment
- 040 (COMPLETE) - Quantifying Uncertainties in Predicting Aircraft Noise in Real-world Situations
- 043 - Noise Power Distance Re-Evaluation (NPD+C) to Include Airframe Noise in AEDT
- 045 - Takeoff/Climb Analysis to Support AEDT APM Development
- 046 - Surface Analysis to support AEDT APM Development
- 049 - Urban Air Mobility Noise Reduction Modeling
- 053 - Validation of low exposure noise modeling by open source data management and visualization systems integrated with AEDT
- 054 - AEDT Evaluation and Development Support
- 058 - Improving Policy Analysis Tools to Evaluate Aircraft Operations in the Stratosphere
- 060 - Analytical Methods for Expanding the AEDT Aircraft Fleet Database
- 062 - Noise Model Validation for AEDT
- 064 - Alternative Design Configurations to meet Future Demand

A Cross-Cutting Research Example:

Supersonic Civil Aircraft

https://ascent.aero/topic/supersonics/

Multiple ASCENT Projects support technology analysis for ICAO/CAEP rulemaking activity and development of new technologies for the next generation of supersonic aircraft.



NASA STCA Concept

ASCENT Supersonics Related Projects

- 007 (COMPLETE) - Civil, Supersonic Over Flight, Sonic Boom (Noise) Standards Development
- 010 - Aircraft Technology Modeling and Assessment
- 022 - Evaluation of FAA Climate Tools
- 041 - Identification of Noise Acceptance Onset for Noise Certification Standards of Supersonic Airplanes
- 042 - Acoustical Model of Mach Cut-off
- 047 - Clean Sheet Supersonic Aircraft Engine Design and Performance
- 057 - Support for Supersonic Aircraft Noise Efforts in ICAO CAEP
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- 059 - Jet Noise Modeling to Support Low Noise Supersonic Aircraft Technology Development
- 074 - Low Emissions Pre-Mixed Combustion Technology for Supersonic Civil Transport

ASCENT Project 001(A)

Alternate Jet Fuel Supply Chain Analysis

Washington State University

PI: Michael Wolcott, Kristin Brandt

Cooperators: Hasselt University, Volpe

PM: Nathan Brown, FAA

Cost Share Partner: Port of Seattle

Objective:

Create techno-economic analyses (TEAs) that treat analytical components similarly (i.e. harmonized) for seven certified pathways.

Create a simplified "rules of thumb" tools for those not needing the detail of the full TEAs.

Project Benefits:

Publication of open-source models will simplify pathway comparisons.

Policy scenarios inform users on the impact of various policies and the investment required to reach price parity with petroleum jet fuel.

Research Approach:

Harmonized TEA spreadsheets were built using a factored approach and allow for customization of analyses.

The "rules of thumb" tools include summary tables of baseline scenarios and charts to show the impact of key variables.

Both tools can be used to assess the required capital investment, feedstock requirements, cost differential, and policy implications of future fuels production scenarios.

Major Accomplishments (to date):

To date, five harmonized TEAs for certified pathways and a feedstock preparation TEA have been completed.

Three of the pathway TEAs have informed CAEP FTG and LTAG efforts.

Future Work / Schedule:

Complete harmonized TEAs for two additional fuel pathways: adapted version of Virent BioForming® and DSHC.

Complete a harmonized PTL TEA with MIT using flue gas or DAC and electricity source options.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 001A through FAA Award Number 13C-AJFE-WaSU-16 under the supervision of Nathan Brown. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 01

Alternative Jet Fuel Supply Chain Analysis - CORSIA Fuels Support

Purdue University

PI: Farzad Taheripour

PM: Anna Oldani

Cost Share Partner: NESTE Corporation

Objective:

- Provide data and modeling practices to **estimate ILUC values for alternative SAF pathways**
- Develop required economic analysis to **assess economic feasibility and profitability of SAF pathways**

Project Benefits:

- Improve ILUC estimation method for SAF pathways
- Develop methodologies to calculate direct land use change (DLUC) emissions
- Improve emissions factor databases and modeling approach

Research Approach:

Sustainable aviation fuels (SAFs) are essential in achieving carbon-neutral growth in aviation

Biomass-based SAFs may induce global land use changes and associated carbon stock

CORSIA Life Cycle Analysis (LCA) has two components: **Core LCA** and **ILUC**

- Use GTAP-BIO model to **assess induced land use change (ILUC) emissions**
- Use PE models for **economic feasibility analysis**
- Use Techno-Economic Analysis to study supply chain from feedstock production to aviation fuel

Major Accomplishments (to date):

Provide required data and modeling practices to **estimate ILUC values for alternative SAF pathways** and **developed required land use analyses** to support the Fuels Task Group (FTG) activities and goals.

Future Work / Schedule:

- Further improve the GTAP-BIO model to assess ILUC values for new pathways and new regions
- Develop policy analyses to support SAF production

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project ASCENT 001 through FAA Award Number 13-C-AJFE-PU under the supervision of Anna Oldani}. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 1

Alternative jet fuel supply chain analysis

Massachusetts Institute of Technology & UHasselt (subaward)

PI: S. Barrett, R. Malina, F. Allroggen

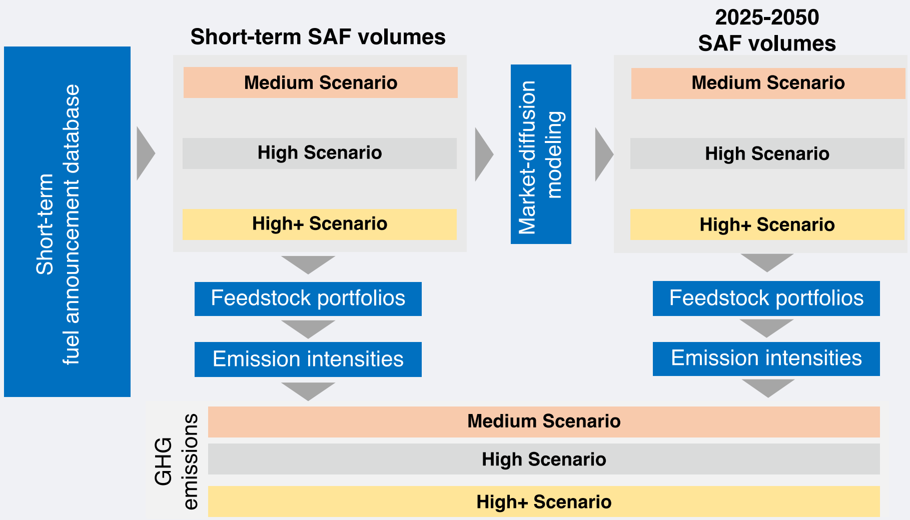
PMs: *Dan Williams, Nate Brown, Jim Hileman*

Objective:
Analyze lifecycle GHG emissions, costs, and availability of Sustainable Aviation Fuels, considering a wide range of production pathways and feedstocks. Research is conducted in support of efforts under ICAO CAEP.

Focus topic today: Future availability of SAF out to 2050

Project Benefits *(focus topic)*:
1. Detailed outline of potential SAF uptake scenarios over the coming decades
2. Analysis of future GHG reduction potential from SAF

Research Approach *(focus topic)* **:**



Major Accomplishments (to date) *(focus topic)* **:**
- SAF production scenarios and associated range of GHG emission reductions out to 2050 finalized.

Future Work / Schedule (MIT-ASCENT 1):
- Run LCA for additional pathways to be considered under CORSIA (e.g.: catalytic thermolysis)
- LCA and TEA and production potential of PtL Fuels, considering different carbon sources
- Analysis of optimized production scenarios for SAF in the U.S. under uncertainty

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 1 through FAA Award Number 13-C-AJFE-MIT under the supervision of Dan Williams, Nate Brown and Jim Hileman. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 003

Cardiovascular Disease and Aircraft Noise Exposure

Boston University School of Public Health

PI: Junenette Peters

PM: Donald Scata and Sean Doyle

Cost Share Partner: Donators to Nurses' Health Study

Collaborators: Harvard & MIT

Objective:

To evaluate the relationship between aircraft noise exposure and health including hypertension and sleep disturbance in existing health cohorts – Nurses Health Studies (Health Impacts)

To assess economic benefits or harm to businesses underneath regular flight paths at selected airports (Economic Impacts)

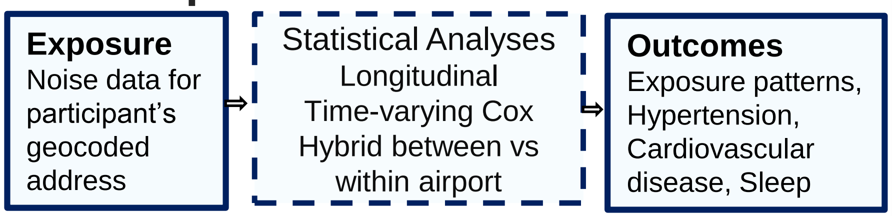
Project Benefits:

Contribution to the body of knowledge of potential health and economic impacts of aircraft noise.

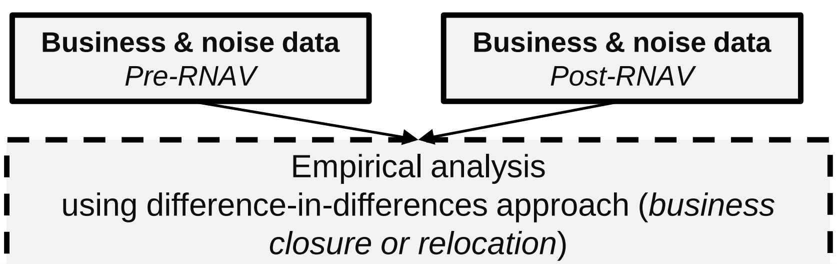
Responsive to Section 189 of the 2018 FAA Reauthorization.

Research Approach:

Health Impacts



Economic Impacts



Major Accomplishments (to date):

1. Submitted papers to journals for publication on sociodemographic patterns of noise exposure and noise and potential risk of hypertension.
2. Submitted abstracts to international conferences on noise and potential sleep and hypertension effects.
3. Acquired business data, mapped business changes for 8 airports, and ran initial analysis for 1 airport.

Future Work / Schedule:

1. Continue analysis on noise and sleep markers – 9/2021
2. Continue analysis on noise and CVD – 12/2021
3. Complete analysis of noise patterns – 12/2021
4. Roll-out economic assessment to a set of airports and run cross-comparisons – 12/2021

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project {add project number here} through FAA Award Number {add grant number} under the supervision of {add PM names here}. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 009

Geospatially Driven Noise Estimation Module

Georgia Institute of Technology
PI: Dimitri Mavris, Holger Pfaender
PM: Joseph DiPardo
Cost Share Partner: Georgia Institute of Technology

Objective:

Develop a novel geospatially driven noise estimation module to support computation of noise resulting from the operation of Unmanned Aircraft Systems (UAS) and other upcoming vehicle concepts.

Project Benefits:

- A GIS driven noise estimation module to evaluate the noise from large numbers of UAS vehicles.
- This tool will help provide decision-makers UAS noise exposure distributions as well as provide insight on where the noise would be located and identify mitigation solutions.

Research Approach:

- Literature Review and GIS Software Evaluation
- Investigate Emerging Computational Technologies
- Collaboration with ASSURE CoE Team at Mississippi State
  - UAS Source Noise Data Development
  - UAS Noise Computation Module
  - UAS Demand Studies
- Noise Computation Engine Integration

Major Accomplishments (to date):

- Delivered Review of GIS Software
- Initial benchmark study of computing and visualization techniques
- Close collaboration with ASSURE CoE team at Mississippi State

Future Work / Schedule:

Aligning schedule with Mississippi State Team on

- Source Noise, Demand Scenarios, Trajectories

Completing Benchmarking Tests

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 009 through FAA Award Number 13-C-AJFE-GIT-059 under the supervision of Joseph DiPardo. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 10

Aircraft Technology Modeling & Assessment

Georgia Institute of Technology & Purdue University

PI: Dimitri Mavris, GT
William Crossley, Purdue

PM: Rangasayi Halthore
Maryalice Locke
Laszlo Winhoffer

Cost Share Partner: Boom Supersonics, Gulfstream, Georgia Institute of Technology, Purdue, OAG

Objective: Model and assess potential evolution of commercial airline fleet due to the introduction of future supersonic aircraft and how technology development could affect the environmental impacts of aviation (e.g., fleet-level fuel burn, emissions and noise). The effort will examine ***SST vehicle modeling (in support of CAEP Exploratory Study); fleet route simulation; fleet simulation, and AEDT supersonic modeling.***

Project Benefits: Provide an understanding of how introduction of new supersonic transports that could enter into commercial airline service and private use will affect fleet-wide fuel burn, noise and emissions.

