Emissions Research Update

Presented To: REDAC E&E Subcommittee

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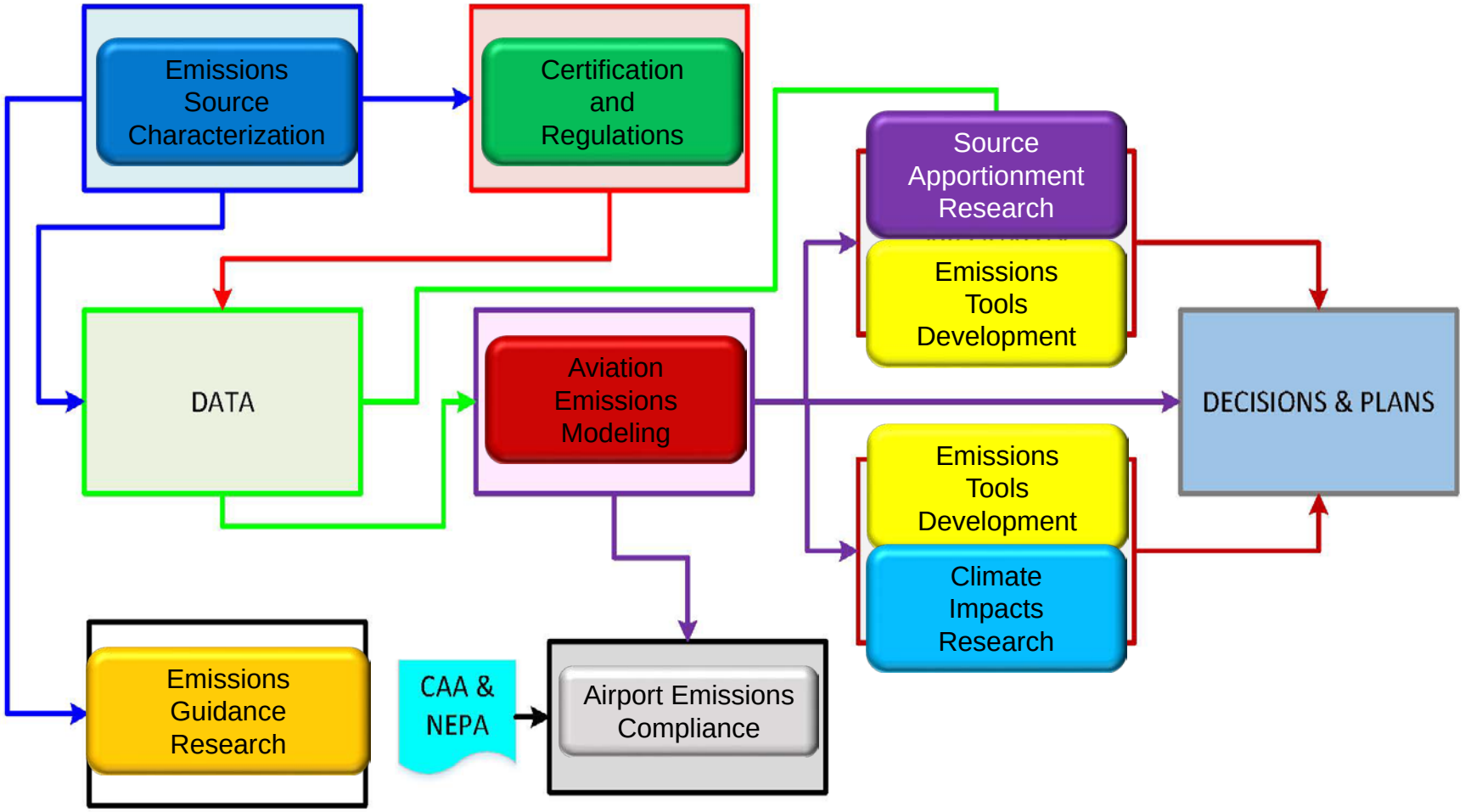
Date: 17 March 2020

Federal Aviation Administration

Outline

- **Emissions Research Roadmap**
- **A02: Emissions Measurements**
- **A19: Aviation-Specific Dispersion Model**
- **A18: Airport Impacts Monitoring**
- **Potential Contrail Research Plan**
- **AQ Screening Criteria for Attainment Areas**

Emissions Research Roadmap



EMISSIONS RESEACH ROADMAP ELEMENTS – CURRENT AND FUTURE

EMISSIONS MEASUREMENT	**A02:** Characterize emissions, Develop Corrections, Quantify Fuel Composition Effects, Characterize Emissions from Advanced Technology, Rig Tests, Engine Tests, Collaborate with CLEEN, NASA, Industry and International Partners
AVIATION SPECIFIC DISPERSION MODEL	**A19:** Develop an Aviation specific dispersion model for demonstrating compliance to regulations
MONITORING AND SOURCE APPORTIONMENT	**A18:** Acquire comprehensive measurements in and around airports for source apportionment and validation updated or new compliance models.
VOLATILE PM MODELING	**Contract:** Develop a new methodology to model volatile particulate matter in the vicinity of airports
NVPM MASS CALIBRATION	**A69:** Develop the charged particle mass analyzer (CPMA) methodology for in-line and in situ calibration of nvPM mass instruments
IMPACTS OF HIGH ALTITUDE EMISSIONS	**A58 & A22:** Quantify Impacts of various sources of emissions in the upper atmosphere including supersonic transport, high altitude long endurance UAVs, rocket emissions
SUPERSONICS	**A10 & A47:** Develop Technology, Forecasts and Emissions in collaboration with Noise/ CLEEN Divisions
CONTRAIL PHYSICS	**Potential:** Improve understanding of contrail formation and real-time predictability of the radiative forcing of contrails as affected by technology, fuels and operations
CONTRAIL MITIGATION	**Potential:** Explore Mitigation and Avoidance of Contrails through technology, fuels and operations

LEGEND

- Source Apportionment/ Health Impacts Research
- Emissions Tools Development
- Emissions Source Characterization
- Climate Impacts Research
- Certification and Regulations
- Aviation Emissions Modeling
- Airport Emissions Compliance

