Emissions Roadmap Update

Office of Environment & Energy (AEE)

Presented to: REDAC E&E Subcommittee

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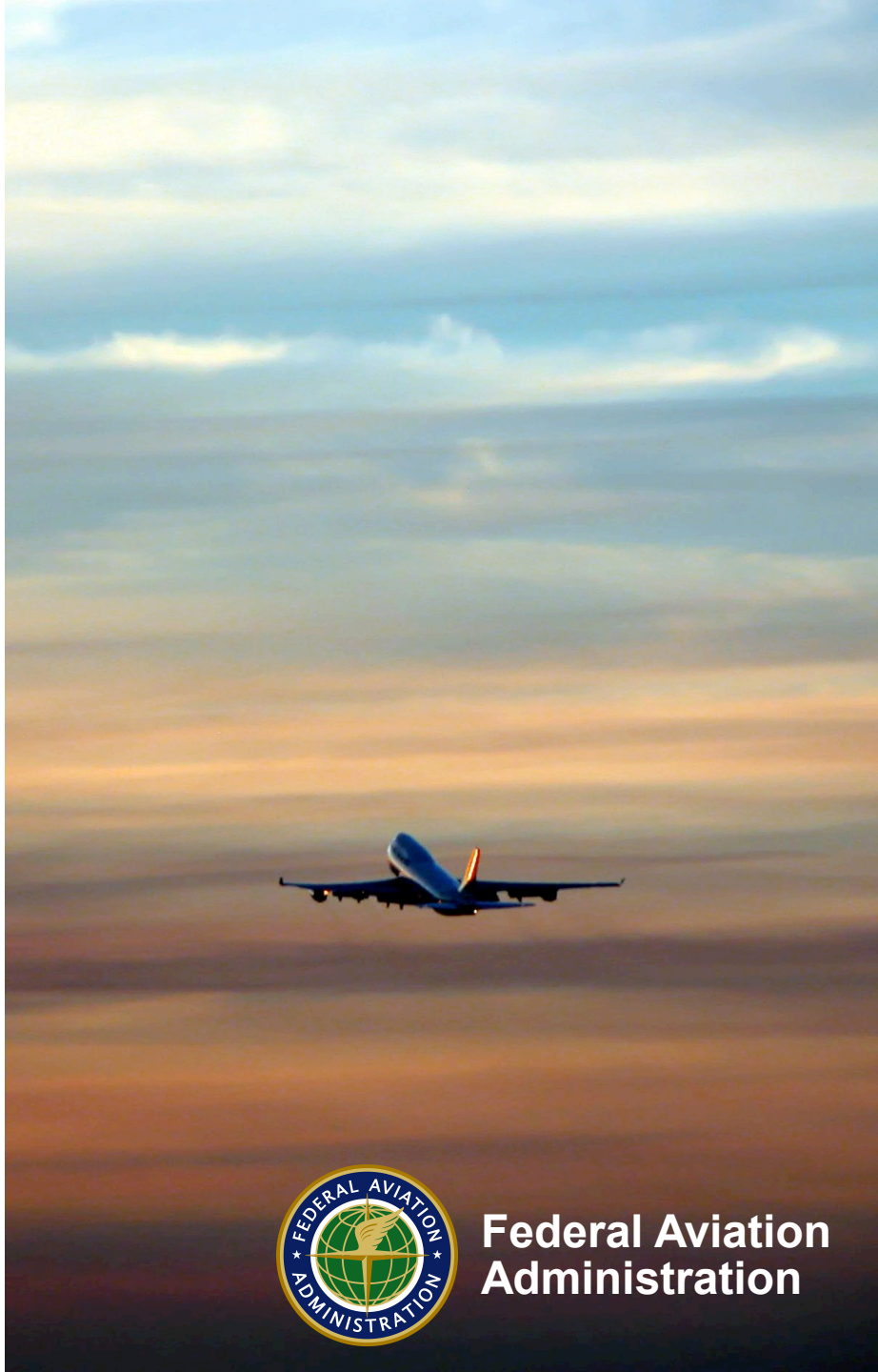
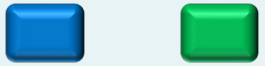
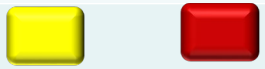
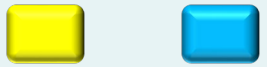
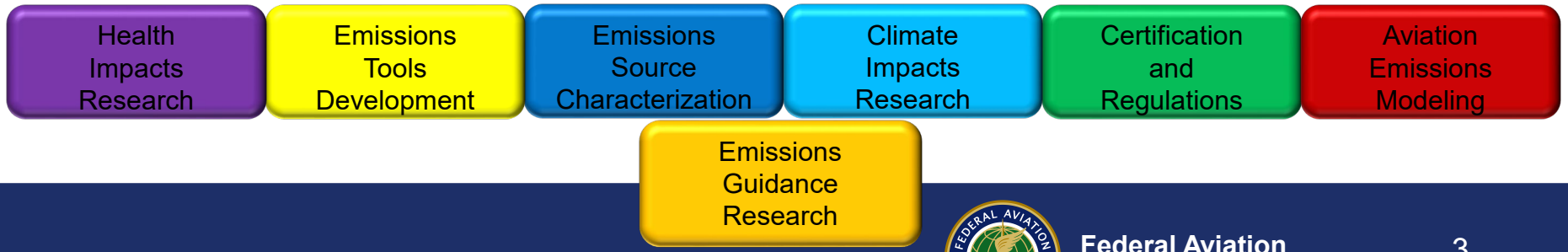