Research Approach:

SST Vehicle Modeling:

- CFD based aero shaping; installed propulsion modeling; mission analysis; emissions and LTO noise analysis
- Perform design Mach trade study for three SST classes
- Model facsimile of OEM SST for CAEP E-Study

Fleet Route Simulation:

- Computing potential time savings per OD pair
- Computing value of travel time savings per OD pair
- Detailed SST aircraft performance on complex mixed missions

Fleet Simulation: See slide 4

AEDT SST Modeling:

- Generate performance data via aero and propulsion models
- Construct appropriate physics-rooted regression functions to model drag, thrust, and fuel-burn
- Fit regressions to performance data, predict, and validate

Major Accomplishments (to date):

SST Vehicle Modeling: Completed 7 SSTs for design Mach trade study; completed 3 OEM vehicles; completed study on VRNS impact on climb out NOx; completed nvPM study

Fleet Route Simulation: Developed flexible route optimization tool; Completed future SST demand study where demand depends on vehicle; Support for CAEP E-Study

Fleet Simulation: See slide 4

AEDT SST Modeling: Developed new approach for regressing SST aircraft data; completed data generation and initial model development for 2 SSTs; models demonstrate good predictive accuracy

Future Work / Schedule: Complete modeling remaining SSTs (8/2021); complete design Mach trade study (5/2021); complete route simulations for OEM vehicles (5/2021); Check extensibility of SST performance modeling on all SSTs and OEM data (8/2021)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 10 through FAA Award Number 13-C-AJFE-GIT-006 under the supervision of Rangasayi Halthore, Maryalice Locke, and Laszlo Windhoffer. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 18

Community Measurements of Aviation Emissions Contribution to Ambient Air Quality

Boston University School of Public Health

PI: Kevin J. Lane PhD, MA

PM: Jeetendra Upadhyay

Cost Share Partner: Women's Health Study Initiative

Objective:

- Measure aviation-related air pollution such as ultrafine particles (UFP) using a stationary and mobile monitoring platform near Boston Logan International Airport.
- Quantify the contribution of flight activity to community air pollution.

Project Benefits:

- Improved understanding of aviation-related UFP in communities near airports.
- Pairing of empirical monitoring data and source attribution models to validate dispersion air pollution models that could be applied at airports across the US.

Research Approach:

- Collection and analysis of community air pollution measurements UFP, NO2 and BC.
- Stationary sites and mobile monitoring are being conducted continuously at varying distances from flight paths for Boston Logan International Airport.
- Statistical analyses will compare the stationary and mobile measurements with flight activity data and meteorology to determine aircraft contributions to ground measurements for source attribution.

Major Accomplishments (to date):

- We have collected air pollution data at stationary sites across multiple seasons during COVID-19.
- Over 200 hours of mobile air pollution data has been collected covering a wide variation of meteorology and ramp-up of aviation activities.

Future Work / Schedule:

- Analysis of mobile and stationary data is being used to identify air pollution during COVID-19 that will inform source attribution modeling
- Regression modeled source attribution estimates will be compared to outputs from atmospheric dispersion models with ASCENT Project 19.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 18 through FAA Award Number FAA-COE-AJFE 2014-2022 under the supervision of Jeetendra Upadhyay. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 019

Development of Aviation Air Quality Tools for Airport-Specific Impact Assessment

University of North Carolina at Chapel Hill

PI: Sarav Arunachalam

PM: Jeetendra Upadhyay

Cost Share Partner: LAWA, EDF, EU-AVIATOR

Objective:

- Develop new aircraft dispersion model (ADM) for assessing local air quality due to aircraft sources during LTO cycles

Project Benefits:

- Improved characterization of air quality due to aircraft sources in the vicinity of the airport
- Directly feeds into AEDT development
- Support for NEPA Analyses, and Health Impact studies
- Inputs for ICAO-CAEP Impacts Science Group (ISG)

Research Approach:

Focus on 3 aspects of LAQ Modeling

- Source characterization
- Physical Processes
- Chemical Processes

Develop a series of options for testing and implementing in a 2-year timeline

- Prototype and preliminary evaluation at LAX for Winter 2012
- Apply to other case studies in the US and EU

Major Accomplishments (to date):

- ADM Prototype developed, evaluated against LAX
- Identified role of meteorology and plume rise in aircraft dispersion
- Draft manuscript focusing on role of meteorology in aircraft plume dispersion prepared
- Active engagement with EPA OAQPS and OTAQ

Future Work / Schedule:

- Continue evaluation for Summer 2012 (Summer 2021)
- Implement chemical conversion (Fall 2021)
- Evaluate at other airports (Spring 2022)
- Finalize v1 of ADM for FAA (Summer 2022)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 19 through FAA Award Number 13-C-AJFE-UNC under the supervision of Jeetendra Upadhyay. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 022
Evaluation of FAA Climate Tools

University of Illinois at Urbana-Champaign

PI: Donald Wuebbles
PM: Daniel Jacob
Cost Share Partner: University of Illinois

Objective:

- Further enhance the overall understanding of aviation impacts on climate and environment
- Studies exploring regional climate impacts from aircraft emissions.
- Evaluate capabilities, limitations, and uncertainties of climate metrics and simple models (e.g., APMT) to aid policy decisions.

Motivation

- Science-based evaluation of analytical tools used by the FAA;
- Development of ideas and concepts for the next generation treatment of aviation effects on the Earth system;
- Updated evaluation and analyses of the science of aviation effects on atmospheric composition and climate;
- Evaluation of potential environmental effects from assumed fleets of supersonic commercial and business jet aircraft
- Address policy questions and consideration of potential policymaking.

Project Benefits:

- Science-based evaluation of analytical tools used by the FAA;
- Development of ideas and concepts for the next generation treatment of aviation effects on the Earth system;
- Updated evaluation and analyses of the science of aviation effects on atmospheric composition;
- The evaluation of potential environmental effects from assumed fleets of supersonic commercial and business jet aircraft;
- To address policy questions and consideration of potential policymaking quantifying regional climate impacts.

Research Approach:

Analyses of atmospheric composition changes and climate effects from aviation emissions

- State-of-the art climate-chemistry modeling capabilities (we are using the greatly extended Whole Atmosphere Community Climate Model (WACCM) version of NCAR's Community Earth System Model) – ground to 140 km with comprehensive tropospheric and stratospheric chemistry.
- Conduct simulations with different emissions scenarios as well as sensitivity studies for different parameters (e.g., fuel burn, NOx) for supersonic and subsonic aircraft fleets.

Consideration of regional analyses concepts (potentially of value for APMT)

- Explore possible ways to derive temperature change for specific regions from subsonic emissions.

Major Accomplishments (to date):

- Two journal papers
- Biweekly telecons with FAA
- Quarterly reports to FAA
- Annual report summarizing progress
- Participate in writing reports for ICAO through ISG
- Presentations and participation in CCR and ASCENT meetings, ICAO, AGU and other conferences

Future Work / Schedule:

- Plan studies using inventories (from ASCENT Project 10) to estimate atmospheric impacts from projected supersonic fleets.
- Results from these studies inform the development of Aviation Portfolio Management Tool – Impacts Climate (APMT-IC) for supersonic impacts (ASCENT Project 58).

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project A22 through FAA Award Number 13-C-AJFE-UI-029 under the supervision of Daniel Jacob. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 23

Analytical Approach for Quantifying Noise from Advanced Operational Procedures

Massachusetts Institute of Technology

PI: John Hansman

PMs: Christopher Dorbian & Joe Dipardo

Cost Share Partner: Massachusetts Port Authority

Objective:

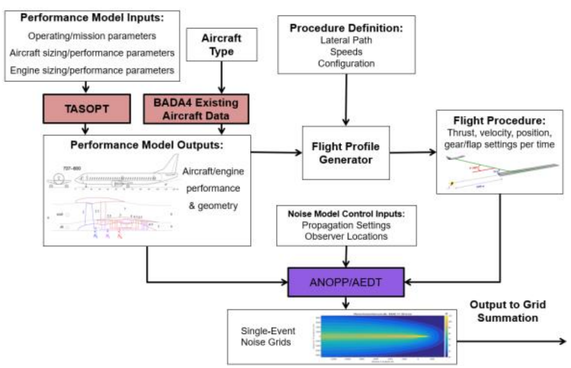
The objective of the research is to continue development of a noise analysis method with improved fidelity, accuracy, and utility for evaluation of advanced operational procedures.

Project Benefits:

The current phase of the project is focused on continued refinement of the analysis tools and application to a broad set of sample problems to demonstrate noise reduction opportunities leveraging Performance Based Navigation in the National Airspace System (NAS).

Research Approach:

This project involves development of a noise modeling framework to be used to evaluate candidate advanced operational procedures for community noise reduction, with additional focus on identifying operational repercussions and implementation barriers.



Major Accomplishments (to date):

- Developed recommendations for new operational procedures as well as modifications to current procedures for Boston Logan Airport (BOS). Depending on the context, proposed procedures offer:
  - Reduction in net population exposure, or;
  - Re-distribution of noise targeting higher equity.
- Developed new metrics and means of communicating effects of noise re-distribution caused by modifications to procedures.
- Documented the set of procedure design constraints that restrict how noise-abating procedures can be designed and implemented in today's NAS.

Future Work / Schedule:

- June 2021: BOS Block 2 final report submitted to communities.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 31 through FAA Award Number 13-C-AJFE-MIT-031 under the supervision of Christopher Dorbian. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 25

Rapid IR Fuel Screening

(Previously: Shock Tube and Flow Reactor Studies of the Kinetics of Jet Fuels)

Stanford University

PI: Ronald K. Hanson

PM: Anna Oldani

Cost Share Partner: Stanford University

Objective:

Develop a **compact, low-volume prescreening tool** for the prediction of physical and chemical properties of sustainable aviation fuels (SAFs) using Fourier-Transform Infrared (FTIR) spectrometry and advanced statistical analysis methods.

Project Benefits:

FTIR prescreening approach will **make SAF design and approval process less costly and more efficient**.

This low-volume (<1 mL) method yields insights that are **complementary to other prescreening approaches** (e.g., GCxGC).

Research Approach:

Develop statistical models that **correlate the physical and chemical properties of a fuel** (e.g., boiling point, heat of combustion, flash point, etc.) **with its vapor-phase FTIR spectrum**.

Apply these models to **predict the physical and chemical properties of next-generation SAFs** and fuel components.

Major Accomplishments (to date):

- Separate **models have been trained for key physical/chemical properties** using a dataset of pure hydrocarbons
- The **models accurately predict the properties of all fuels** in the training dataset
- An FTIR spectrometer facility has been modified to enable wide-spectrum IR measurements (2-16 μm)

Future Work / Schedule:

- Expand the training dataset to include more fuels (>C8) and additional property data
- Use the optimized models to predict the properties of SAFs and SAF components
- Explore other prescreening opportunities enabled by IR spectral analysis

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 25 through FAA Award Number 13-C-AJFE-SU-017 under the supervision of Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 31

Alternative Jet Fuel Test and Evaluation

University of Dayton Research Institute

PI: Steve Zabarnick

PM: Anna Oldani

Cost Share Partner: Boeing, Shell, IHI, Neste, GE Aviation, NRC Canada, LanzaTech

Objective:

Coordinated performance testing capability to support the evaluation of promising alternative jet fuels. This project provides the capability to support fuel testing and **evaluation of novel alternative jet fuels** toward ASTM approval.

Project Benefits:

ASTM research reports for OEM approval and **creation of D7566 annexes**

Management of D4054 qualification process

Increased supply of secure, safe, low life cycle carbon, sustainable aviation fuels

Research Approach:

Fuel property and composition testing

Support for rig/engine evaluations

Coordination of OEM approval process

Goal is new D7566 approved annex for each candidate fuel

Major Accomplishments (to date):

New ASTM D7566 Annexes – ATJ & HC-HEFA

New D4054 Fast Track Process

Two GCxGC analysis methods documented

New co-processing pathway in ASTM D1655

Testing of Shell IH2, HFP-HEFA, Global Bioenergies, CSIRP-IIP, and Swedish Biofuels fuels

Future Work / Schedule:

Continue working with new fuel producers to guide them through the approval process

Continue fuel testing & evaluation

Continue OEM committee and report reviews toward ASTM approvals

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 031 through FAA Award Number 13-C-AJFE-UD under the supervision of Dr. Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 33

Alternative Jet Fuel Test Database Library

University of Illinois Urbana-Champaign

PI: Tonghun Lee

PM: Cecilia Shaw

Cost Share Partner: Ansys, Inc.

Objective:

This objective is to establish a comprehensive and foundational database of current and emerging alternative jet fuels by integrating relevant pre-existing jet fuel data into a common archive that can support scientific research, enhance operational safety, and provide guidelines for the design and certification of new jet fuels. We also plan to establish the foundation for a transnational network to track both SAF development and integration in the global arena.