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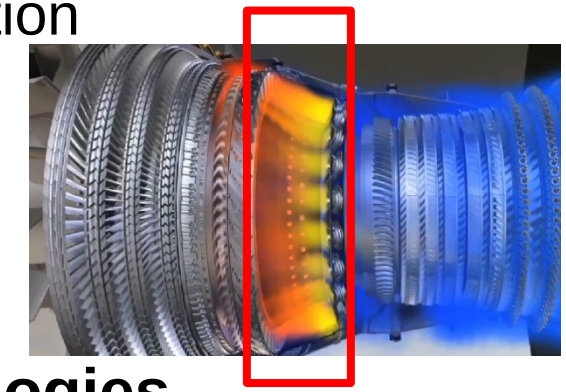
A02: Emissions Measurements

- **Develop Standard Day Corrections for nvPM (i.e. Ambient Conditions)**
  - ICAO Standards and Regulatory Practices (SARPs) – certification
- **The role of Naphthalenes on nvPM Emissions**
  - Emissions Modeling of Blended Fuels
  - ICAO SARPs - certification
- **Inform Cruise nvPM and NOx Emissions Modeling Methodologies**
  - Develop models for use by ICAO CAEP Modeling and Databases Group
  - Implementation in FAA Tools (AEDT)
- **Collaboration: CLEEN Projects on nvPM Prediction Models**
  - Improve FAA Tools



A02: Emissions Measurements

ASCENT 02: HONEYWELL RIG TEST

Jet A with 29 P3 T3 Test Points

Deliverables: Ambient Conditions Corrections Methodology and Cruise nvPM Methodology Validation → **Success Criteria: Methodology applicable to all technologies Inclusion in ICAO Annex 16 Vol.II**

Fuel 1 — **Deliverables: nvPM Emissions for Fuel 1 and Cruise nvPM Methodology Validation** → **Success Criteria: Usable data for emissions prediction for different fuel composition**

Fuel 2 — **Deliverables: nvPM Emissions for Fuel 2 and Cruise nvPM Methodology Validation** → **Success Criteria: Usable data for emissions prediction for different fuel composition**

Fuel 3 — **Deliverables: nvPM Emissions for Fuel 3 and Cruise nvPM Methodology Validation** → **Success Criteria: Usable data for emissions prediction for different fuel composition**

Fuel	Aromatics	Naphthalene
Test 1 – Jet A	Jet A	Jet A
Test 2 – Fuel 1	8%	0%
Test 3 – Fuel 2	16.5%	1.5%
Test 4 – Fuel 3	25%	3%

Possible Collaborators: USAF, NASA, EPA, Swiss FOCA, Transport Canada, EU/ EASA

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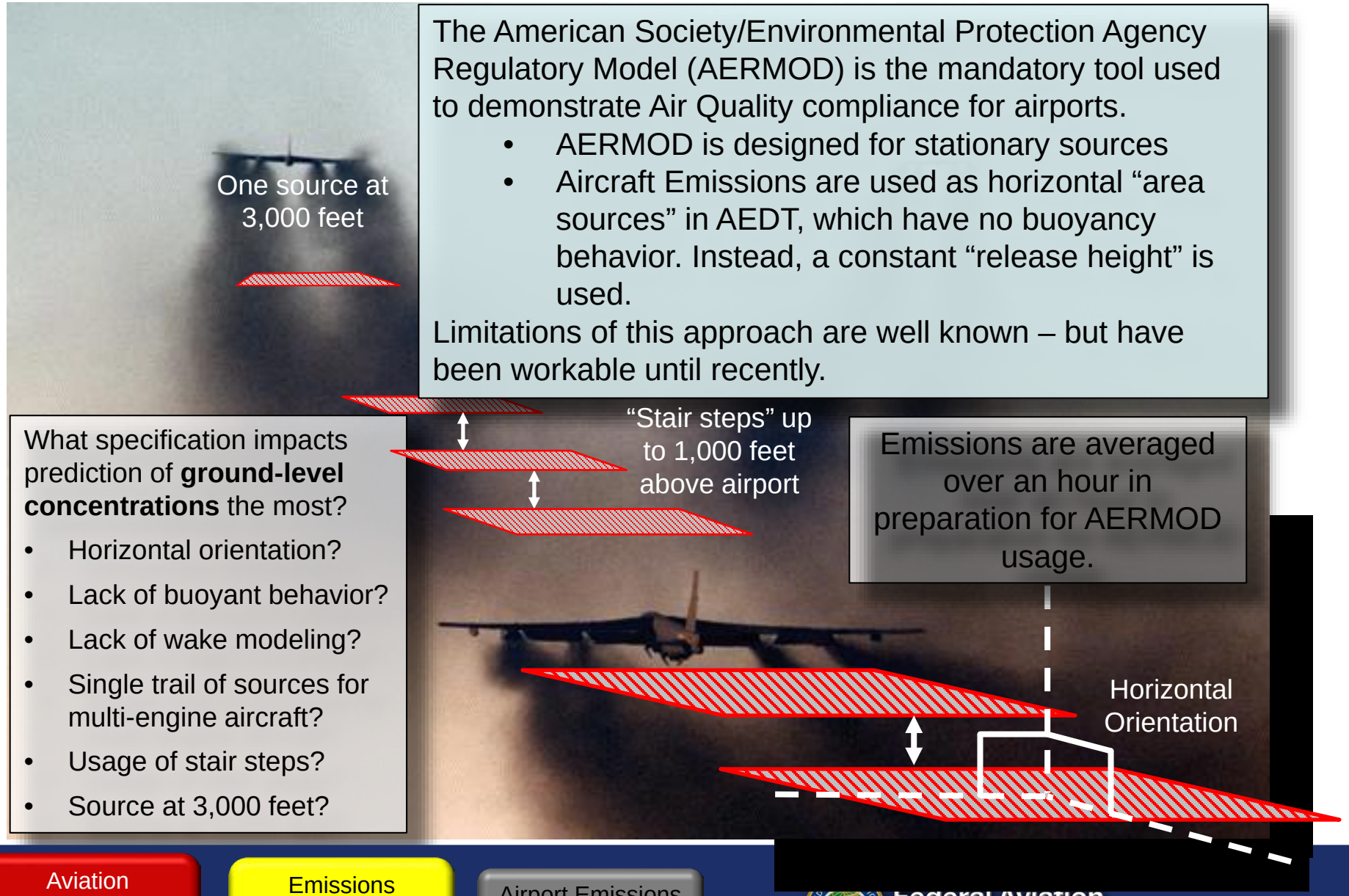
Dispersion Model Development (A19)

CURREN DISPERSION MODEL IMPLEMENTATION



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.

