Emissions Research Update

Office of Environment & Energy (AEE)

Federal Aviation Administration

Presented to: REDAC E&E Subcommittee

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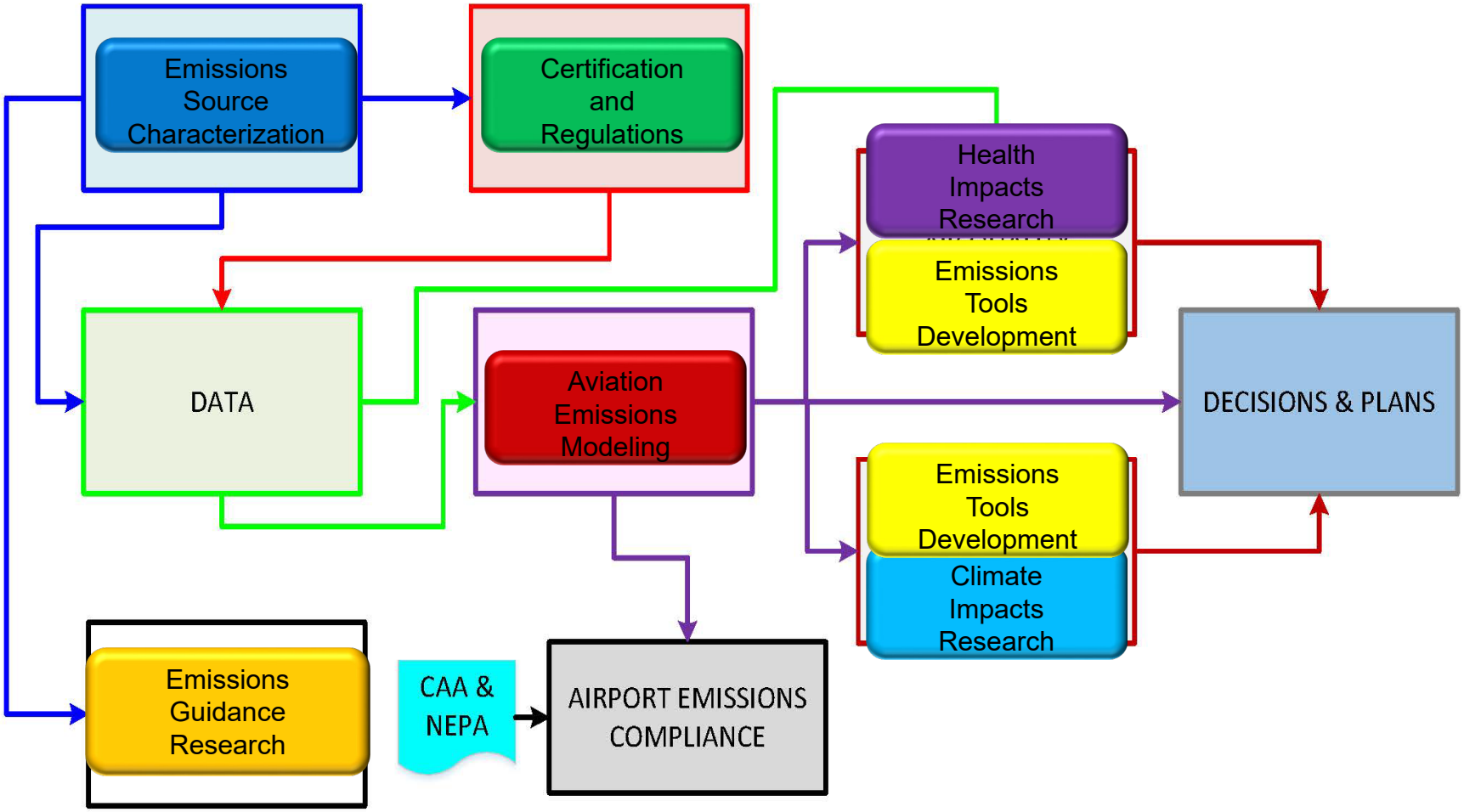
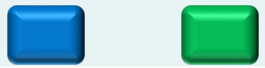
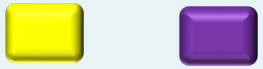
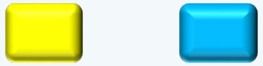
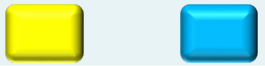
Outline