Project Benefits:

Domestic benefits include integration of SAF data into a centralized database which can support future research and fuel certification. The internationally connected database structure will also increase our understanding of the global fuel infrastructure and variability, increase sustainability by supporting the certification and integration of new SAFs, and safeguard US airlines by monitoring the fuel consumed across the complex global aviation landscape as new fuels are integrated into the system.

Research Approach:

Develop a Comprehensive SAF Database on Properties & Testing

- Compile data into a centralized database for SAF
- Select data storage format: non-relational JSON & CSV
- Apply advanced analysis technique: Machine learning based
- Connect database to international network: JETSCREEN & beyond
- Inclusion of current jet fuel data in use

With integration of new fuels into our global aviation infrastructure, establishment of this database can help to (1) monitor current jet fuel development and deployment, and (2) shorten the jet fuel certification process by supplying key data and analysis. In the future, this database can potentially be the basis for a transnational network that can be used to monitor worldwide fuel usage in real time and provide critical information that can ensure enhanced sustainability and airline safety in a complex global arena.

Major Accomplishments (to date):

Accomplishments in Current Year

- Functional updates to database (display, export, import, etc.)
- Inclusion of IHI alternative jet fuel data
- Conversion of data to CSV format for machine learning
- Selection of data sync with JETSCREEN as well as privacy protocols
- Machine learning: detection of novelty fuels and data imputation
- Machine learning based chemical kinetics mechanism for SAF
- COVID Impact: airport data integration delayed

Future Work / Schedule:

- Continued collection of data for integration into the database
- Improvements to the online analysis tools
- Extension of database with connections to A-Light and NEWJET programs (Europe)
- Continued development of analysis using machine learning: prediction, imputation, and chemical kinetics development
- Integration of real time airport data (fuel properties)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 33 through FAA Award Number 13-C-AFJE-UI-026 under the supervision of Cecilia Shaw. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 034

Integration and Coordination of the National Jet Fuels Combustion Program

University of Dayton

PI: Joshua Heyne

PM: Anna Oldani

Cost Share Partner: DLR Germany, University of Dayton, NRC Canada

Objective:

Streamline the evaluation and qualification process of novel Sustainable Aviation Fuel candidates

Project Benefits:

Development of **focused tests** to minimize operability impacts of SAFs *with prescreening*

Proposed testing to reduce and eventual elimination Tier 3 and 4 operability tests *with Referee Rig*

Research Approach:

Evaluate the **operability impacts of alternative aviation fuels** across NJFCP institutions and allied partners

Test fuels were designed to stress several **key property effects in engines**

Diverse rigs evaluate test fuels at **varying conditions** and compare results to **OEM experience**

Model chemical kinetics and operability limits of fuels

Major Accomplishments (to date):

Evaluation of ~12 fuels across dozens of experimental devices

Analysis suggests bounding of **~8 properties** can account for **~90% of all observed variance**

Referee Rig operability limits at relevant conditions match all known OEM hardware trends

CFD matches operability trends for several fuels conditions

Process for custom chemical kinetics developed

Future Work / Schedule:

June 2021 - Completion of the AIAA book

TBD – Additional testing of CPK-0

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 034 through FAA Award Number 13-C-AJFE-UD-024 under the supervision of Dr. Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 37

CLEEN II System Level Assessment

Georgia Institute of Technology

PI: Dimitri Mavris

Co-I: Jimmy Tai & Josh Brooks

PM: Roxanna Moores

Cost Share Partner: Georgia Institute of Technology

Objective:

To support the FAA through independently modeling and assessing the technologies that are being developed under the CLEEN II at the system and fleet levels.

Project Benefits:

This project will quantify the expected U.S. fleet wide reductions in aviation fuel burn, airport community noise, and NOx emissions projected from inclusion of CLEEN II technologies on future aircraft.

Research Approach:

- Perform modeling of individual CLEEN II fuel burn, noise, and emissions technologies
- Incorporate these models into vehicle level performance analyses
- Include a demand forecast, fleet replacement matrix, and set of technology introduction scenarios
- Evaluate the fuel burn, noise, and emissions performance of the US fleet across each of these scenarios to articulate the efficacy of the CLEEN programs

Major Accomplishments (to date):

Of the 14 technologies in CLEEN II:

- 8 have been fully modeled
- 3 are in final contractor review
- 3 are awaiting data

Preliminary fleet fuel burn assessment completed

Future Work / Schedule:

- Completion of remaining technology modeling
- Incorporation of final technologies into fleet analysis
- Initiation of CLEEN III technology modeling

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 37 through FAA Award Number 13-C-AJFE-GIT-013 under the supervision of Roxanna Moores. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 38

Rotorcraft Noise Abatement Procedure Development

Penn State

PI: Dr. Kenneth S. Brentner

PM: Rick Riley

Cost Share Partner: Continuum Dynamics, Inc.

Objectives:

- Analyze NASA 2019 flight test data for mid-size aircraft in steady and maneuvering flight.
- Compare effectiveness of procedures by class of helicopters (2017 & 2019 flight tests).
- Develop coupling with FAA noise prediction tools.
- Develop noise abatement flight maneuvers for mid-size aircraft and compare with light vehicles.

Project Benefits:

Quick and accurate models of various, untested flight maneuvers will allow for optimized flight path recommendations for pilots.

Research Approach:

- Validate noise prediction system for noise abatement procedures/maneuvers
- Analyze noise abatement procedures in support of the flight test
- Model noise to demonstrate advantages procedure
- Evaluate noise abatement procedures against each helicopter category
  - Determine effectiveness of abatement procedures
  - Consider if a category is representative of a helicopter's classification

Major Accomplishments (to date):

- Acoustic post processing options and speed improvements added to noise prediction code.
- Simulation models developed for 2019 flight test helicopters (S-76D, Bell 205, AW139, MH-65)

Future Work / Schedule:

- Create a trajectory optimizer tool to test maneuvers not flown in NASA previous flight tests.
- Improve integration between PSU-WOPWOP and AAM to enable direct data transfer to AAM.
- Predict noise for S-76D and Bell 206 and compare to 2019 flight test data

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 38 through FAA Award Number 13-C_AJFE-PSU-038 under the supervision of Rick Riley. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 40

Quantifying Uncertainties in Aircraft Noise Prediction in Real-world Situations

The Pennsylvania State University

Purdue University

PIs: Dr. Victor Sparrow & Dr. Philip Morris, PSU;

Dr. Kai Ming Li, PU

PM: Dr. Bill (Hua) He, FAA

Cost Share Partners: Airbus & ANOTEC Engineering

Objective:

- Improving the understanding of uncertainties for predicting aircraft noise in the current FAA modeling tools.
- Need to account for uncertainties in modeling of the aircraft noise (source), meteorological conditions (propagation path) and ground impedance, terrain profile (receiver).

Project Benefits:

Development of methodologies to improve the FAA tools for predicting aircraft noise in the presence of real-world weather.

Research Approach:

Penn State: Utilizing events from the BANOERAC database to assess the role of aircraft directivity and uncertainties in the propagation path.

Purdue: Using acoustic data and atmospheric data in the DISCOVER-AQ acoustic data set to quantify the overall uncertainties during the propagation of aircraft noise.

Major Accomplishments (to date):

Penn State: has managed to predict en-route aircraft noise (cruise @37 kft) within 5 dB of the measured data. Assessed the importance of including correct meteorological conditions.

Purdue: has evaluated the accuracy of the propagation model in AEDT with measured data. Found that AEDT's propagation model can be improved with a more accurate moving source model and ground model.

Future Work / Schedule:

Nearly completed; Analyze Airbus data & write up.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 40 through FAA Award Number 13-C-AJFE-PSU & 13-C-AJFE-PU under the supervision of Dr. Hua He. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 43

Noise Power Distance Re-Evaluation

Georgia Institute of Technology

PI: Dr. Michelle Kirby, Dr. Dimitri Mavris

PM: Joe DiPardo, Mohammed Majeed

Cost Share Partner: Industry in-kind

Objective:

Construct an NPD correction function for implementation in AEDT to account for changes in source noise due to flight configuration, speed from the baseline conditions

Project Benefits:

- AEDT can better capture changes in approach noise emissions due to aircraft configuration
- Potential improvement from default AEDT calculations for analyzing approach noise

Research Approach:

- ANOPP is used to capture configuration-related noise results for range of engine parameters across different aircraft classes
- Regression model is generated to calculate difference between baseline NPD and specific aircraft configuration NPD
- Correction function is implemented with FOQA data in AEDT and validated against real-world noise monitor data

Major Accomplishments (to date):

- Designed correction functions for 50, 150, 210, and 300pax aircraft classes
- Validated 150pax correction function against real-world noise monitor data at SFO; simulated tracks using the correction function resulted in noise readings closer to the noise monitor readings than default AEDT simulated tracks for 7/11 cases

Future Work / Schedule:

- AEDT corrected NPDs will be compared against high fidelity data to ensure accuracy
- Provide initial implementation plan for AEDT to developers and refine based on feedback for all classes

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 43 through FAA Award Number 13-C-AJFE-GIT-021 under the supervision of Joe DiPardo. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 044

Aircraft Noise Abatement Procedure Modeling and Validation

Massachusetts Institute of Technology
University of California, Irvine
PI: John Hansman, Jacqueline Thomas
PM: Chris Dorbian, Joe DiPardo
Cost Share Partner: Massachusetts Port Authority

Objective:

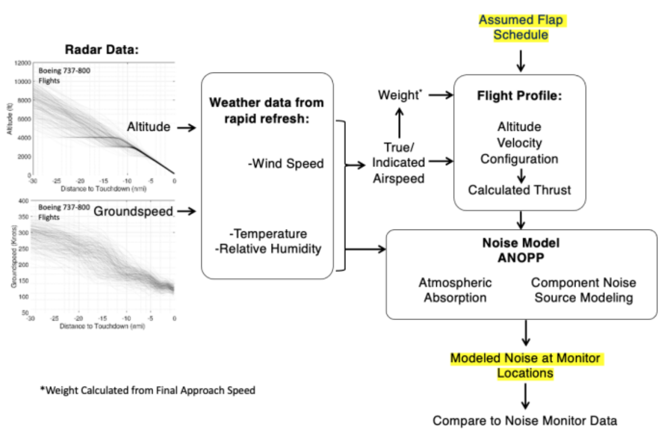
To utilize empirical noise data to develop data-based/learned noise models and validate and improve both existing noise models and advanced operational flight procedure design

Project Benefits:

Aircraft states, performance, and noise abatement flight procedures have been modeled and assessed through ASCENT projects 11 and 23. This project will validate and improve those models and provide insight into the modeling of noise abatement procedures like delayed deceleration approaches

Research Approach:

Noise based on radar and weather data is modeled and compared to airport noise monitor data for validation



Major Accomplishments (to date):

Modeled noise from radar observations from Boston Logan Airport (BOS) of three aircraft types corrected for atmospheric conditions are consistent with noise monitor readings under reasonable flap setting assumptions.

Future Work / Schedule:

The analysis is currently being repeated for data collected at Seattle Tacoma Airport (SEA) to gather more flight cases and additional aircraft types

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 044 through FAA Award Number 13-C-AJFE-MIT-006 under the supervision of Chris Dorbian and Joe DiPardo. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 46

Surface Analysis to Support AEDT Aircraft Performance Model (APM) Development

Massachusetts Institute of Technology

PI: Hamsa Balakrishnan and Tom Reynolds

PM: Joseph Dipardo and Mohammed Majeed

Cost Share Partner: MIT

Objective:

Identify and evaluate methods for improving taxi performance modeling in the Aviation Environmental Design Tool (AEDT) in order to better reflect actual operations

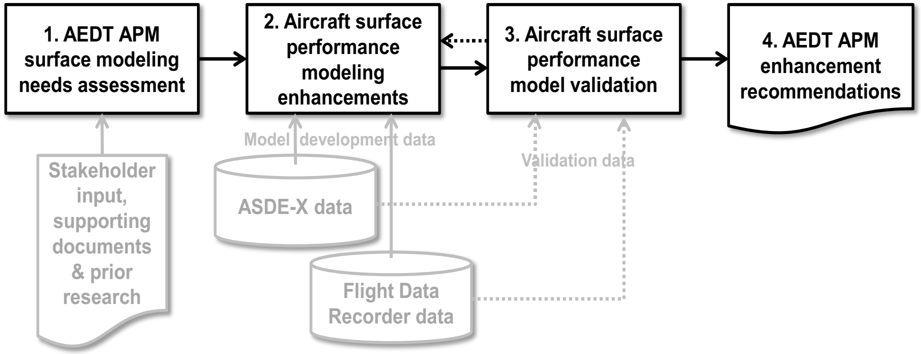
Project Benefits:

Improved taxi performance modeling in AEDT

Need accurate surface fuel burn prediction to support range of stakeholder analysis needs

Improved surface models could make AEDT outputs even more useful for different stakeholder needs

Research Approach:



Major Accomplishments (to date):

Recommendations for AEDT 3e:

- Updating of baseline fuel flow rates, airport taxi times, and pre-taxi fuel burn
- Queuing model of airport surface operations to support dispersion analysis and analyses of future demand scenarios

Machine Learning models of spatial dispersion of emissions

Future Work / Schedule:

Investigate thrust variations for noise modeling

Identify functionality corresponding to different user classes

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 46 through FAA Award Number 13-C-AJFE-MIT, Amendment Nos. 21, 35, 44, 47, & 63 under the supervision of J. Dipardo & M. Majeed. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 47

Clean-sheet supersonic engine design and performance

Massachusetts Institute of Technology

PIs: Steven Barrett, Raymond Speth

Students: Prashanth Prakash, Laurens Voet

PM: László Windhoffer, FAA

Cost Share Partner: Byogy Renewables Inc.