E&E R&D Emissions Accomplishments over past 5 years

- **nvPM Engine Emissions:**
  - Developed and deployed North American nvPM Measurement Reference System
  - Funded 6 nvPM emissions engine certification tests
  - Ambient conditions corrections combustor rig test
  - 25 engine-to-engine variability tests
  - Successful decision re ICAO Engine nvPM Emission Transition Standard (Feb 2016)
- **Successful decision re ICAO Aircraft CO_2 Emissions Standard (Feb 2016)**
- **Development and extensive use of APMT-Impacts to support decision making at ICAO CAEP**

FY18 Emissions Research Overview

		
18	Health Effects of Aviation Emissions	
20		
	Independent Evaluation of **APMT-I Climate** Model	
		

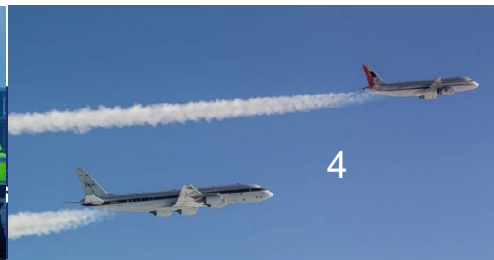


A2: Particle emissions tests

- ND-MAX/ECLIF-II Studies = NASA/DLR Multidisciplinary Airborne eXperiments/Emission and Climate Impact of Alternative Fuels Second Campaign
  - FAA (MS&T), NASA, German DLR, Canadian NRC, and Others
- Overall research objectives include:
  - Examining the effects of alternative fuels and engine technology on aircraft emission and contrails
  - Collecting aerosol and trace gas data for validating models and satellite-sensor measurements
  - Evaluating the performance of new instruments and inlets for potential use in future earth-science missions







A2: Particle emissions tests

FY17 Funding:

- NASA NDMAX Data Analysis – Impact of Alt Fuels on nvPM Emissions
- Detailed combustor rig tests at Honeywell.
  - Addresses ambient conditions variability corrections development for nvPM
  - Provides data to evaluate cruise modeling methods – note that a significant portion of the fuel is combusted above 3000 ft altitude.

FY18 Funding:

- Use of two additional alternative fuels in combustor rig tests
- Inform modeling blended fuels

FY19 Funding:

- NASA NDMAX Follow on – Understanding of Cruise Emissions and Contrail Formation – Will be discontinued if no funding

A10: Forecast Technology and Influence of Commercial SST

- Define potential demand and develop a forecast supersonic air travel (out to 2050)
- 3 types of Super Sonic Transports (SST)
  - Type 1: operate at supersonic speeds in unrestricted areas and subsonic speeds over other areas
  - Type 2: same as Type 1 except has technology to fly at Mach cut-off speeds over prohibited areas.
    - Uses atmospheric characteristics to prevent sonic booms from propagating to the ground (Mach 1.1 to 1.15)
  - Type 3: aircraft designed to produce very low sonic boom levels during all phases of supersonic flight
- Fuel burn, CO_2, H_2O, and if possible NOx, by altitude
- Comparison of fuel burn to subsonic traffic
- Estimate community & en-route noise impacts
- Evaluate AEDT capabilities with respect to SST modeling