- Emissions Research Overview
- Selected Research Results
- Summary

Emissions Research Roadmap



Emissions Research Overview

ASCENT Project	Description	Emissions Roadmap
2	nvPM Emissions Engine Measurements	
10	Forecast Technology and Influence of Commercial SST	
18[1]	Health Effects of Aviation Emissions	
19	AQ Dispersion Model Development	
20[1]	Fast-time **APMT-I AQ** Model Development (Adjoint)	
21[1]	Updates to **APMT-I Climate** Model	
22[1]	Independent Evaluation of **APMT-I Climate** Model	
39[1]	Removing Naphthalene from Jet-A	
47[1]	Clean-Sheet Supersonic Engine Evaluation (New)	
48[1]	Engine nvPM Emissions Standard Setting Support	

[1]On Hold – Projects in varying stages of grant process

Health Impacts Research | Emissions Tools Development | Emissions Source Characterization | Climate Impacts Research | Certification and Regulations | Aviation Emissions Modeling

A2: Engine Emissions Measurements

Major Accomplishments:

- Standardized non-Volatile Particulate Matter (nvPM) Measurement for Certification
- 2016 CAEP/10 nvPM Standard
- 2019 CAEP/11 nvPM Landing Take Off (LTO) mass and number standards
  - Representative Engine nvPM Emissions Measurement
  - Engine to Engine Variability
  - Combustor Rig nvPM Emissions Measurement
- ND-MAX/ECLIF-II Studies = NASA/DLR Multidisciplinary Airborne eXperiments/Emission and Climate Impact of Alternative Fuels Second Campaign - Measurements completed February 2018
  - FAA (MS&T and Aerodyne), NASA, German DLR, Canadian NRC

A2: Engine Emissions Measurements

Future Work Plan – Proposal submitted March 2018 – In Process:

- NASA NDMAX Data Analysis – Impact of Alt Fuels on nvPM Emissions
- Conduct combustor rig tests at Honeywell
  - Addresses nvPM ambient condition corrections for certification
  - Data collection for ground-to-cruise nvPM correlation and cruise-climb NOx modeling
    - Evaluate cruise modeling methods (supports work for ASCENT Project 48)
    - Feeds in to ASCENT Projects 20, 21 and 22 on NOx and nvPM Impacts on the atmosphere and air quality.
  - Use of two additional alternative fuels in combustor rig tests
- Inform modeling blended fuels

A48: Engine nvPM Emissions Standard Development and Modeling Research

Major Accomplishments:

- Application of Tools to inform CAEP/11 nvPM standards decision making
- Analysis in support of characteristic factors development (i.e. engine to engine variability)
- Evaluation of Smoke Number replacement with the CAEP/10 nvPM mass concentration standard – Smoke Number replaced on 1 January 2023

Future Work Plan – Proposal submitted June 2018 – In Process:

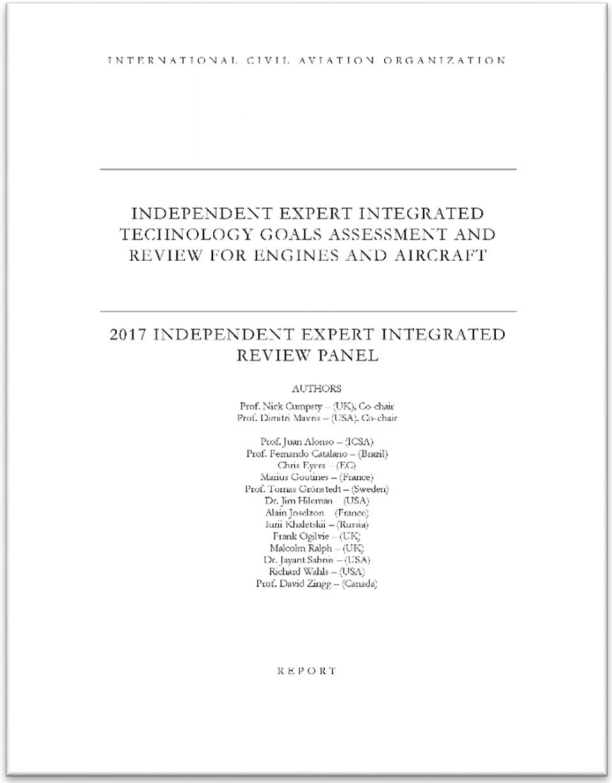
- Develop nvPM and NOx cruise-climb modeling using data from ASCENT Project 2
  - Addressing a major gap critical for Impacts Modeling
- Analysis of reported nvPM emissions data and margins with respect to CAEP/11 nvPM LTO mass and number standards
- ICAO Doc 9889 updates – More accurate representation aircraft emissions

A10: CAEP IEIR

Independent Experts Integrated Technology Goals Assessment and Review for Engines and Aircraft (IEIR) Outcomes:

- Considered Noise and Fuel Burn Interdependencies to establish mid-term (MT 2027) and long-term (LT 2037) technology goals
  - Business Jets, Regional Jets, Single Aisle, and Twin Aisle
- Independent Experts recommended new MT LTO NOx goal and examination of cruise NOx.

- Georgia Tech team and their modeling was essential to the successful completion of the work
- Had good collaboration between IEs and industry, which was a direct result of Georgia Tech's work