Objective

- Assessing the environmental performance of clean-sheet and derivative engines for supersonic transport (SST)
- Evaluating the suitability of LTO emission certification standards for supersonic transport using variable noise reduction systems (VNRS)

Project Benefits

- Development of roadmap for technology development to mitigate of the environmental signature of supersonic transport engines.

Research Approach

- Identify the operating requirements for SST propulsion systems
- Develop framework for tracing the fuel burn, noise and emissions of engines for SST to their design parameters.
- Quantify and compare fuel burn, noise and emissions characteristics of clean-sheet and derivative engines

Major Accomplishments (to date)

- Presented our work at SciTech 2021 Conference
- Co-submitted a working paper to WG3 with Georgia Tech on impacts of VNRS on emissions from supersonic aircraft

Future Work / Schedule

- Modeling of soot emissions

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 47 through FAA Award Number 13-C-AJFE-MIT under the supervision of László Windhoffer. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 48

Analysis to Support the Development of an Engine nvPM Emissions Standards

MIT

PIs: Raymond Speth, Steven Barrett

Student: Akshat Agarwal

PM: Daniel Jacob

Cost Share Partner: NuFuels LLC

Objective:

ICAO-CAEP has worked to develop new nvPM standard over last 5 years. FAA is a key contributor to this process. This project supports FAA's decision making by providing technical analyses related to nvPM emissions and the costs and benefits of regulating these emissions.

Project Benefits:

The analyses produced in this project provide FAA with a rigorous scientific basis to inform decisions related to the nvPM standard and promote an efficient implementation process that provides industry with regulatory certainty.

Research Approach:

To implement the nvPM standard, we focus on:

- Developing a method to predict nvPM mass and number emissions
- Generating candidate stringency options
- Conducting an environment cost-benefit
- Develop "no-change" emissions criteria to decide engine re-measurements
- Identify margins to current nvPM standard

Major Accomplishments (to date):

- Novel approach to predict nvPM emissions published in ES&T (Agarwal et al., 2018)
- Cost-benefit analysis for all nvPM options
- Analyses are regularly presented to ICAO-CAEP during teleconferences and meetings of CAEP-WG3

Future Work / Schedule:

Continuing work to support FAA decision making. Next focus is on relating the benefit of ground-based emissions regulations with cruise emissions

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 48 through FAA Award Number 13-C-AJFE-MIT under the supervision of Daniel Jacob. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 49

Urban Air Mobility Noise Reduction Modeling

Penn State

PI: Kenneth S. Brentner

PM: Rick Riley

Cost Share Partner : Penn State

Objective:

- Develop a first-principles noise modeling system for future UAM aircraft with varied configurations
- Produce noise database for notional UAM configurations for hover, transition, cruise
- Identify configuration changes and operational strategies that minimize acoustic impacts

Project Benefits:

- Initial capability to analyze UAM acoustics
- Understanding of UAM noise characteristics
- Identification of noise reduction opportunities
- Low noise design tool for the UAM industry
- Initial set of representative UAM noise data for AAM and integration with AEDT

Research Approach:

- Build on success of helicopter noise prediction system developed under ASCENT Projects 6 & 38:
  - couple flight simulation, aerodynamic modeling (CDI's CHARM), and PSU-WOPWOP
- Tailor approach to unique characteristics of UAM
  - Use PSU Distributed Electric Propulsion Simulation (DEPSim) code to model flight state of multiple propellers and rotors
- Develop low noise UAM trim strategies

Major Accomplishments (to date):

- Added time-varying broadband noise prediction capability to PSU-WOPWOP
- Noise prediction system coupled for rotors
- Conference publications:
  - 2021 VFS aVTOL Technical Meeting

Future Work / Schedule:

- Validation and verification of system
- Couple non-rotating lifting surfaces
- Development of noise abatement procedures

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 49 through FAA Award Number 13-C-AJFE-PSU-052 under the supervision of Rick Riley. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 050

Over-Wing Nacelle Placement Evaluation

Georgia Institute of Technology

PI: Dimitri Mavris, Chung Lee

PM: Chris Dorbian

Cost Share Partner: Georgia Institute of Technology

Objective:

- Use multidisciplinary design analysis and optimization (MDAO) methods to assess environmental impact of over-wing nacelle (OWN) placement
- Emphasis on high fidelity aerodynamics to capture drag penalty

Project Benefits:

- Enable accurate tradeoffs between noise benefits and fuel burn penalties
- Demonstrate computationally efficient methods for aircraft design studies

Research Approach:

- Computational efficiency is key challenge
- MDAO architecture aims at efficient information passing between disciplines: aerodynamics, propulsion, weights, noise
- Probability-based design methods aid efficiency
  - Design dimension reduction
  - Adaptive sampling
  - Multi-fidelity

Major Accomplishments (to date):

- Aircraft mission and propulsion cycle models
- CFD optimization of baseline nacelle
- Aero-propulsion coupling technique tested
- Active subspace reduces design space
- Multi-fidelity adaptive sampling tested

Future Work / Schedule:

- Test full multidisciplinary analysis (MDA) (summer 2021)
- Sequential stages of large-scale CFD-based optimization (fall/winter 2021)
- Final deliverable in Feb 2022

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 050 through FAA Award Number 13-C-AJFE-GIT-057 under the supervision of Chris Dorbian. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 51

Combustion Concepts for Next-generation Aircraft Engines

Massachusetts Institute of Technology
PIs: Raymond Speth, Jayant Sabnis, Steven Barrett
Students: Yang Chen, Jad Elmourad, Shayan Zahid
PM: Roxanna Moores
Cost Share Partner: NuFuels, LLC

Objective:

Evaluate performance characteristics of novel fuel, combustion, and engine technologies such as **water injection** and addition of **fuel additives**.

Use detailed combustion chemistry models to understand the impacts of these technologies on emissions.

Project Benefits:

New engine designs with higher efficiency and lower emissions offer the potential to increase the economic efficiency of the aviation sector.

Research Approach:

The research targets three sections for screening future engine technologies:

- Engine cycle thermodynamic analysis
- Combustor chemical kinetic modeling
- Overall emission analysis

The performance outputs of the cycle analysis, as well as the emissions outputs of the combustor model, are to be used to calculate the overall emissions impact for various missions.

Major Accomplishments (to date):

A thermodynamic cycle analysis for water injection was performed for a high-bypass turbofan engine, and the combustor chemistry model is being developed.

Future Work / Schedule:

Complete combustor and emissions analysis for various water injection strategies. Investigate fuel composition and additives as another means for emission reduction. Evaluate aircraft mission-level impacts on fuel consumption.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 51 through FAA Award Number 13-C-AJFE-MIT under the supervision of Roxanna Moores. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 52

Comparative assessment of electrification strategies for aviation

Massachusetts Institute of Technology

PIs: *S. Barrett, F. Allroggen, R. Speth*

PM: *Anna Oldani*

Objective:

To evaluate:

(1) the operational and economic feasibility of electrification strategies, and

(2) the life-cycle emissions and their associated impacts, relative to conventional petroleum-powered aircraft.

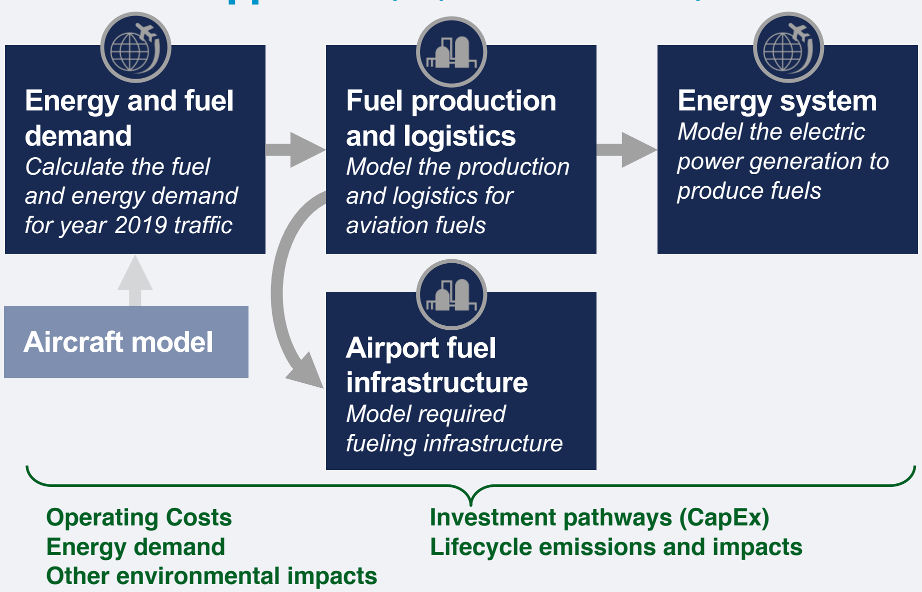
Today's focus:

Comparison of fuel production and distribution, with specific focus on energy demand and upstream investments for PtL and hydrogen scenarios

Project Benefits:

Provide data and guidance on the most promising electrification approaches for aviation

Research Approach (fuel production and distribution):



Major Accomplishments (to date):

For PtL and LH_2 scenarios: We analyzed…

1. Production pathways and lifecycle impacts
2. Energy demand
3. Investments for fuel production
4. Logistics and distribution challenges

Future Work / Schedule:

- Integration of aircraft model to assess feasibility and impacts at the system-level
- Provide integrated economic and environmental assessment
- Compare to other electrification strategies

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 52 through FAA Award Number 13-C-AJFE-MIT under the supervision of Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 053

Validation of Low-Exposure Noise Modeling by Open-Source Data Management and Visualization Systems Integrated with AEDT

Stanford University

PI: Juan J. Alonso, Don Jackson, Tom Rindfleisch

PM: Sean Doyle

Cost Share Partner: various

Objectives:

- Develop a modern, open-source, aviation-noise-data collection, processing, and archiving infrastructure
- Automation of AEDT analyses to (a) perform V&V studies and to (b) rapidly explore traffic-pattern alternatives
- V&V AEDT predictions in low noise (DNL 55-65 dB) areas with attribution of discrepancies for noise model improvement
- Propose alternative air traffic routes to minimize and distribute noise footprint in Bay Area metroplex

Project Benefits:

- Understanding of potential improvements for AEDT noise modeling in low-noise areas
- New infrastructure combining simulation + experimental data repositories for noise impact assessments
- Better analysis automation and visualization to engage multiple stakeholders for further action

Research Approach:

- Data collection, processing and archiving framework for air traffic (ADS-B receivers) and noise data (sound-level monitoring stations) in metroplex contexts
- Automated AEDT analyses (via scalable cloud resources) for daily / seasonal traffic in Bay Area metroplex
- Statistically-significant datasets for V&V of AEDT noise predictions in low noise (DNL 55-65 dB) areas
- Studies and visualizations for better understanding and for communication with diverse stakeholders
- Alternative air traffic routes to minimize and distribute remaining noise footprint

Major Accomplishments (to date):

- V1 of complete MONA (Metroplex Overflight Noise Analysis) framework
- Cloud-based automation of AEDT analyses
- Preliminary V&V of AEDT noise predictions

Future Work / Schedule:

- Extension of V&V efforts to statistically-significant numbers of flights
- Attribution of remaining errors / uncertainties
- Inform decisions on new routes
- Real-time visualization of individual noise events

Team Members:

- Current: Nick Bowman, Priscilla Lui, Brian Munguia, Aditeya Shukla
- Alumni: Brynne Hurst, Vikas Munukutla, Chetanya Rastogi, Avi Singh

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 053 through FAA Award Number ASCENT COE 13-C-AJFE-SU under the supervision of Sean Doyle. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 54

AEDT Evaluation and Development Support

Georgia Institute of Technology
PI: Dimitri Mavris, Michelle Kirby
PM: Joseph DiPardo
Cost Share Partner: Delta Air Lines

Objective:

- Provide data and methods to continue to improve the aircraft weight, takeoff thrust, and departure and arrival procedure modeling capabilities within AEDT
- Utilize real-world data flight and noise monitoring data to improve departure, full flight, and arrival modeling
- Conduct system evaluation of AEDT features

Project Benefits:

- The main benefit of this research is to address the gaps in AEDT related to departure profiles that are outdated and arrival procedures that might not reflect current airport operations.