!New! Project: Clean-Sheet Supersonic Engine Evaluation

- Industry has proposed using existing engine cores for new civil supersonic transport engines.
- What would a civil supersonic engine look like if it was designed from scratch using state-of-the-art technologies?
- What environmental performance in terms of regulated pollutants and noise could be potentially achieved?
- Use SST aircraft designs announced in media to determine thrust requirements, specific fuel consumption, engine size and weight limits, etc. Consider trade-offs in terms of performance with cruise Mach number and design range.
- Integrate results into system modeling work of ASCENT Project 10.

A18: Health Effects of Aviation Emissions

FY17 Funding:

- Conducted ambient monitoring of Ultra Fine Particles (UFP) + other pollutants in communities underneath flight paths near BOS, to determine the locations and atmospheric/flight activity conditions under which exposures could be elevated
- Worked with collaborators on ASCENT Projects 19 + 20 to quantify the health implications of modeled aviation-related air pollutant concentrations, on an as-needed basis

FY18 Funding:

- Construct regression models to determine the contributions of aircraft arrivals to UFP + Black Carbon (BC) concentrations
- Based on 2017 data, conduct site selection for the 2018 monitoring campaign by considering optimal sites to determine multiple types of aviation source contributions.
  - Measure UFP + other air pollutants at sites near BOS
- Develop platforms that would allow for modeling and monitoring comparison study with ASCENT Project 19.

FY19 Funding:

- Continue to collect monitoring data and refine modeling/monitoring comparisons to develop predictive modeling capabilities and health impact studies.
- Under FY19 President Budget, project will operate at a slower pace

A18: Health Effects of Aviation Emissions

- **Near-term Objectives**:
  - Measure Ultra Fine Particles and Black Carbon concentrations at strategically selected sites near arrival flight paths
  - Quantify the contribution of flight arrivals to measured concentrations

- Focus on arrivals to Boston Logan International Airport on 4R
- The goal was to choose sites to be > 200 m from major roadways, at varying distances from airport and from flight path