INTERNATIONAL CIVIL AVIATION ORGANIZATION

INDEPENDENT EXPERT INTEGRATED TECHNOLOGY GOALS ASSESSMENT AND REVIEW FOR ENGINES AND AIRCRAFT

2017 INDEPENDENT EXPERT INTEGRATED REVIEW PANEL

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REPORT

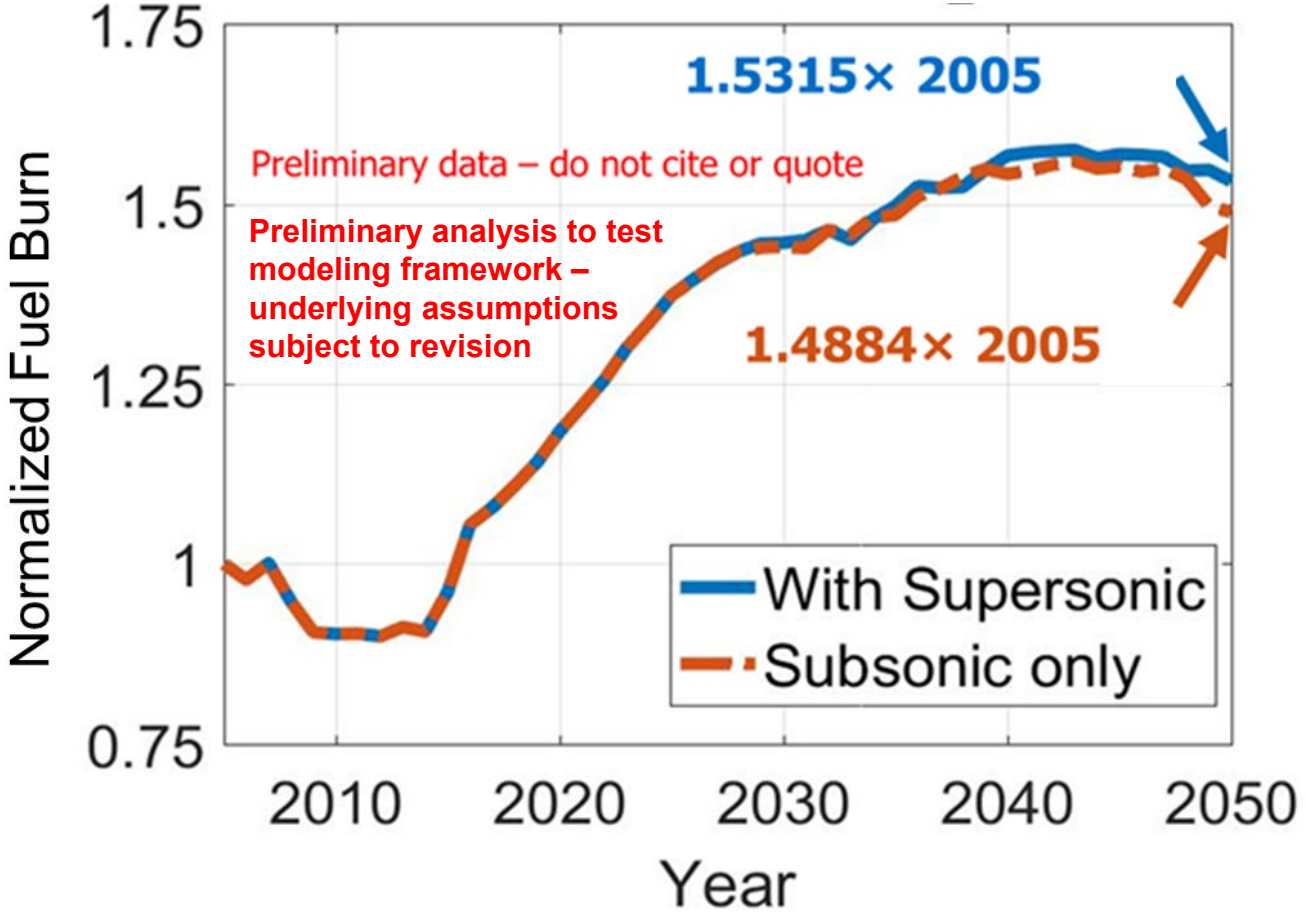
A10: Forecast Technology and Influence of Commercial SST

FY17 Outcomes:

- Completed first supersonic demand and route estimates
  - Demonstrated that presence of supersonic aircraft can change the use, retirement and acquisition of subsonic aircraft in the fleet
- Developed preliminary supersonic vehicle sizing environment and key environmental indicator (KEI) estimates
- Tested AEDT modeling for supersonic vehicles
- Computed first fleet level supersonic results using multiple fleet evaluation tools