Research Approach:

- Using real-world data (flight data, noise monitoring data) develop methods to automatically model actual operations in AEDT
- Perform comparisons between thousands of real flights against the outputs of AEDT's performance models for arrival, departure, and en-route phases to obtain statistics about the overall agreement with existing AEDT definitions
- Perform system testing and evaluation of AEDT features to identify discrepancies, quantify differences, and document possible improvements for future efforts

Major Accomplishments (to date):

- Compared AEDT profiles with real-world operations for arrival and departure procedures to identify key differences
- Implemented method for full flight modeling using airline data for comparison against AEDT
- Performed system testing on various AEDT features and made recommendations

Future Work / Schedule:

- Complete comparison of arrival profiles at all identified airports
- Complete comparison of full-flight modeling in AEDT with real-world flight operations

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 54 through FAA Award Number 13-C-AJFE-GIT-054 under the supervision of Joseph DiPardo. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 055

Noise Generation and Propagation in Advanced Combustors

Georgia Institute of Technology

PI: Timothy Lieuwen

PM: Roxanna Moores

Cost Share Partner/Collaborator: Raytheon Technologies Research Center

Objective:

- Develop and validate physics-based design tools for noise prediction.
- Data generation, benchmarking and validation through a combination of experiments, high-fidelity simulations, and physics-based reduced order modeling.

Project Benefits:

- Industry relevant noise prediction design tool for next generation engines.
- Expected benefits from this work are reduced noise pollution and reduced development time/cost of new engines.

Research Approach:

- **Task 1 – Mechanistic Understanding and Tool Development (Years 1-2)**
  - Focus on physics of sound generation from the inception of disturbances in the front-end all the way to the far-field perceived noise
  - Combination of experiments, simulation and reduced order modeling
- **Task 2 – Facility Development (Year 1)**
  - Development of complimentary experimental facilities and diagnostic capabilities at GT and RTRC
- **Task 3 – Model Integration and Validation (Years 2-3)**
  - Collating results from Tasks 1 to create validated prediction models in design tools

Major Accomplishments (to date):

Task-1

- Established multiple reduced order model frameworks to address physics at various parts of engine; connections between tasks across the 2 teams.

Task-2

- Completed design of GT and RTRC facilities.
- Identified locations for measurements and diagnostic
- Fabrication of facilities: additively manufactured components.

Task-3

- Identified benchmarking and validation targets to connect measured data to simulations to reduced order models.

Future Work / Schedule:

Task-1: Incorporate measured/simulated data as inputs into models. Connect model input/outputs between sequential tasks/physics. High-fidelity simulations and validation of simulation data

Task-2: Generate measurement data from rigs at multiple operating conditions

Task-3: Benchmarking reduced order model assumptions from comparison between reduced order model predictions and measurements.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 055 through FAA Award Number 13-C-AJFE-GIT-058 under the supervision of Roxanna Moores. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 056

Turbine Cooling through Additive Manufacturing

The Pennsylvania State University

PI: Karen Thole / co-PI: Stephen Lynch

PM: Cecilia Shaw

Cost Share Partner: Pratt and Whitney

Objective:

Cooling of turbine hot section components is necessary for durability but contributes to increased fuel burn. This study investigates novel cooling designs enabled by additive manufacturing (AM), which are tested in a full-scale rotating turbine facility.

Project Benefits:

Advanced microchannel cooling technology could lead to lower cooling flow requirements, where even a 5% reduction in needed cooling air would decrease specific fuel consumption of the aircraft by >1%. This will also be the first public comparison of cast vs AM blades at relevant rotating conditions.

Research Approach:

Cast turbine blades from a prior FAA CLEEN II program are scanned using CT technology, replicated using additive manufacturing (AM), and tested in a rotating turbine facility at PSU, to generate a direct comparison between cast and AM blades. In parallel, a large number of novel microchannel design concepts are tested in a stationary linear cascade at Penn State. Finally, best designs will be integrated into the rotating turbine blades and tested to determine quantitative reductions in cooling flow with advanced microchannel technology.

Major Accomplishments (to date):

The cast turbine blades were CT scanned and a model for AM was developed. A stationary turbine blade cascade design for rapid vetting of novel microchannel designs is nearly complete. Two vendors have been selected for AM fabrication of the turbine blades.

Future Work / Schedule:

The first set of additively manufactured turbine blades will be fabricated in summer and tested in fall; novel microchannel designs will be vetted in the stationary cascade in summer.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 056 through FAA Award Number 13-C-AJFE-PSU-054 under the supervision of Cecilia Shaw. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 57

Support of Supersonic Aircraft En-route Noise Efforts in ICAO CAEP

Pennsylvania State University, Queensborough Community College, Volpe

PI: Victor Sparrow, Penn State

PM: Sandy Liu, FAA

Cost Share Partners: Boom, Gulfstream

Objective:

- Research continues to support FAA in the development of technical standards for civil supersonic aircraft under the ICAO CAEP
  - Task 1: Efforts focus primarily in the area of en-route sonic boom noise assessment
  - Task 2: Testing capability of PCBoom software to model secondary sonic booms

Project Benefits:

- Predictive capabilities for sonic boom impacts
- Continued study of secondary sonic boom prediction
- Applicability of certain metrics
- Testing of signal processing methodologies for sonic boom signals
- Scheme assessment for sonic boom certification

Research Approach:

- Task 1: Simulate the effects of turbulence on shaped sonic boom within the atmospheric boundary layer
  - Propagate from cruise altitude to ABL with no-turbulence tool and ABL to ground with turbulence tool (involving both vector and scalar types)
- Task 2: Currently looking at prediction of secondary sonic boom for supersonic aircraft approaching U.S. coastlines, using flight conditions similar to Concorde.
- Task 3 (Volpe): Recover Concorde secondary boom signatures recorded by Volpe in 1979.

Major Accomplishments (to date):

- Using extended shaped boom input waveform file provided by NASA and tapers before and after propagation prevented artifacts before and after shocks
- Performed secondary sonic boom predictions for U.S. west coast for the first time

Future Work / Schedule:

- Determine sources of non-physical spiking in KZKFourier produced signatures
- Diagnose PCBoom secondary boom signal amplitude anomalies

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 57 through FAA Award Number 13-C-AJFE-PSU under the supervision of Sandy Liu. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 58

Improving Policy Analysis Tools to Evaluate Higher-Altitude Aircraft Operations

MIT

PI: Steven Barrett and Sebastian Eastham

PM: Daniel Jacob

Cost share partner: NuFuels LLC

Objective:

- Develop the APMT tool to quantify environmental impacts of aircraft operations, consistent with **current understanding of impact mechanisms**
- Extend APMT-IC to cover a **broad range of parameters**, including **high-altitude/ supersonic aviation**

Project Benefits:

- APMT that includes impacts of **higher altitude emissions** including supersonics
- **Rapid evaluation** of environmental impacts of aviation, including **divergence from currently dominant patterns and technologies**

Research Approach:

- **Evaluate and assimilate** changes in scientific understanding of aviation's impacts on **climate and air quality**
- Use **atmospheric modeling** to quantify sensitivity of climate and air quality to emissions up to **65 kft**
- **Re-engineer** APMT to support changes in **spatial distribution of emissions** and aircraft **emissions characteristics**
- Provide a **single tool** which can accept **gridded fuel burn and emissions** and return **climate and air quality damages**

Major Accomplishments (to date):

- Updated APMT-IC to **latest standards**
- Established **sensitivity framework** to quantify emissions with altitude change
- Developed **parametric emissions estimator** for representative supersonic aircraft
- Integrated new **RF assessment capability**

Future Work / Schedule:

- Mid-2021: **architectural plan** for APMT
- End of 2021: **scenario** impact estimates and development of **gridded env. sensitivities**
- Mid-2022: **new version** of APMT

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 58 through FAA Award Number 13-C-AFJE-MIT under the supervision of Daniel Jacob. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 59A/E

Jet Noise Modeling To Support Low Noise Supersonic Aircraft Technology Development.

Georgia Institute of Technology & Penn State University

PI: Dimitri Mavris, GT
Philip J. Morris, PSU

Co-I: Jimmy Tai & Joshua Brooks, GT

PM: Sandy Liu

Cost Share Partner: Georgia Institute of Technology & Penn State University

Objective:

To develop and assess computational tools to simulate the flow and noise of Civil Supersonic Aircraft engines.

To assess the impact of noise reduction methods on the overall engine performance

Project Benefits:

The developed tools will enable airframe and engine manufacturers to assess the noise impacts of engine design changes and to determine if particular designs will meet current or anticipated noise certification requirements

Research Approach:

Perform steady and unsteady numerical simulations of the internal and external flow from dual-stream, subsonic and supersonic jet nozzles using a commercial CFD application

Predict the radiated noise using an acoustic analogy and compare with experimental measurements

Select operating conditions for initial experimental geometry. (Project 59B).

Assemble zeroth-order methods for predicting supersonic inlet performance.

Determine installed thrust loss by jet noise reducing nozzles and find inlet designs that overcome this.

Major Accomplishments (to date):

Grids generated and boundary conditions specified for the Georgia Tech nozzles (Project 59B)

Reynolds-averaged Navier-Stokes solutions performed

Initial zeroth-order supersonic inlet performance and structural analysis complete for 2D inlets.

Future Work / Schedule

Improve grids for Large Eddy Simulation (LES) of jet exhaust flow and use Ffowcs Williams & Hawkings acoustic analogy to predict radiated noise (3/22)

Dual-stream nozzle noise predictions (7/22)

Convert inlet analysis into design environment, including axisymmetric configurations (1/22)

Incorporate sizing and installation performance (7/22)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 59A (GT) and 59E (PSU) through FAA Award Number 13-C-AJFE-GIT-63 and 13-C-AJFE-PSU-058 under the supervision of Sandy Liu. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 59B

JET NOISE MODELING AND MEASUREMENTS TO SUPPORT REDUCED LTO NOISE OF SUPERSONIC AIRCRAFT TECHNOLOGY DEVELOPMENT

Georgia Institute of Technology

PI: Krish Ahuja (PI), D. Mavris and Jimmy Tai (Co-PIs)

Experimental support: Aharon Karon, Robert Funk and Nate Ramsey (GTRI)

Cost Share Partner: Gulfstream (POC: Brian Cook)

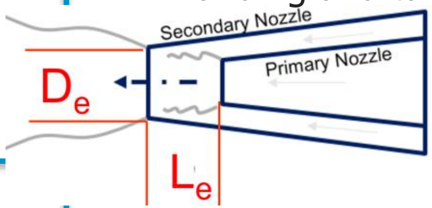
PM: Sandy Liu

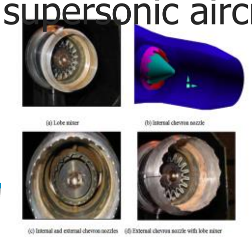
Objective:

To acquire acoustic and flow measurements to be used by Project 59 jet noise modelers for the validation of low, medium, and high-fidelity jet noise prediction methods for supersonic transport applications (SST).

Project Benefits:

The validation of these prediction codes will give confidence in the noise prediction, which will aid in the design of low noise engines for reduced landing and takeoff noise of supersonic aircraft





Research Approach:

- Design and fabricate a simple model-scale test nozzle made of a round core primary nozzle buried in a coaxial secondary flow with the mixed flow exhausting some distance downstream of the primary nozzle exit.
  - Geometry was designed as a scaled model of a paper engine design
- Acquire acoustic and related flow measurements as a function of mixing distance between the primary nozzle exit and the final exhaust nozzle exit
- Provide the measured data to modeling teams for validation of prediction codes

Major Accomplishments (to date):

- The test nozzle designed and fabricated
- The model design shared with the modelers
- Acoustic data acquisition is in progress and initial data shared with the modelers

Future Work / Schedule:

- Complete the acoustic and flow measurement acquisition (5-15-2021)
- Share all data with modelers and be available for interactions (present through (5-28-2021)
- Select a mixer design for the Year 2 effort (5-28-2021)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 59 through FAA Award Number 12972897 under the supervision Krishan Ahuja (PI), Dimitri Mavris (Co-PI), and Jimmy Tai (Co-PI). Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 59C

Modeling Supersonic Jet Noise Reduction with Global Resolvent Modes

University of Illinois at Urbana-Champaign

PI: Daniel J. Bodony

PM: Sandy Liu

Cost Share Partner: Boom (in negotiation)

Objective:

Develop a rapid prediction capability to estimate changes in jet take-off noise due to design changes

Project Benefits:

Reduce sound environmental impact due to anticipated return of supersonic civilian transport aircraft

Research Approach:

Utilize input-output (resolvent) descriptions of the jet aeroacoustics to link nozzle design choices to their impact on the radiated noise.