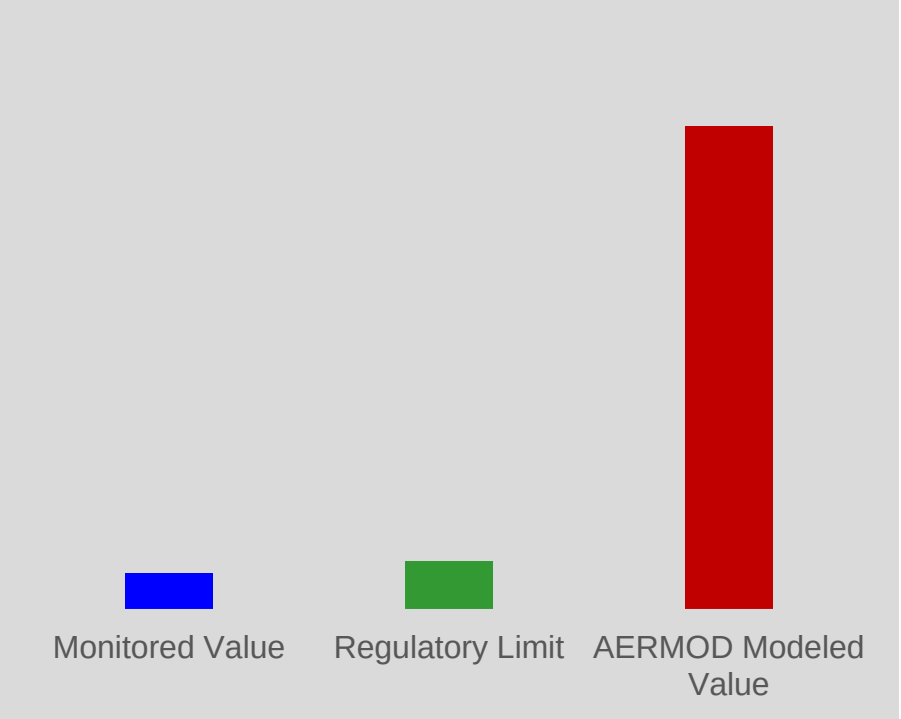
What specification impacts prediction of **ground-level concentrations** the most?

- 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: Aviation Specific Dispersion Model Development

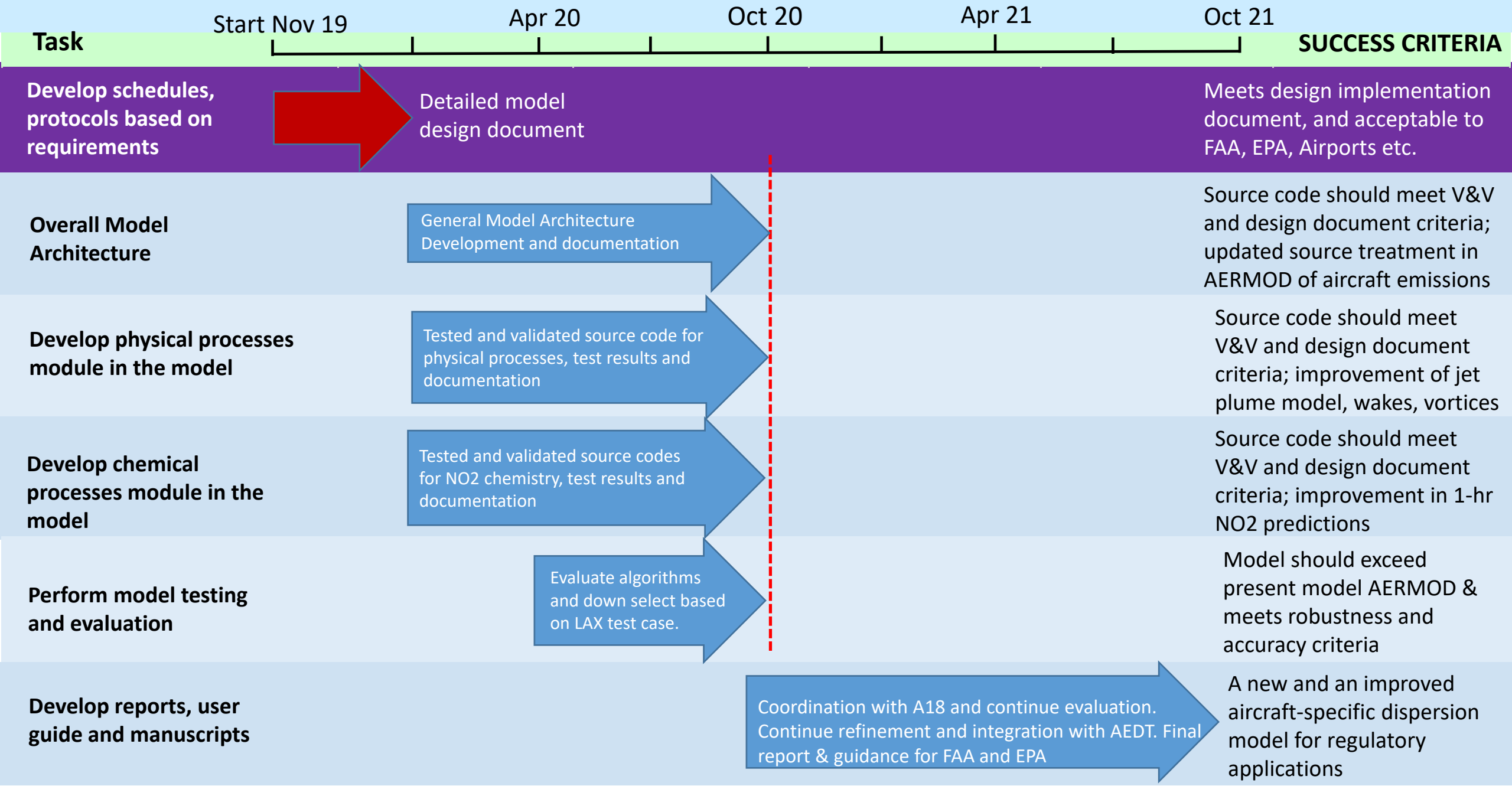
- **Challenge: EPA-mandated AERMOD model produces artificial violations of 1-hour NO_2 National Ambient Air Quality Standard**
  - Delays National Environmental Policy Act (NEPA) review
- **Solution: Develop an aviation specific emissions dispersion model for compliance with EPA regulations**
- **Tasks Completed:**
  - Comprehensive review of various modeling approaches for modeling aircraft sources and existing limitations in existing models
  - Conceptual approach for modeling aircraft sources for local air quality at airports has been identified