A10: Forecast Technology and Influence of Commercial SST

Fleet-level Fuel-Burn Predictions with Placeholder Supersonic Aircraft

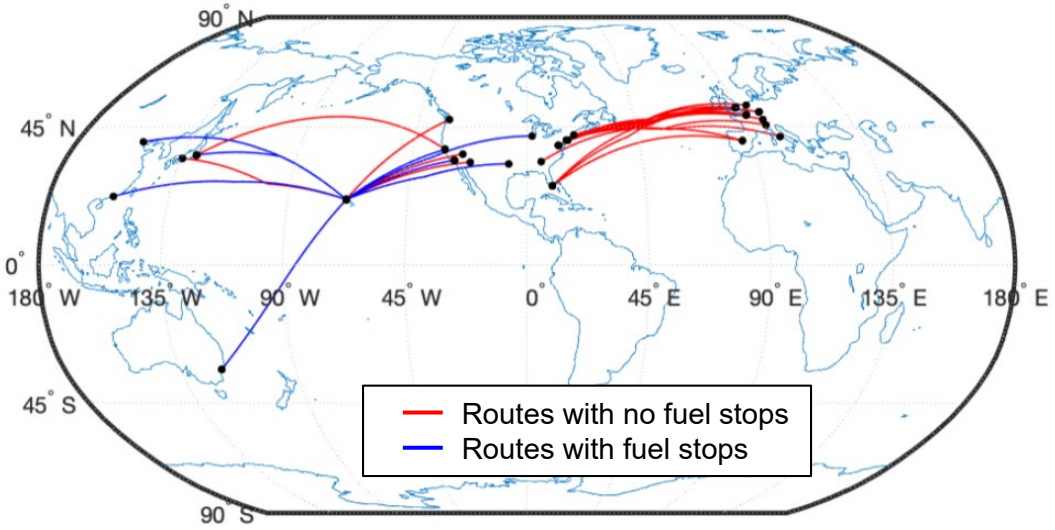


Have forecasting efforts with A10 team, Volpe and BAH

A10: Forecast Technology and Influence of Commercial SST

FY18 Funding - Ongoing:

- First order estimates for conceptual supersonic vehicles
- Recommendations for AEDT supersonic modeling capability
- Fleet Level Results



FY19 Funding - Plan:

- Refine fleet assumptions & demand assessments – Demand, Distance, Ticket Price
- Fleet analysis with gradual introduction of supersonic aircraft in to the fleet
- Vehicle modeling and AEDT vehicle definition
- Assess Interdependencies – Cruise efficiency vs LTO Noise, NOx vs Noise etc.

A47: Clean-Sheet Supersonic Engine Evaluation

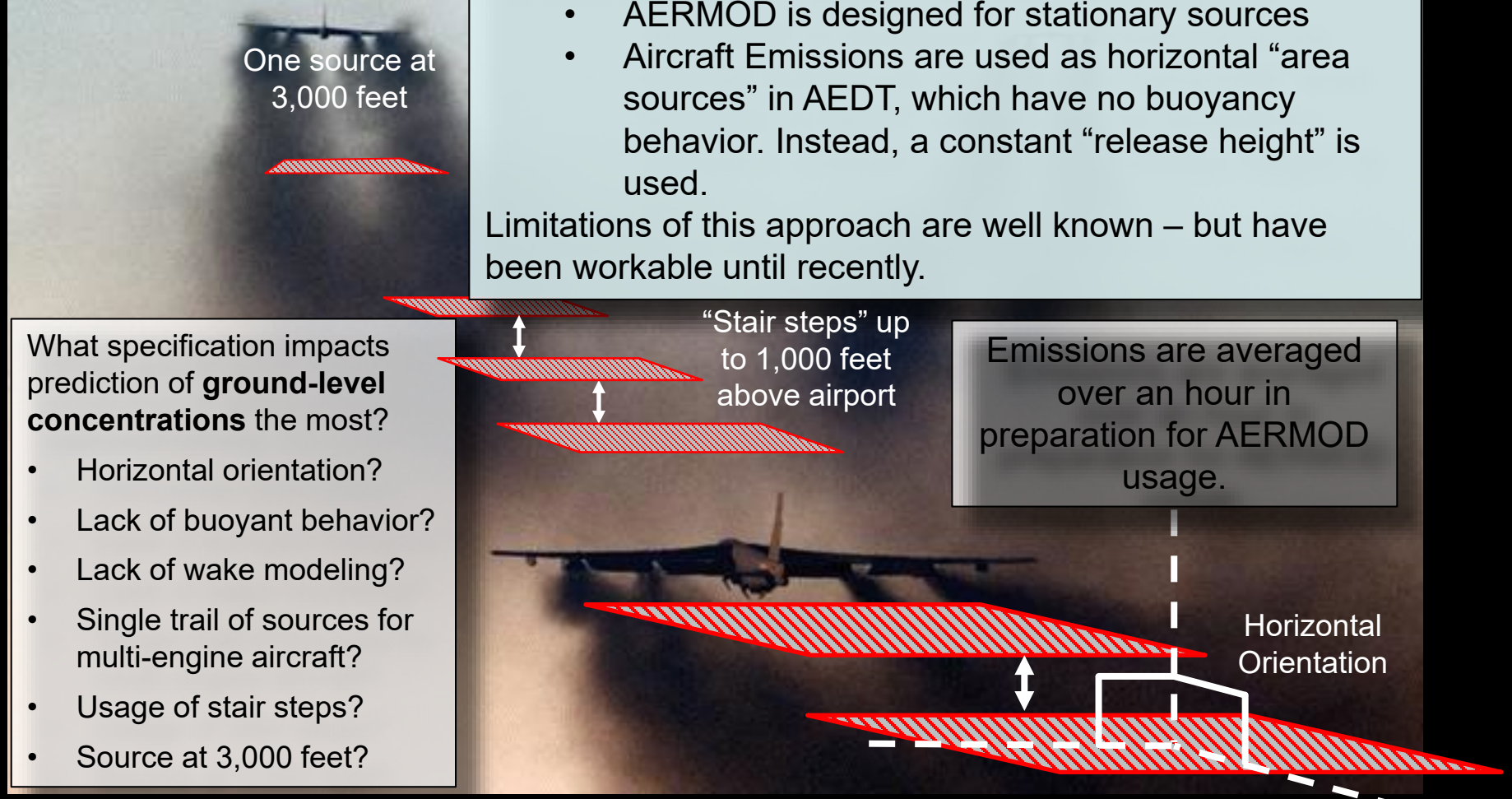
- Industry has proposed using existing engine cores for new civil supersonic transport engines.
- What would a civil supersonic engine look like if it was designed from scratch using state-of-the-art technologies?
- What environmental performance in terms of regulated pollutants and noise could be potentially 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.