Envisioned usage:

1. Compute RANS of baseline nozzle with identified design parameters
2. Compute input-output operator and its derivatives wrt design parameters
3. Select new design parameters that reduce far-field noise
4. Return to 1.) with new nozzle and repeat

Major Accomplishments (to date):

- Python-based nozzle CAD → RANS grid ready
- RANS solver modified for hot jet flows and verified
- Input-output operator code developed and verified
- Evaluation of input-output gain sensitivities to nozzle design demonstrated

Future Work / Schedule:

- Develop self-consistent scaling of resolvent amplitudes on RANS TKE
- Develop automated design workflow

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 59c through FAA Award Number 13-C-AJFE-UI (Amendment 31) under the supervision of Dr. Sandy Liu. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 59D

Physics-based Analysis and Modeling for Supersonic Aircraft Exhaust Noise

Stanford University

PI: Sanjiva K. Lele, Juan J. Alonso

PM: Sandy Liu

Cost Share Partner: TBA

Objective:

In collaboration with ASCENT partners in Project 59, develop multi-fidelity physics-based analyses for supersonic aircraft exhaust noise.

The main goals are to develop improved jet noise prediction methods and better understand the uncertainty associated with the noise predictions, for a range of engine cycle parameters and operating conditions relevant for commercial supersonic aircraft.

Project Benefits:

Aircraft and engine companies, and organizations such as NASA, FAA, and DoD R&T community would also benefit from the improved methods and tools. Ultimately, supersonic jet noise tools with predictive capabilities can be used to design better noise mitigation systems and to provide estimates of noise for certification studies.

Research Approach:

- In consultation with Project 59 and other project partners in ASCENT define the plans for high-fidelity simulations and jet noise modeling.
- Develop and validate high-fidelity jet noise predictions for baseline configurations
- Develop and validate RANS-based jet noise predictions for baseline configurations
- Develop and validate high-fidelity jet noise predictions for configurations with noise mitigation concepts
- Develop and validate RANS jet noise predictions for configurations with noise mitigation concepts

Major Accomplishments (to date):

Preliminary LES of primary nozzle and primary+secondary buried nozzle (GaTech geometry)

Development and validation of far-field noise propagation model (Adjoint-Green's function)

Future Work / Schedule:

Noise prediction for selected cases from GaTech baseline experiments using LES (Year 2)
Development and validation of RANS based approach
Noise source model improvements (Year 3)
Noise predictions for noise mitigation concepts (Year 3)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project {add project number here} through FAA Award Number {add grant number} under the supervision of {add PM names here}. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 60

Analytical Methods for Expanding the AEDT Aircraft Fleet Database

Georgia Institute of Technology

PI: Yongchang Li, Dimitri Mavris

PM: Joseph DiPardo, Jeetendra Upadhyay

Cost Share Partner: Georgia Institute of Technology

Objective:

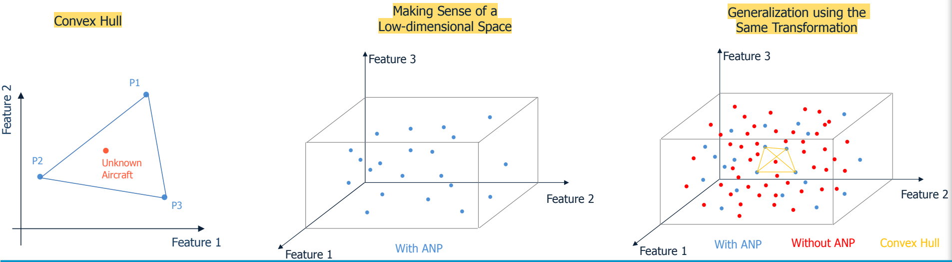
Improve the accuracy of AEDT noise and emissions modeling of aircraft not currently in the Aircraft Noise and Performance (ANP) database by developing ANP data for those aircraft to expand the AEDT FLEET database.

Project Benefits:

This research will improve the noise and emissions modeling of the aircraft that are not currently represented in AEDT's FLEET database and eventually enhance AEDT's environmental modeling capability. This will also improve the accuracy of AEDT to better reflect the environmental assessment of the aircraft operations.

Research Approach:

- Construct a master database to collect information and necessary data of the aircraft
- Formulate a statistical learning method – Mixture Models to develop ANP and noise data for the target aircraft
- Utilize high fidelity data to validate the developed methods



Major Accomplishments (to date):

- Conducted literature review and constructed a master database to better under the characteristics of the target aircraft
- Proposed representative aircraft model portfolio and mixture model to develop ANP data for the aircraft

Future Work / Schedule:

- Investigate new methods or improve the proposed analytical methods
- Validate the developed methods against high fidelity data and develop ANP and noise data to expand the current FLEET database

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 60 through FAA Award Number 13-C-AJFE-GIT-065 under the supervision of Joseph DiPardo and Jeetendra Upadhyay. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 061

Noise Certification Streamlining

Georgia Institute of Technology

PI: Dimitri Mavris, Jimmy Tai, Michael Balchanos

PM: Sandy Liu

Cost Share Partners: Boeing, Bell, Gulfstream, Rolls-Royce

Industry Partners: Boeing, Bell, Gulfstream, Rolls-Royce Embraer, Cessna/Textron, De Havilland Canada

Objective:

Examine current noise certification procedures and identify opportunities to streamline the noise certification process in addition to recommending methodologies for building the needed flexibility to accommodate all air vehicle types

Project Benefits:

Recommendations towards a more efficient, streamlined, and flexible aircraft noise certification:

- Proposition of equivalent procedures, supported by latest technologies and hardware
- Evaluation of alternative practices through a Model-Based Systems Engineering (MBSE) model of the noise certification process (in SySML)
- Analysis techniques to support certification of future air vehicles types

Research Approach (Year 1 Tasks)

Task 1: Interview Industrial Partners on Current Noise Certification Process
- Task 1.1: FAA Noise Certification Regulation Review
- Task 1.2: Industrial Partner Interviews via Workshops

Task 2: Develop a Streamlined Noise Certification Procedure for Existing Aircraft
- Task 2.1: Current Process Assessment
- Task 2.2: Streamlined Process Definition

Task 3: Develop a Flexible Noise Certification Procedure for New Aircraft
- Task 3.1: Flexibility Assessment of Streamlined Process

Task 4: Simulate Streamlined and Flexible Noise Certification Procedure
- Task 4.1: Identify Modeling Approach
- Task 4.2: Noise Certification Process Metric Definition

Major Accomplishments (to date):

- Completed documentation of current noise certification regulatory framework (14 CFR Part 36 , AC 36-4D)
- Hosted workshops/interviews with Industry Partners for transport category aircraft (jet & turboprop)
- Benchmarking of current practices in certification flight testing and identification of improvement opportunities
- Baseline certification process model in SySML

Future Work / Schedule (Year 1 Tasks):

- Planned workshop/interview for rotorcraft and small propeller-driven vehicle categories
- Improvements on the SySML certification process model
- Exploration of lateral microphone equipment options, conformity, NAC substantiation methods, and > 0.1 db certification by analysis

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, Project 061 through FAA Award Number 13-C-AJFE-GIT-066, under the supervision of Sandy Liu, and Bill He. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 62

Noise Model Validation for AEDT

Georgia Institute of Technology

PIs: Dimitri Mavris, Michelle Kirby

PM: Bill He

Cost Share Partner: Delta Air Lines

Pennsylvania State University

PI: Victor Sparrow

PM: Bill He

Cost Share Partner: Spire Global

Objective:

- Assess the accuracy of AEDT in estimating noise compared to real-world measurements in both the vicinity of airports as well as further afield under various modeling assumptions
- Enable incorporation of high-fidelity weather in AEDT noise modeling for real-world flights

Project Benefits:

- One of the main benefits of this project is to suggest possible improvements that could be made in future releases that enhance the predictive capability with respect to real world measurement data

Research Approach:

- Using real-world data (flight data, noise monitoring data, high-fidelity weather) identify the various modeling options available in AEDT
- Develop capabilities to automatically model real-world flights in AEDT (using high-fidelity weather information where possible) and compare outputs against noise measurements from corresponding events
- Identify discrepancies, quantify differences, and document possible improvements for future efforts

Major Accomplishments (to date):

- Developed automation scripts that enable modeling real-world flight operations at any desired settings in AEDT
- Developed a new workflow to process and utilize high-fidelity weather in AEDT modeling and demonstrated on sample flights

Future Work / Schedule:

- Model selected flights that span a broad range of operational scenarios
- Improve existing workflow for high-fidelity weather modeling to demonstrate on new flights

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 62 through FAA Award Numbers 13-C-AJFE-GIT-061 (GT), 13-C-AJFE-PSU (PSU) under the supervision of Bill He. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 63

Parametric Noise Modeling For Boundary Layer Ingesting Propulsors

Georgia Tech

PI / CO-PI: Dimitri Mavris / Jonathan Gladin

PM: Chris Dorbian

Cost Share Partner: Georgia Tech

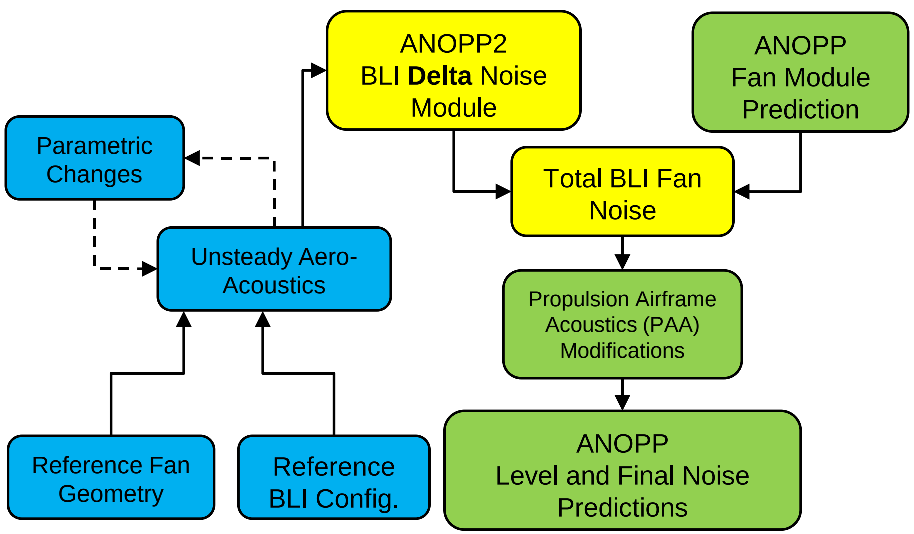
Objective:

To identify, develop, and validate a parametric fan noise module for a generic BLI propulsor based on the specifics of a configuration and design

Project Benefits:

- New capability for design engineers to determine the noise impact of new concepts
- Perform trades of fuel burn benefit versus noise at the conceptual level
- Reduce overall community noise by improving the accuracy of noise predictions for future advanced concepts
- Allowing vehicle designers to find the best opportunity for BLI technologies that offer fuel burn and noise benefits simultaneously

Research Approach: Quasi-Empirical



Major Accomplishments (to date):

- Validation of fan noise module with NASA ANOPP and experimental data.
- Successful Creation of CFD meshes for Unsteady CAA with baseline SDT geometry
- Integrated Geometry Design and Testing in STAR-CCM steady RANS for Tail Cone Thruster

Future Work / Schedule:

- Finalize design work for the 4 remaining parametric BLI geometries
- Validation of CAA results for the SDT fan
- Mesh and generate CAA results for each BLI case

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 13-C-AJFE-GIT-064 through FAA Award Number 13-C-AJFE-GIT-064 under the supervision of Chris Dorbian. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

Project 64

Alternative Design Configurations to meet Future Demand

Georgia Tech

PI: Prof. Dimitri Mavris, Dr. Michelle R. Kirby

PM: Arthur Orton

Cost Share Partner: Georgia Tech

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 64 through FAA Award Number 13-C-AJFE-FIG-062 under the supervision of Arthur Orton. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

Objective:

Assist FAA in projection of long-term CO2 emissions forecasts by assessing the aircraft technology and configurations possible in the 2050 time frame and utilize results to inform FAA of possible future scenarios to support for engagement at ICAO

Impact Statement:

The impact of this project will be an improved understanding of the impacts of potential alternative design and technology choices by the aircraft manufacturers on potential CO2 reduction goals of the future

By assessing the potential CO2 reduction potential of the future fleet, the FAA will be informed by a data driven process on the potential long term CO2 reduction goals.