A19: Aviation Specific Dispersion Model Development - Status

- **Ongoing: Implementation of two different approaches for evaluation**
  - Gaussian Plume Model with chemically active Lagrangian Puff Component
  - Lagrangian Particle Model
- **Evaluation Approach:**
  - Use existing model inputs and monitor data at LAX
  - Quantitatively compare the results with current AERMOD results
  - Should address 1hr NO_2 issues while accurately predicting annual average emissions.
- **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

Schedule and Deliverables: A19 – Aircraft-Specific Dispersion Model Development Plan



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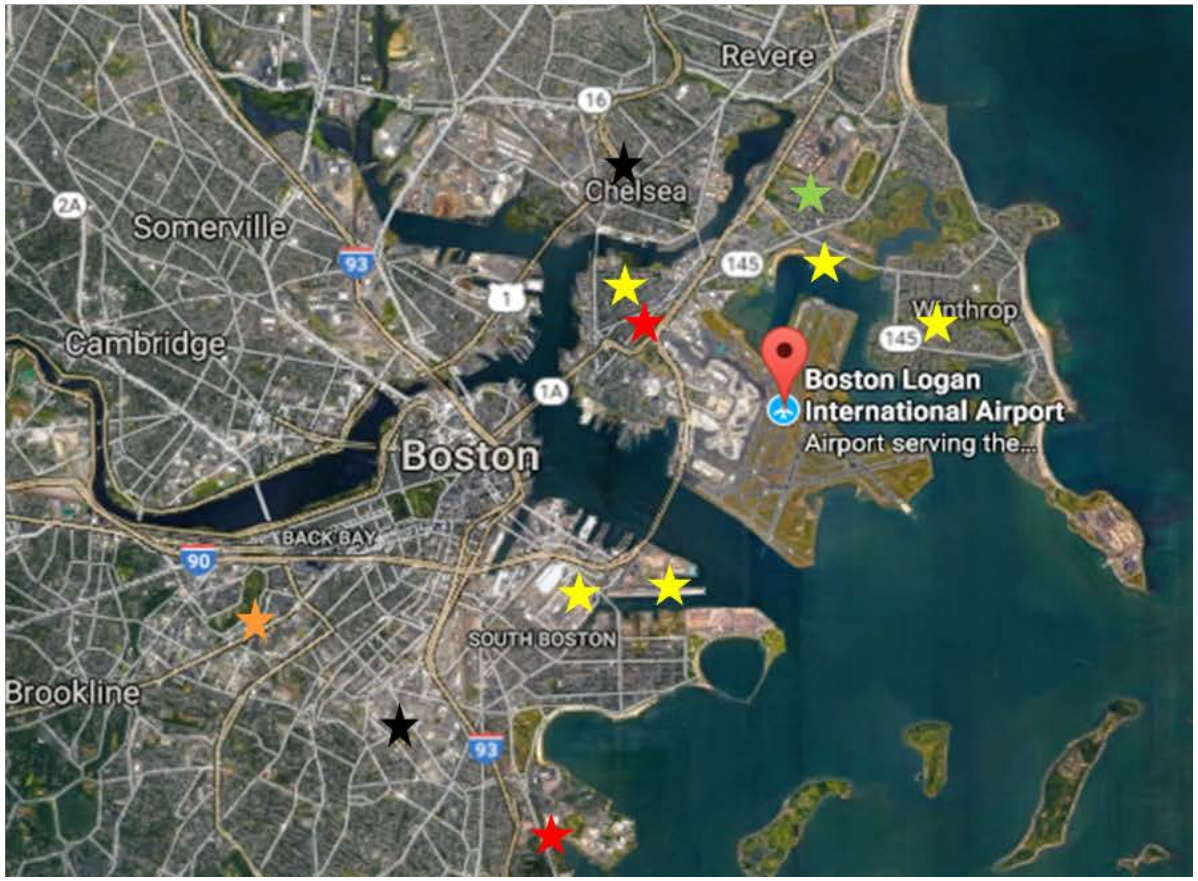
A18: Health Effects of Aviation Emissions

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



- Funded in February of 2020
- Restarting work of installing monitors
  - 2017 Sites will become operational by May 2020
  - New Sites by July 2020

PNC: Particle Number Concentration

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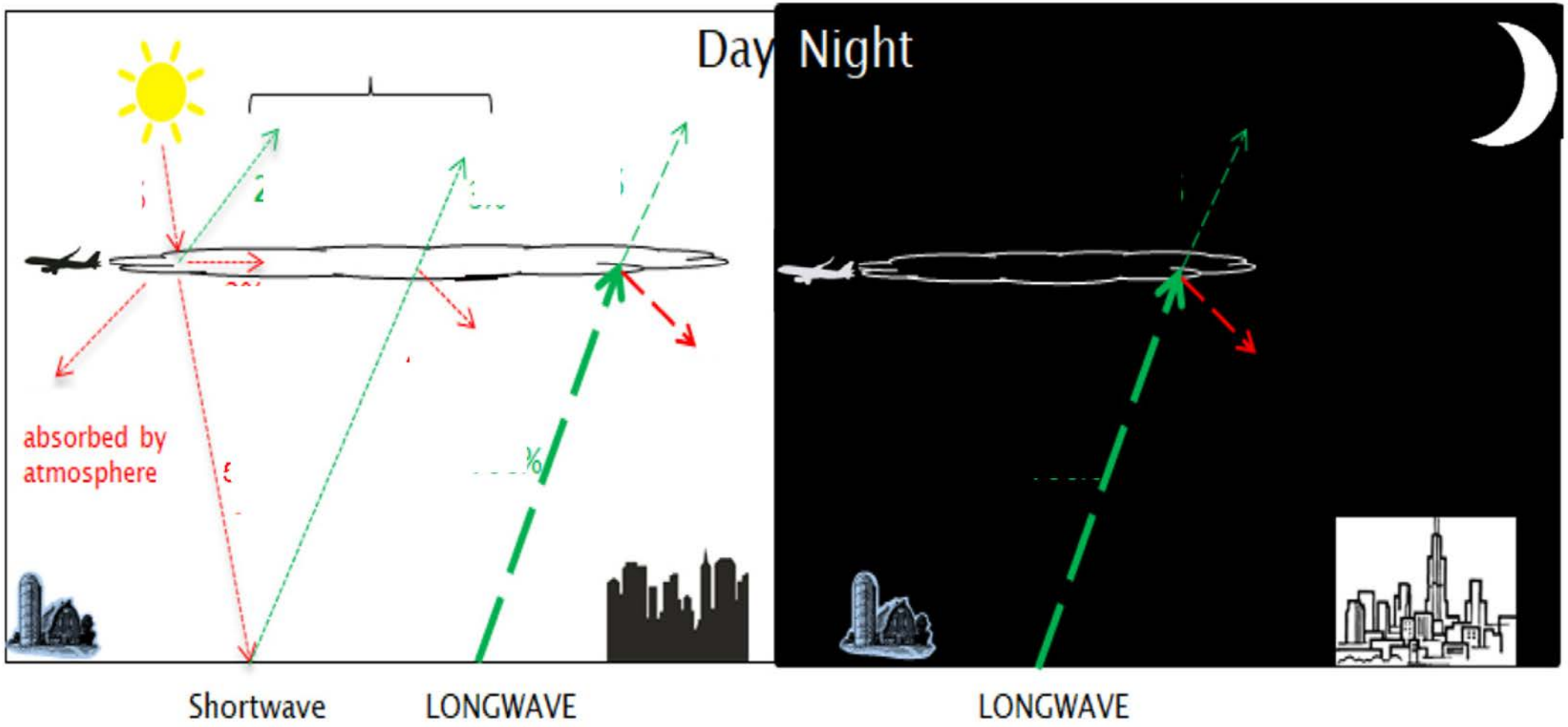
Action: Contrail Research