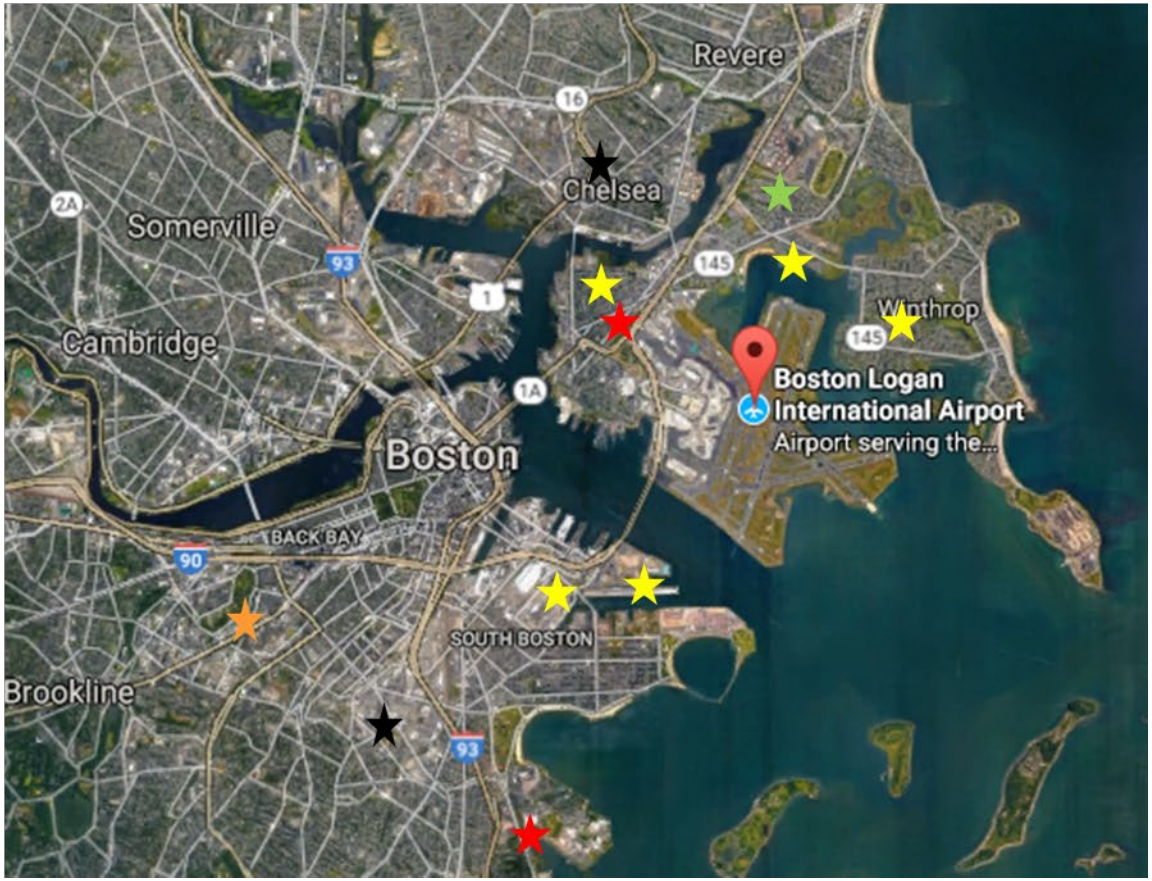
Field Campaign 2018

Site Selection

CURRENT SITES

- ★ Tufts long term PNC site
- ★ Harvard long term Monitor site
- ★ BU long term PNC site
- ★ New monitor site (preliminary agreement)
- ★ Potential monitoring site (seeking authorization)

- Sites chosen to be > 200 m from major roadways.
- Near population areas
- At varying distances from multiple runways based in part on projected wind direction and runway usage



A19: CMAQ-based Airport AQ Model Development

FY17 Funding:

- Developed generalized gridding tool for AEDT
- Provided support for High fidelity weather in AEDT - MERRA and WRF for model performance analyses
- Explored aviation modeling collaboration with NAU, Ukraine

FY18 Funding:

- Develop detailed emissions inventory for BOS using AEDT2d
  - Above proposed task will be used in developing a complete study based on monitoring and modeling task, with model validation task using measured data at Boston Airport in 2019. The tasks List for 2019 are below:
- Create a 12/4-km nested application of CMAQ for two seasons (summer and winter) and simulate two emissions scenarios:
  - Background emissions from all sources except Boston Logan
  - Background + Boston Logan airport emissions during LTO cycles
  - Perform multiple sensitivity simulations with CMAQ v5.2 base, and v5.2 augmented with the new particle nucleation mode.
- Perform model-measurement comparisons with ASCENT-18 team

FY19 Funding:

- Initiate development of aviation-specific dispersion modeling tool
- Under FY19 President Budget, project will close out BOS effort at a slower pace without any new model development

A20: Fast-time APMT-I AQ Model Development (Adjoint)

FY17 Funding:

- Developed Global Ozone and PM2.5 GEOS-Chem Adjoint Model
- Developed nested grids for Southeast Asia + Extend North America focused to represent Canadian impacts
- Investigated the impact of uncertainties in ammonia background emissions
- Investigated the impact of uncertainties in aviation cruise emissions

FY18 Funding:

- Conduct multi-sector and multi-species 2nd-order sensitivity analysis to quantify uncertainty in impacts of aviation emissions arising from uncertainty in non-aviation emissions, including surface ammonia, NOx, and VOCs; incorporate into tool
- Enhancement of adjoint capabilities to enable higher-resolution global simulations; incorporated into tool
- Develop European nested grid

FY19 Funding:

- Develop and incorporate ultra fine particle analysis capabilities into APMT-I AQ
- Under FY19 President Budget, project will end after FY18 funds are expended.

A21: Updates to APMT-I Climate Model

FY17 Funding:

- Developed APMT-I Climate version 24
  - Improved carbon cycle modeling
  - Captured latest IPCC background scenarios
  - Ready for use for CAEP decision making
- Updated alternative fuels life cycle emissions representation

FY18 Funding:

- Implementation of latest scientific results on short lived climate forcers
- Regional Impacts analysis and representation in APMT-I Climate
- Update of contrail impacts beyond fuel burn scaling
- Develop ability to examine impacts due to varied cruise altitudes and potential ozone layer impacts (needed for supersonic aircraft, high altitude long endurance UAS evaluations and commercial space)

FY19 Funding:

- Proposed to develop operational APMT-I version 25.
- Under FY19 President Budget, project will end after FY18 funds are expended.