Research Approach:

Development of an overall analysis methodology to support the CO2 Long Term Aspirational Goal (LTAG) effort, including the role of aircraft/technology inputs in this analysis workflow

Execution and assessment of 2050 projections of all technology reference aircraft, all five classes of vehicles (turboprop, business jet, regional jet, narrow body, wide body)

Execution and assessment of 2050 projection of advanced configuration aircraft

Major Accomplishments:

Engaged with the broader ICAO community to develop a framework for the identification and quantification of potential conventional and advanced technologies and aircraft concepts

Established a turboprop model

Assessed wide body technology impacts to 2050

Future Work:

Conduct the full analysis across aircraft types for conventional and alternative configuration aircraft through 2050

Coordinate with other LTAG sub-groups

Projected Benefits:

This project will provide the FAA with an understanding of the impacts of future trends in aircraft technology on fuel burn and CO2 emissions from international aviation

The work will support FAA engagement and decision-making at the International Civil Aviation Organization (ICAO), in particular relating to the effort to assess the feasibility of a Long Term Aspirational Goal for CO2 emissions from international aviation.

ASCENT Project 065a

Fuel Testing Approaches for Rapid Jet Fuel Prescreening

University of Dayton

PI: Joshua Heyne

PM: Anna Oldani

Cost Share Partner: VUV Analytics and DLR Germany

Objective:

To develop early-stage low volume evaluations of novel Sustainable Aviation Fuel (SAF) candidates via ASTM property tests and internal predictions

Project Benefits:

Rapid feedback to novel fuel producers on the blend ratios, compatibility, and combustor operability impacts of SAF candidates

Research Approach:

Evaluation methodologies are developed around a two-tiered prescreening

Tier α focuses on predictions; Tier β focuses on measurements

Tier	Measured Property	Predicted Property	Vol. (mL)	No. tested
α	GCxGC	LHV, Density, Surface tension, Freeze point, Viscosity, DCN, Flash point	1	58
	Distillation			
β	Density	LHV	10	38
	Viscosity			
	Surface ten.			
	Freeze point			
	Flash point			
	DCN		140	8

Major Accomplishments (to date):

Facilitated the process development of a volatile fatty acid pathway (PNAS paper)

Tools developed in P65a have been used to evaluate **58 SAF candidate samples** from approximately 8 labs and 12 pathways

Publications: 3

Invited talks: 8

Future Work / Schedule:

Development of additional Tier α methods

- May ’21 – Method completion on simple mixtures
- August ’21 – Complex fuel method development
- August ’21 – Property prediction updates

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 065a through FAA Award Number 13-C-AJFE-UD-026 under the supervision of Dr. Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 65B

Fuel Testing Approaches for Rapid Jet Fuel Processing

University of Illinois Urbana-Champaign

PI: Tonghun Lee

PM: Cecilia Shaw

Cost Share Partner: Convergent Sciences

Objective:

The objective is to develop a new compact test rig (M1 combustor – conceived in the National Jet Fuel Combustion Program (NJFCP) which can complement ASTM D4054 evaluation and qualification guidelines for prescreening of fuels prior to Tier 3 & 4 tests. The M1 may have the potential to carry out these tasks at much reduced fuel volumes (~gallons vs. ~hundred of gallons) in a simplified and open architecture that can be readily shared and operated at different locations at a fraction of the cost.

Project Benefits:

Though prescreening is not a formal step in ASTM D4054, it would enable fuel producers to assess the viability of new blends using small volumes prior to increased production. This proposal (65b) is a novel attempt to implement a small scale (~low cost) combustor test that can potentially predict many key targets of a full annular rig. It would allow fuel providers and OEMs to conduct basic combustor tests using identical combustor architecture to mitigate uncertainty in actual Tier 3 & 4 ASTM tests. The platform can also be used for other combustion tests for SAF performance evaluation.

Research Approach:

Characterization of M1 combustor

- Advanced X-ray diagnostics at Argonne Advanced Photon Source
- Diagnostics at UIUC (PLIF, PDPA, PIV)
- Numerical simulation effort at Argonne National Laboratory
- High altitude testing Army Research Laboratory (APG)
- Comparison of M1 vs. Referee Rig (**Ignition and lean blow out**)
- OEM and national laboratory buy-in and collaboration

Establish a common and accessible combustor to (1) enable fuel producers and OEMs to individually predict confidence levels in the capital intensive Tier 3 & 4 tests using low quantities of fuel, (2) shorten jet fuel certification process by reducing the uncertainties in full-scale ASTM testing, (3) enable access to combustor performance data without a centralized combustor such with large operational overhead, (4) contribute to various fast track processes for fuel certification, and (5) produce a test platform for testing of fuel performance and emission.

Major Accomplishments (to date):

Accomplishments in Year I

- Integration and operation of the M1 combustor and control system
- Conducted short workshop with OEM and laboratory (at project start)
- Setup of numerical simulation team at Argonne National Laboratory
- High altitude testing Army Research Laboratory (APG) Nov. 2020
- Preliminary measurements of lean blow out – identification of issues
- Setup of diagnostics at UIUC (high speed PLIF & PIV)
- COVID Impact: Argonne APS measurements delayed

Future Work / Schedule:

Continued Characterization of M1 combustor

- Optimization of spray injection system for M1 combustor
- Obtain X-ray diagnostics at Argonne Advanced Photon Source
- Obtain data from PLIF, PDPA, PIV at UIUC
- Obtain data for Ignition and lean blow out (fuel sensitivity)
- Couple with numerical simulation from Argonne National Laboratory

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 65B through FAA Award Number 13-C-AFJE-UI-030 under the supervision of Cecilia Shaw. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

Project 66

Evaluation of Engine Fuel Burn and Thermal Management Benefits with Use of High Thermal Stability Fuels

University of Dayton

PI: Joshua Heyne / Randall Boehm

PM: Anna Oldani

Cost Share Partner: DLR Germany (POC: Bastian Rauch)

Objective:

Evaluation of Engine Fuel Burn and Thermal Management Benefits with Use of High Thermal Stability Fuels

Project Benefits:

Quantifying advantages of sustainable alternative fuel (SAF) supports argument to promote accelerated implementation.

An energy savings of a least 0.5% is predicted when superior thermal stability is leveraged by straight-forward design changes

Research Approach:

Monte Carlo Simulation (fuel composition)

Fuel properties from composition

1D thermal model of fuel system (FSTM)

Brayton cycle model of engine (EPM)

- 5 engine design configurations considered

Major Accomplishments (to date):

Proof of concept, paper submitted:

R. Boehm, L. Scholla, J. Heyne "Sustainable Alternative Fuel Effects on Energy Consumption of Jet Engines" Fuel, submitted Mar 17, 2021

Future Work:

Leverage OEM engine performance models and mission mix to substantiate savings estimates

Integrate methodology with JudO to suggest fuels that are optimized with respect to both engine efficiency and aircraft efficiency (weight)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 66 through FAA Award Number13-C-AJFE-UD-027 under the supervision of Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 67

Impact of Fuel Heating on Combustion and Emissions

Purdue University

PI: Robert P. Lucht; Co-PI: Carson D. Slabaugh

PM: Cecilia Shaw

Cost Share Partner: Purdue University

Graduate Students: John J. Philo, Colin T. McDonald, Tristan T. Shahin

Research Engineer: Rohan Gejji

Objective:

This project will characterize the global and local impact of hot fuel injection on the performance of aviation gas turbine combustion systems in high-OPR aircraft engines using extractive exhaust sampling and advanced optical and laser-based diagnostics. Conditions where the fuel temperature is above the critical temperature are of great interest.

Project Benefits:

The benefit of this project will be advancement of low emissions gas turbines to the next level of cycle efficiency by providing key insights needed to design combustion devices for operation with hot fuels.

Research Approach:

Purdue's COMRAD facility houses a high-pressure, liquid-fueled, swirl injector (GE TAPS) in an optically-accessible chamber that closely replicates engine conditions. An 81 kW fuel heater heats liquid fuel to temperatures up to 800F. To detect changes in combustion behavior, optical diagnostics and exhaust gas sampling are performed. Advanced laser diagnostics to be applied are planar laser-induced (PLIF) OH fluorescence for reaction zone imaging, particle imaging velocimetry, PLIF and Mie scattering for fuel vapor and liquid imaging, and coherent anti-Stokes Raman scattering (CARS) for temperature measurements.

Major Accomplishments (to date):

- Designed and built fuel heating system.
- Began initial emissions sampling to down-select conditions of interest from test matrix, operated with fuel at 200F.
- Acquired high-speed chemiluminescence images.

Future Work / Schedule:

- Perform survey emission sampling measurements with fuel temperatures of 400F and 600F (April-July 2021).
- Down-select conditions for detailed laser diagnostic measurements (Aug 2021)
- Detailed laser diagnostic measurements (Aug 2021-June 2022).

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 67 through FAA Award Number 13-C-AJFE-PU-038 under the supervision of Cecilia Shaw. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 068

Combustor Wall Cooling with Dirt Mitigation

The Pennsylvania State University

PI: Karen A. Thole / co-PI: Stephen P. Lynch

PM: Cecilia Shaw

Cost Share Partner: Pratt & Whitney

Objective:

Dirt accumulation on the surfaces of gas turbine components severely diminish the performance of various cooling technologies. The objective of this study is to investigate new cooling designs that are insensitive to dirt accumulation effects.

Project Benefits:

The expected benefit from this study is a cooling design for combustor walls that is insensitive to dirt accumulation, as well as an gaining an understanding as to why particular designs may be insensitive to the dirt accumulation. These results will lead to reduced turbine maintenance.

Research Approach:

The research approach for developing new cooling designs for the combustor liner is: testing of a range of cooling technologies at engine scale using a multi-phase flow that contains small dirt particles downselecting the most promising design; measuring detailed flow and heat transfer measurements of the most promising design; scaling the most promising design for integration into an annular configuration for testing in a laboratory test turbine.

Major Accomplishments (to date):

Computational and experimental methods have been established to ensure repeatable results using a generic combustor liner geometry. Two different dirt feeds were developed to include continuous and slug flows of the dirt. Several liner coupons with each having a unique cooling design have been manufactured.

Future Work / Schedule:

Testing of the combustor liner coupons will begin in May and extend throughout the summer.

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 068 through FAA Award Number 12914694 under the supervision of Cecilia Shaw. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 69

Transitioning a Research nvPM Mass Calibration Procedure to Operations

Missouri University of Science and Technology

PI: Philip D. Whitefield

PM: Daniel Jacob

Cost Share Partner: EASA and EMPA

Objective:

Investigate the validity of the Centrifugal Particle Mass Analyzer (CPMA) mass calibration research approach for non-volatile Particulate Matter (nvPM) certification measurement systems. The assessment will extend across all nvPM mass ranges encountered during certification tests. The primary goal will be the successful transitioning of the research methodology to operations

Project Benefits:

- This project will validate an advanced calibration method that reduces the current time constraints imposed for annual nvPM mass instrument calibration.
- The method will reduce measurement uncertainty during certification.
- Once successfully demonstrated, the method can be implemented in ICAO Annex 16 Vol. II.
- Currently each engine emissions certification test costs approximately $500k, the implementation of this new method will reduce (~50%) instrument calibration costs.
- This approach will provide in-the-field real-time performance check of the nvPM mass instrument during certification testing, improving confidence in the PM mass concentration measurements.

Research Approach:

- Acquire instruments for use with the CPMA calibration system
- Develop a suitable sampling and test configuration for evaluating the CPMA-based nvPM mass calibration using laboratory aerosol sources at MS&T
- Investigate the validity of the CPMA mass calibration research approach across all nvPM mass ranges encountered during certification tests to successfully transition the methodology to operations
  - Deploy the measurement system, to engine testing facilities at Arnold AFB, TN. Specifically, these engine testing facilities will include the J85 turbojet and a gas-turbine-based "start cart" as nvPM sources.
  - Evaluate the performance of the CPMA-based mass calibration system, surveying across all mass ranges using the start cart as the nvPM source, and compare these results with concomitant mass calibration data acquired using the SAE E-31 OCEC-based mass calibration methodology.
  - Undertake performance demonstration by performing a mock-certification test on the J85 engine where the calibration will include the standard EC/OC analysis, as well as the CPMA-based calibration system.
- Analyze and interpret the data gathered and deliver a final report that can be used by SAE E31 to update ARP 6320 and by ICAO to update Annex 16 Vol.II.

Major Accomplishments (to date):

- CPMA Calibration System Assembled
- A sampling and test protocol has been proposed and is under evaluation
- Laboratory-based performance assessment experiments are underway
  - Preliminary results are encouraging

Future Work / Schedule:

- Complete Laboratory Tests and develop a Robust Calibration System Configuration
- Tests using gas turbine start cart and parallel reference measurements
- Tests using J85 gas turbine engine
- Based on the results, develop a standardized in situ CPMA calibration protocol for nvPM mass

Schedule Proj 69	Q3 2021	Q4 2021	Q1 2022	Q2 2022	Q4 2022
Subtask 2	■				
Subtask 3		■	■		
Subtask 4	■	■	■	■	■
Subtask 5					■

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 069 through FAA Award Number 13-C-AJFE-MST-014 under the supervision of Daniel Jacob. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 070

Reduction of nvPM Emissions from Aero-Engine Fuel Injectors

Georgia Institute of Technology & Honeywell International, Inc.