"Identify potential research that could be done to improve our understanding of the climate impacts of non-CO_2 emissions in general, and of contrails and aviation induced cloudiness, in particular, and means to mitigate these impacts."

Aviation Induced Cloudiness (AIC) Radiative Forcing Physics



Aviation Induced Cloudiness (AIC)

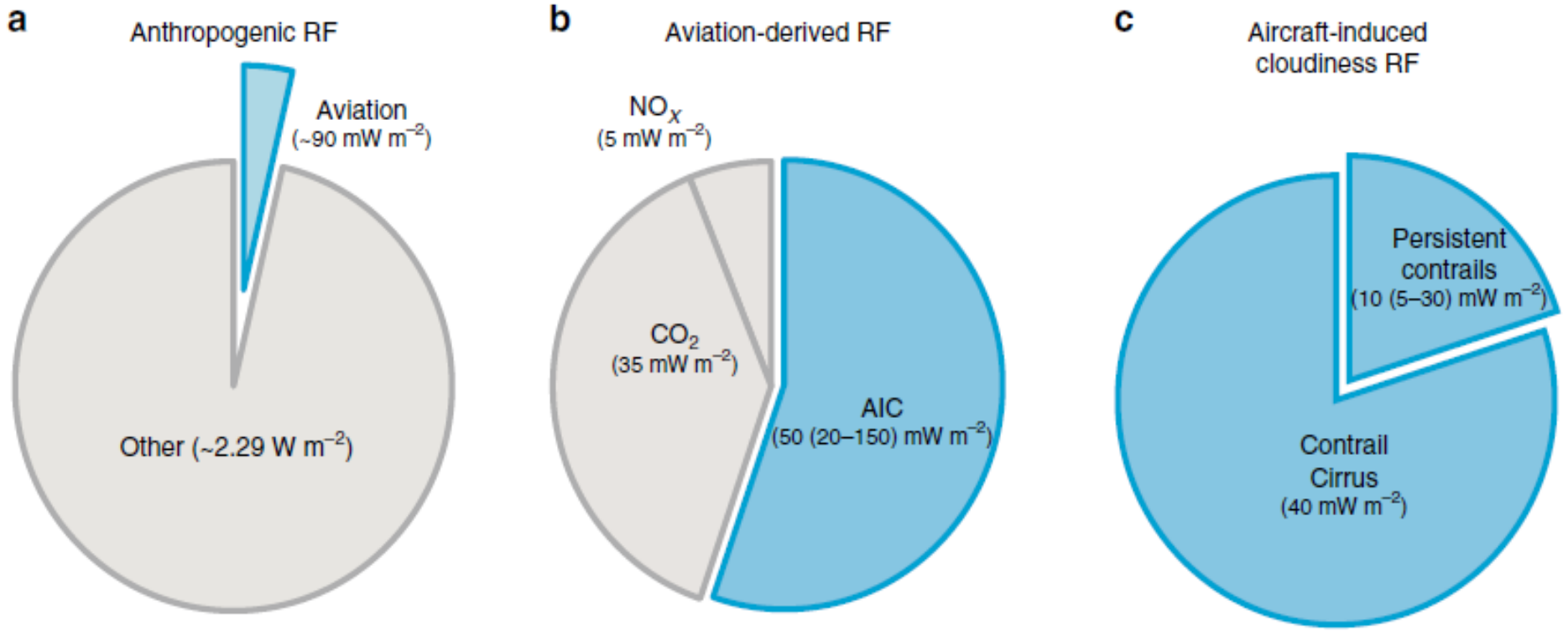
Photographs of contrail spreading into cirrus taken from Athens, Greece, on 14 Apr 2007 at 1900, 1909, 1913, and 1920 local time (from top left to bottom right). Courtesy of Kostas Eleftheratos, University of Athens, Greece.

From: Heymsfield et al. BAMS 2010

Contrail Impacts

Table 1 Characteristics of contrails and contrail cirrus

AIC	Short-lived	Long-lived	
Ice cloud type	Contrail	Persistent contrail	Contrail cirrus
RF potential	Negligible	Small	Large



B. Kärcher, Formation and radiative forcing of contrail-cirrus, Nature Communications, 2018

Current State of Knowledge

- AIC Impacts is **similar climate impacts to that of CO_2**. Subject to large uncertainties and the level of scientific understanding of this impact remains "low".
- The AIC effects are **highly variable in space and time**. Contrail coverage is strongly influenced by the density of air traffic in the contrail forming regions and also has seasonal variations (Duda and Smith, 2018). Increased air traffic implies increased AIC impacts.
- Coarse resolution global climate simulate contrail impacts well in aggregate. Large grid sizes (~2° longitude × 2° latitude in the horizontal and variable in the vertical) in these global climate models introduce uncertainties for higher resolution for individual flight simulations. More recent findings suggest **large contrail clusters are significant contributors to warming**.
- The number of ice crystals during the initial contrail formation phase is **directly proportional to the number of non-volatile particles emitted by the engine**.
  - Sustainable Aviation Fuel (SAF) blends and newer technology engines producing lower number of non-volatile particle emissions will reduce contrail impacts (Bock and Burkhardt 2019).
  - Technology and fuels alone do not compensate for increases in future air traffic.