A19: AQ Dispersion Model Development

The American Society/Environmental Protection Agency Regulatory Model (AERMOD) is the mandatory tool used to demonstrate Air Quality compliance for airports.

- AERMOD is designed for stationary sources
- Aircraft Emissions are used as horizontal "area sources" in AEDT, which have no buoyancy behavior. Instead, a constant "release height" is used.

Limitations of this approach are well known – but have been workable until recently.



What specification impacts prediction of **ground-level concentrations** the most?

- Horizontal orientation?
- Lack of buoyant behavior?
- Lack of wake modeling?
- Single trail of sources for multi-engine aircraft?
- Usage of stair steps?
- Source at 3,000 feet?

Emissions are averaged over an hour in preparation for AERMOD usage.

A19: AQ Dispersion Model Development

- **Challenge: AERMOD produces artificial modelled violations of EPA's new 1-hour NO_2 NAAQS**
  - National Ambient Air Quality Standard (NAAQS) and National Environmental Policy Act (NEPA) compliance very difficult to achieve with modelled exceedences
  - Accuracy of dispersion modeling is important for demonstrating 1-Hour NO_2 NAAQS compliance
  - Representation of aircraft emissions needs to be improved
- **Critical need for approval of new airport infrastructure projects**
- **Perform a comprehensive review of modeling aircraft sources and current science on aircraft emissions dispersion modeling**
- **Expected Outcome – A more accurate model to demonstrate airport air quality compliance that is acceptable to EPA.**
  - Improved version of EPA's AERMOD
  - A new model reflecting the best science and algorithms

MODEL DEVELOPMENT AND VALIDATION DATA GAP

- There are no comprehensive data sets yet to develop and validate models
- Knowledge of NO NO_2 splits based on very small number of monitor data (1 or 2)
- Systematic measurement of emissions species including NO, NO_2 and Particulate Matter along with Meteorological Data is needed
  - Multiple Airports in different climatic zones
  - Multiple monitors in a single airport
  - Co-located meteorological measurements
- Critical need for new infrastructure projects

Summary

- **Have a comprehensive emissions research portfolio**
- **Research is needed to inform:**
  - Cruise-climb NOx and nvPM Modeling
  - nvPM Ambient Conditions Corrections Development
  - Improved Dispersion Modeling for Airport NAAQS/ NEPA Compliance
  - AEDT modeling of Commercial SST including supersonic engine evaluation

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