PI: Wenting Sun, Adam Steinberg, Ellen Mazumdar, Rudy Dudebout

PM: Cecilia Shaw

Cost Share Partner: Honeywell International, Inc.

Objective:

- Characterize the formation and oxidation of non-volatile particulate matter (nvPM)
- Optimize the design of an aeronautical gas turbine fuel injector to reduce nvPM

Project Benefits:

- Improve the understanding of nvPM formation/oxidation at engine relevant conditions
- Develop numerical models to predict nvPM emissions from aero-engines, and guide new fuel injector designs.
- Enable cleaner aircraft engines compliant with the ICAO CAEP/11 nvPM LTO standard.

Research Approach:

- Experimental system development
  - A combustor sector with three fuel injectors is designed and will be fabricated.
- Experiments at practical conditions and numerical simulations.
  - PAH/OH PLIF, LII for soot volume fraction and primary particle size, and PIV for flow field.

Major Accomplishments (to date):

- Design of high pressure system with fabrication in progress
- Combustor design and analysis is underway
- Shakedown of optical diagnostics is also being completing

Future Work / Schedule:

- High pressure combustor commissioning (Y1Q3&Y14)
- Preliminary optical diagnostics (Y1Q4)
- Measurement of nascent soot to cover the entire process of nvPM formation (Y2Q3&Y2Q4)
- Numerical simulation to optimize fuel injector design (Y2Q3&Y2Q4)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 070 through FAA Award Number 13-C-AJFE-GIT-080 under the supervision of Cecilia Shaw. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project: 071

Predictive Simulations of nvPM Aircraft Emissions

Georgia Institute of Technology

PI: S. Menon[1] (with A. Violi[2], M. Yazdani[3], S. Zeppieri[3] and M. Colket[4])

PM: Roxanna Moores

Cost Share Partners: [1]Georgia Institute of Technology, [2]University of Michigan, and [3]Raytheon Technology Research Center.

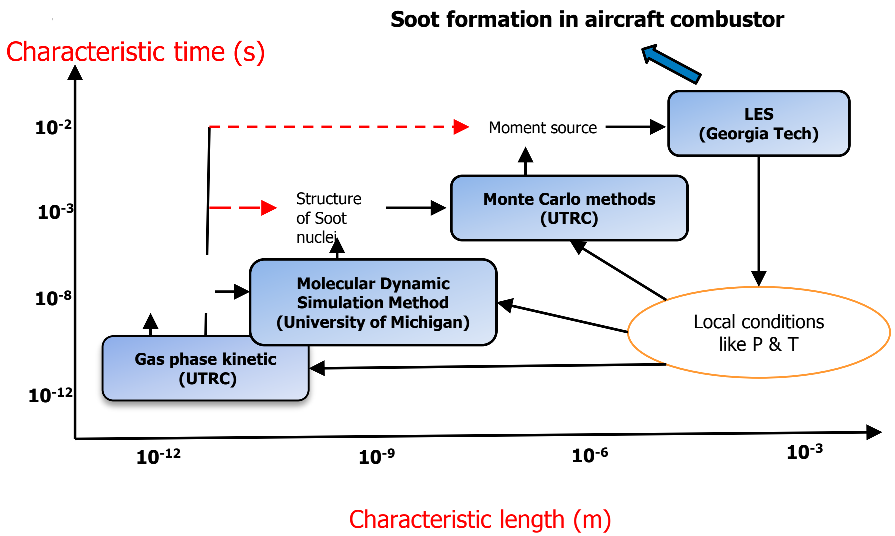
[4]Consultant

Objective:

- Reliable soot kinetics for complex polyaromatic hydrocarbons (PAHs) jet-fuel systems
- Develop a new model for nanoparticle inception
- Link kinetics and particle inception to growth models
- Apply models within large-eddy simulations (LES)

Project Benefits:

- Predictive model for aeroengine combustor emission
- New predictive inception and growth models for soot formation in PAHs dominated fuels
- New CFD to simulate emission from flames using these multi-scale models



Major Accomplishments:

- Developed integrated surface-growth and aggregation model for post-inception particle growth
- Identified major PAHs from the gas-phase for molecular simulations.
- LES-Method of Moment (LESMOM for canonical turbulent combustion to evaluate new models

Future Work / Schedule (2-Year Plan):

- Complete validation of PAH based soot kinetics
- Couple particle growth model with nucleation and inception-growth mode with validation
- Reduced models for LES application
- To LES of canonical and relevant problems

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 71 through FAA Award Number (13-C-AJFE-GIT-067) under the supervision of Roxanna Moores. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 72

Aircraft noise exposure and market outcomes in the U.S.

Massachusetts Institute of Technology

PI: *R. John Hansman, Christopher Knittel et al.*

PM: *Sean Doyle*

Objective:

Provide empirical insights into:

(i) The impact of noise exposure on house prices in communities surrounding U.S. airports.

(ii) The heterogeneities associated with these impacts, which can be driven by factors such as time, location, or noise exposure patterns

Project Benefits:

1. Detailed noise modeling of real flight tracks
2. Updated understanding of impacts of aircraft noise on property prices, incl. heterogeneities
3. Comparison of revealed preference data with stated preference data

Research Approach:

Noise modeling

Model noise around U.S. airports with high spatial and temporal resolution.

Focus on locations with noise differences due to introduction of RNAV procedures

Real estate data

Empirical model

Natural experiment:

$$\Delta Noise \rightarrow \Delta P \ ?$$

- Noise changes following introduction of RNAV procedures (natural experiment)
- Other short-term experiments to be considered

Addresses concerns regarding:

- Omitted variable bias
- Causality concerns

Major Accomplishments (to date):

- Identified key airports of interest based on ASDE-X equipment, community disputes, and changes in runway configuration
- Set up AEDT to process large quantities (months-worth) of ASDE-X flight data and calculate noise based on real flight tracks
- Sourced comprehensive real-estate data set

Future Work:

- Run additional noise analyses for airports with relevant noise exposure changes
- Apply empirical model (static and dynamic) to analyze impacts on house prices
- Identify short-term and long-term dynamics by adding additional short-term experiments

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 72 through FAA Award Number 13-C-AJFE-MIT under the supervision of Sean Doyle. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 73

Combustor Durability Evaluation with Use of Alternative Jet Fuels

University of Dayton Research Institute

PI: Steve Zabarnick

PM: Anna Oldani

Cost Share Partner: Fuel producers, engine/airframe OEMs

Objective:

Understand and characterize the **impact of fuel composition on gas turbine combustor liner lifetime**

Project Benefits:

Determine impact of alternative fuels on combustor liner lifetime

Quantify/qualify **potential benefits for combustor liner lifetime from alternative jet fuel use**

Minimize (hopefully eliminate) engine durability issues with use of alternative fuels

Research Approach:

Develop radiative heat transfer measurement system for referee combustor

Initial experiments to evaluate operating points and sensitivity

Test fuels with varying composition

Major Accomplishments (to date):

This is a new project with no major accomplishments yet

Future Work / Schedule:

Proceed with research approach toward beginning testing late 2021/early 2022

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 73 through FAA Award Number 13-C-AJFE-UD under the supervision of Dr. Anna Oldani. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 74

Low Emission Premixed Combustion Technology for Supersonic Civil Transport

Georgia Institute of Technology & GE

PI: Adam M. Steinberg

PM: Daniel Jacob

Cost Share Partner: GE

GIT: E. Mazumdar, J. Oefelein, J. Seitzman + 8 Students

GE: M. Benjamin, H. Bower, J. Hong, K. Venkatesan, R. Chiranthan, M. Giridharan, H. Nath

Objective:

1) Characterize and understand the emissions and performance of novel premixed combustor architecture for supersonic civil transport
2) Develop methods for computational design/analysis

Project Benefits:

1) Improved combustor architectures with reduced emissions at conditions relevant for supersonic flight
2) Reduced development time/cost through validated tools

Research Approach:

1) Experimental studies at realistic operating conditions using laser measurement techniques
   - High-speed S-PIV (velocity), spray imaging, chemiluminescence
   - Fuel PLIF (mixing), TiRe-LII (nvPM)
   - Exhaust emissions, noise
2) Large Eddy Simulations
   - Research-scale first-principles LES
   - Industrial-scale LES
   - Accuracy/cost trade-offs
3) Combustion dynamics modeling

Major Accomplishments (to date):

1) Design and fabrication of experimental configuration
2) Design, setup, calibration of laser diagnostics
3) Design and setup of computational configuration

Future Work / Schedule:

1) Experimental campaign 1 & production LES (June 2021)
   - Flame structure, operability, emissions
2) Combustor response under forcing (Year 2)

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 74 through FAA Award Number 13-C-AJFE-GIT-079 under the supervision of Daniel Jacob. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 075

Improved engine fan broadband noise prediction capabilities

Boston University & RTRC

PI: Sheryl Grace & Jeff Mendoza

PM: Chris Dorbian

Cost Share Partner: BU, RTRC, AARC

Objective:

Improve low-order (LO) models for the prediction of fan broadband interaction noise by addressing gaps in existing methods using both computation and experimentation. The main gaps being considered are a LO model for the inflow to an exit guide vane and full-scale validation of the LO exit guide vane response.

Project Benefits:

Elimination of time-consuming, high-fidelity simulations or prototype development and testing in order to assess broadband noise levels created by high bypass turbofans.

Research Approach:

- Develop a surrogate model for a fan wake using machine learning. Create the necessary training data and compare different machine learning methods. Determine both the mean and turbulence wake profiles upstream of the exit guide vane using only rotor-based information.
- Test the current LO exit guide vane response method's ability to predict the broadband noise associated with a full-scale case using available experimental data.

Major Accomplishments (to date):

- Data set development started
- ML methods tested for mean wake on initial data
  - SDT data has been the focus
  - Method developed for unrolling the gap wake data so that ML can actually follow the wake shape (feature identification)

Future Work / Schedule:

- Summer: LO response tested on full-scale rig data
- Summer: ML
  - Turbulent wake profile
  - Multiple fans and more speeds

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 075 through FAA Award Number 13-C-AJFE-BU - amendment 022 under the supervision of Chris Dorbian. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 076

Improved Open Rotor Noise Prediction Capabilities

Georgia Institute of Technology

PI: Dr. Dimitri Mavris

PM: Chris Dorbian

Cost Share Partner: GE Aviation

Objective:

- There is a major challenge in meeting noise targets while simultaneously meeting other design constraints.
- The open rotor concept has promising fuel benefits, but there is a need to quantify the impact of design parameters on open rotor noise.
- A study of design parameter sensitivity to CROR system noise responses will be conducted in order to identify impactful design parameters.

Project Benefits:

The study of CROR design parameter sensitivity will identify trends that can aid further research and provide insight to design tradeoffs

Research Approach:

This study is comprised of the following:

- Identification of Open Rotor noise-sensitive design parameters
- Parametric geometry model development
- Simulation campaign – unsteady aero & CAA
- Definition of sensitivity study methodology and its execution

Major Accomplishments (to date):

- Identification of open rotor design variables – from previous studies – classified in groups: rotor, pylon installation and airframe integration.
- Development of a parametric open rotor geometry

Future Work / Schedule:

- Down selection of design parameters for sensitivity study
- Validation – with experimental data – of simulation analysis; unsteady aerodynamics as well as computational aeroacoustics

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project Ascent 076 through FAA Award Number 13-C-AJFE-GIT-078 under the supervision of Chris Dorbian. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT Project 77

Measurements to Support Noise Certification for UAS/UAM Vehicles and Identify Noise Reduction Opportunities

Penn State

PI: Eric Greenwood

PM: Bill He

Cost Share Partner: Beta Technologies

Objective:

To develop repeatable noise measurement methods for UAS and UAM vehicles and to use these methods to collect noise data on a variety of UAS and UAM configurations across different operating modes, speeds, and altitudes.

Project Benefits:

- Inform noise certification standards
- Research database of UAS and UAM noise
- Reduce negative acoustic impacts of UAS and UAM through design changes and operation

Research Approach:

- Simulate UAS and UAM noise measurements
- Develop noise source separation for distributed propulsion vehicles
- Investigate instrumentation requirements for acoustics, weather, and vehicle state
- Collect noise data on UAS and UAM components and vehicles
- Explore acoustical effects of design changes, operating procedures, and flight control laws

Major Accomplishments (to date):

- Simulation of "nearly coherent" multirotor noise
- Development of a noise source separation technique for multirotor aircraft flyover data
- Initial measurements of UAS and UAM component and full-vehicle noise

Future Work / Schedule:

- Development and acoustic measurement of a reconfigurable multirotor UAS platform
- Quantification and modeling of the variability and uncertainty in UAS and UAM noise
- Measurements of UAS and UAM noise across a range of steady and unsteady flight conditions

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, Project 77 through FAA Award Number 13-C-AJFE-PSU Amendment No. 67 under the supervision of Bill He. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.