FAA funded research beyond ACCRI: NDMAX Accomplishments & Preliminary Findings

- *Verified that sustainable alternative fuels reduce non-volatile Particulate Matter (nvPM) number, mass and size in both ground and airborne operations*
- **Verified direct link between nvPM and contrail ice concentrations: reduced soot #= reduced ice # = reduced climate impacts**
- Verified that 100% of nvPM activated to form ice particles
- *Showed that even a 70:30 blend of JetA/HEFA can reduce nvPM emissions by up to 50%*
- *Verified lab results suggesting that Naphthalenes disproportionately increase nvPM emissions: reduced naphthalenes = reduced nvPM # and mass*
- Collected large set of high quality particle and trace gas measurements along with engine data that can be used to 1) advance models that predict cruise emissions from engine certification data and evaluate E-31 protocols
- Demonstrated a successful protocol and technique for sampling behind commercial aircraft in the flight corridors—opens door for emission/contrail surveys

Bruce Anderson (NASA LaRC) AGU 2019

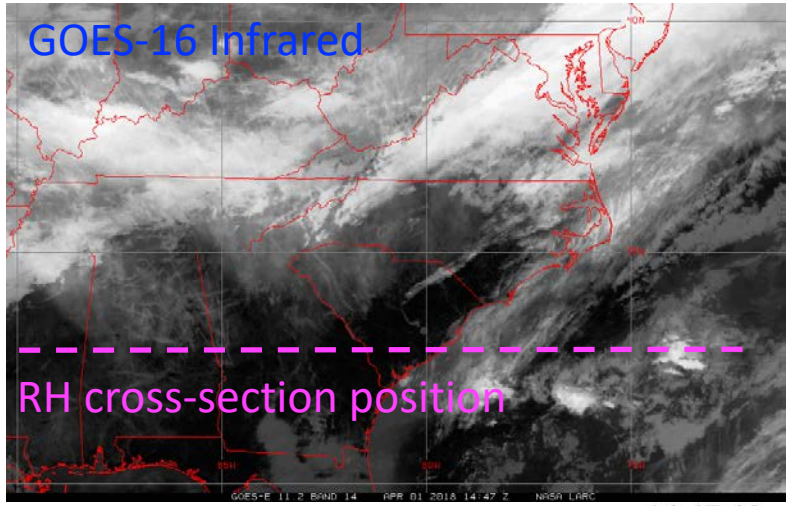
Potential Future Research: Mitigation of AIC Climate Impacts

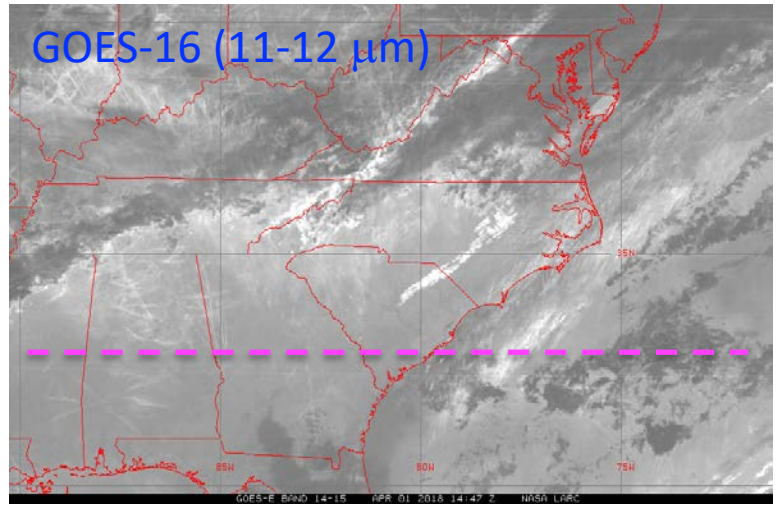
First Task: Evaluation of Forecast Meteorology