A22: Independent Evaluation of APMT-I Climate Model

FY17 Funding:

- Evaluated APMT-I Climate version 24
  - Suggested improvements in the short lived forcer representation
  - Recommended improvements to the carbon cycle model
  - Independently confirmed the suitability of use in CAEP scenario analysis
- Performed sensitivity analysis on regional climate impacts

FY18 Funding:

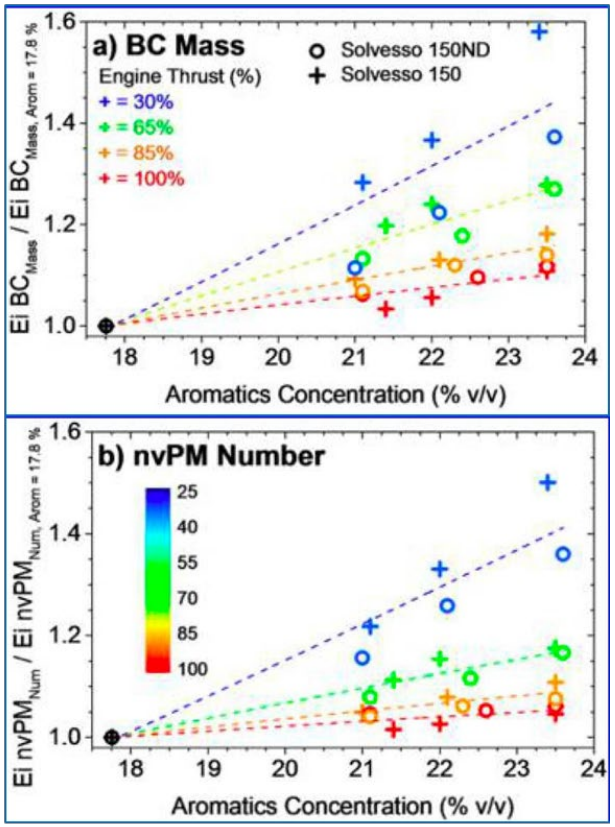
- Regional sensitivity analysis
- Develop steps for refining the aviation atmospheric impacts modeling with a view of increasing signal to noise ratio in climate models
- Inform ASCENT 21 on any changes needed

FY19 Funding:

- Provide input for APMT-I Climate version 25 and evaluation
- Important evaluation for regional sensitivity evaluation
- Under FY19 President Budget, project will end after FY18 funds are expended.

A39: Removing Naphthalene from Jet-A

- Objective: Gather and perform analyses regarding reduction and/or removal of naphthalene from jet fuel in a refinery, and then quantify the public health, global climate change, and economic impacts of reduction and/or removal of naphthalene in jet fuel.
- Team evaluating wide range of jet fuel molecules (including naphthalenes).
- Considering changes in both nvPM and sulfur oxide emissions that could accompany changes in fuel composition.
- Preliminary results suggest naphthalene removal could cost $0.10 per gallon.
- Project will only be funded in FY18 at Congressional level (not at Pres Budget level)



Key [1]

O :Jet A w/ Naphthalene-Depleted Aromatic Additive

\+ :Jet A w/ Aromatic Additive

A48: ICAO/CAEP Engine nvPM Emissions Standard

- Develop LTO nvPM mass and number standards
- Investigate possible replacement of smoke number standard for engine categories ≥26.7kN and other engine categories <26.7kN
- Develop improved nvPM model inputs to both local air quality models
- Project will inform decision making on nvPM Emissions Standard at the CAEP/11 meeting in February 2019

Summary

- **Executing comprehensive emissions research portfolio**
- **Emphasis on ultrafine particulate matter**
- **Shortfall in FY19 funds means AEE research portfolio will not be able to:**
  - Characterize impacts from high altitude supersonic operations
  - Continue analysis of fuel composition effects upon aviation pollutant generation
  - Conduct full impacts analyses (domestic and global) for ultra fine particle emissions