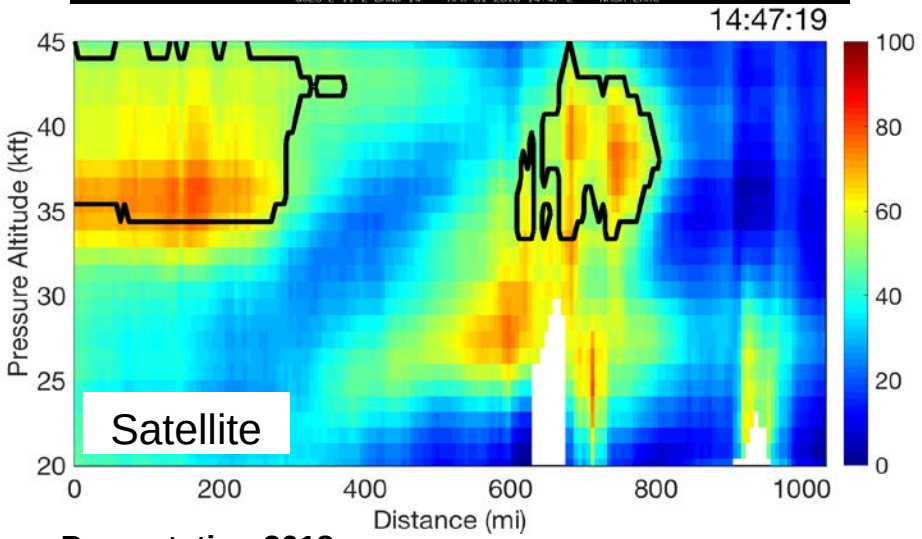
April 1, 2018

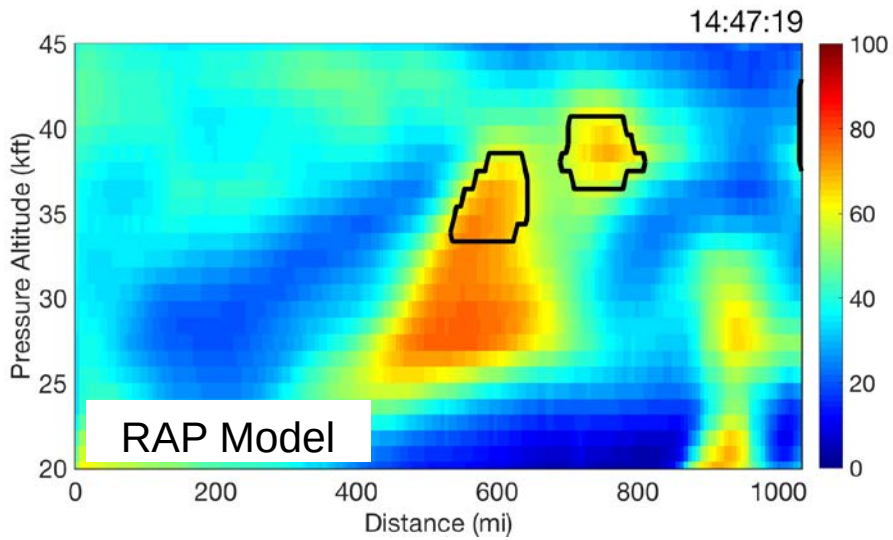
Relative Humidity Cross-section

- Contours show contrail formation potential (Schmidt-Appleman criteria)
- Satellite observations improve knowledge of upper level RH and contrail potential
- Large scale models evaluated during ACCRI Phase II. More work needs to be done for higher resolution models. Collaboration with NOAA, NASA, DoD, DoE needed for improving models







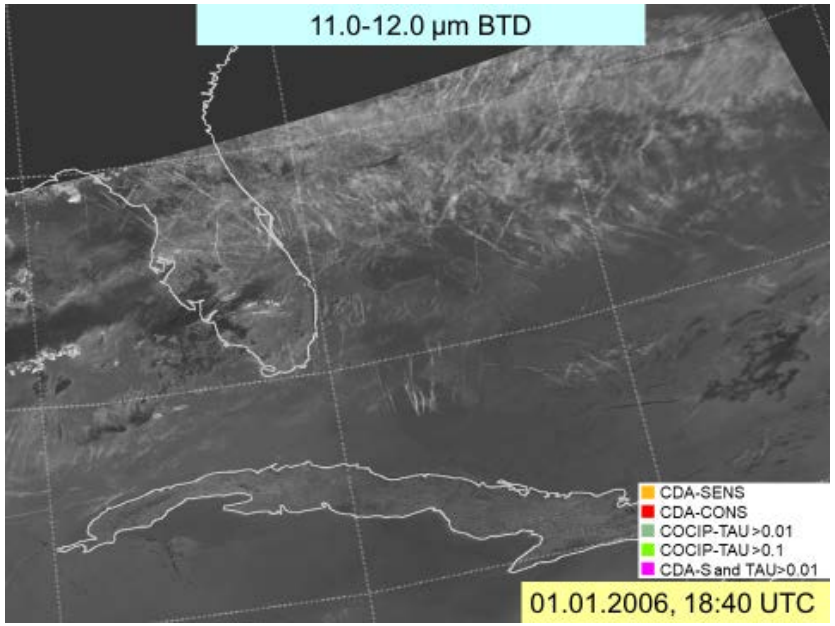


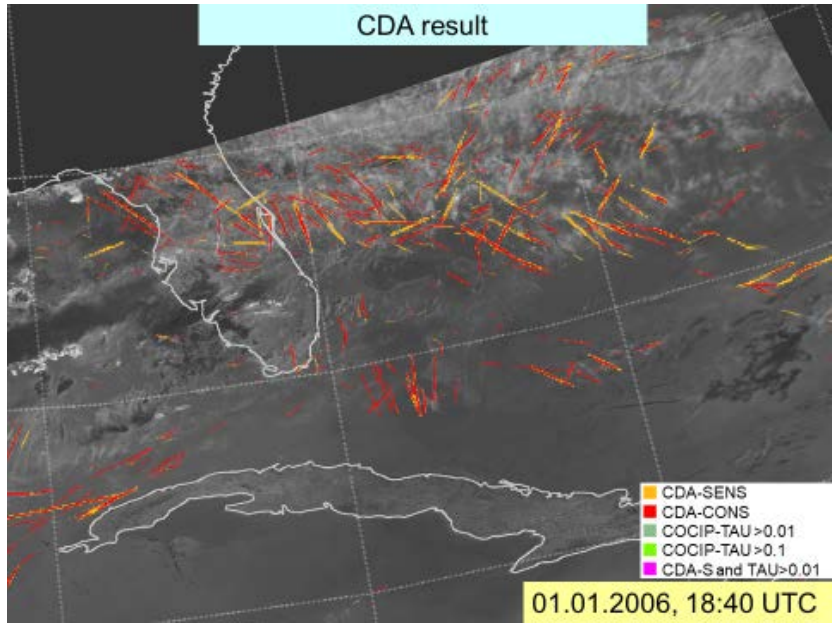
David Duda (NASA LaRC), AEC Roadmap Presentation 2018

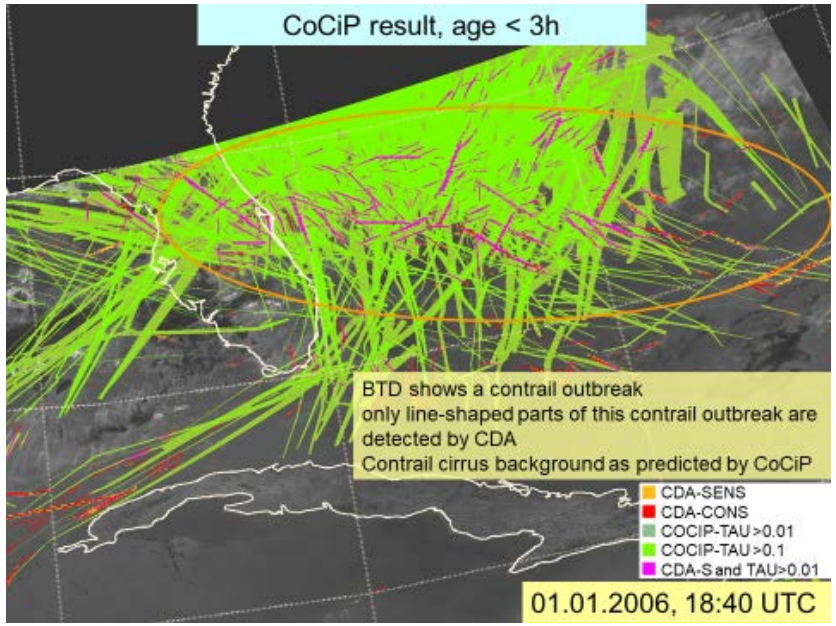
Potential Future Research: Mitigation of AIC Climate Impacts

- Second Task: Evaluation of Contrail Prediction Models for forecasting persistent contrail formation using forecast meteorology, engine technology and fuel type (e.g.: Contrail Cirrus Prediction Model – CoCiP or Contrail Evolution and Radiation Model – CERM) using satellite and other available data.
  - ➢ Contrail Cirrus Prediction and Comparison is a complex problem

ACCRI Results in 2011

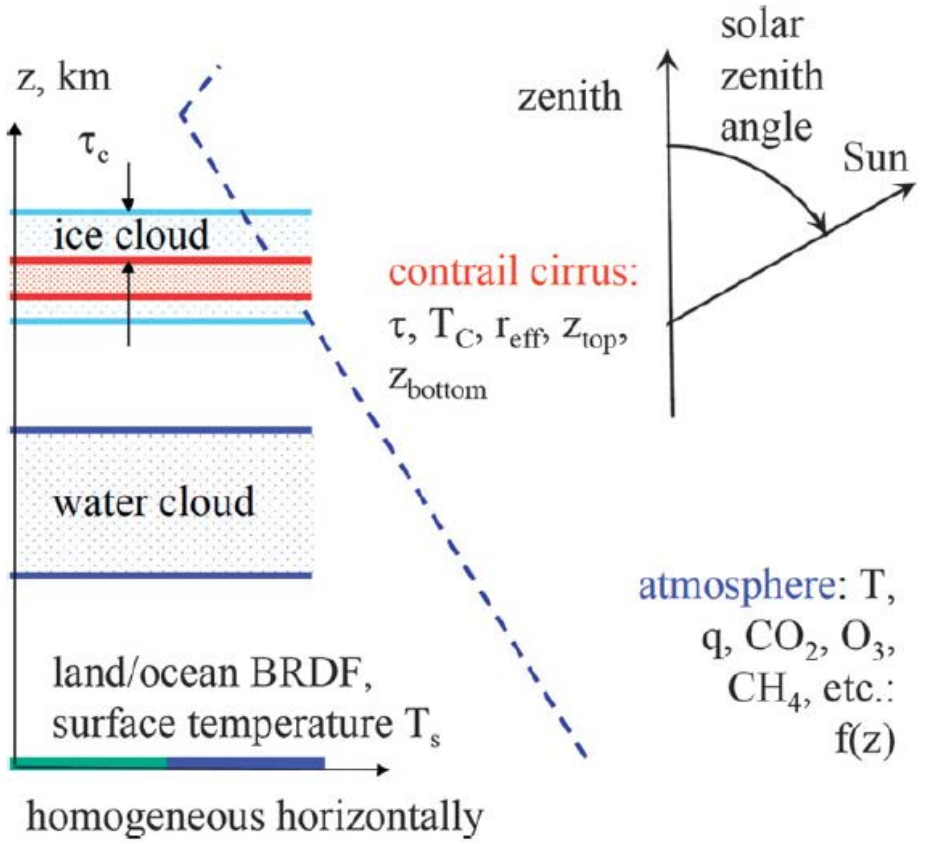






Potential Future Research: Mitigation of AIC Climate Impacts

- Third Task: Real-time Radiative Forcing Estimates of forecast AIC using incoming solar radiation, atmospheric structure, surface albedo and outgoing longwave radiation to forecast warming AIC. Significant reduction in RF uncertainties.



Schumann et al., Journal of Applied Meteorology and Climatology 2012

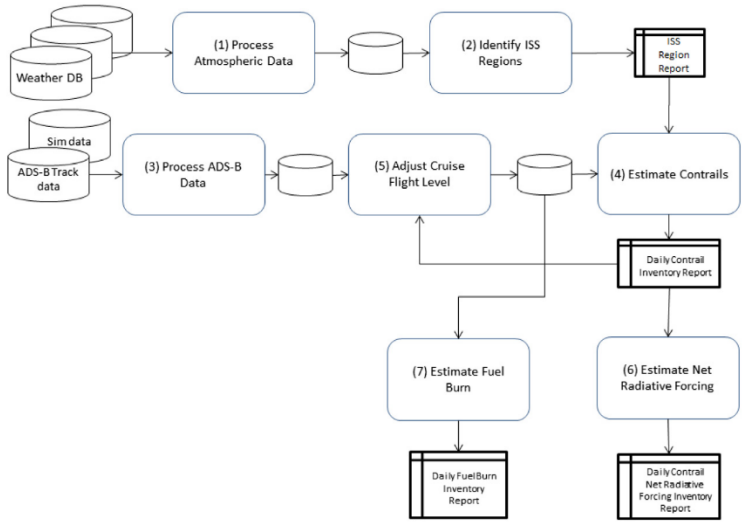
BRDF: Bidirectional Reflectance Distribution Function

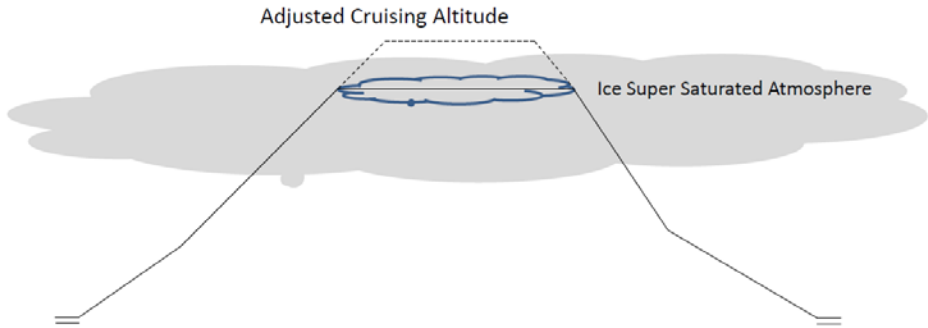
Potential Future Research: Mitigation of AIC Climate Impacts

- Fourth Task: Verify predictions by performing field campaigns such as NDMAX to improve confidence.
- Leverage other resources such as Boeing Eco Demonstrators.
  - Near Field
  - Evolution of Linear Contrails into AIC

Potential Future Research: Mitigation of AIC Climate Impacts

- Fifth Task: Real-time Air Traffic Management avoiding forecast warming contrails that can be integrated into flight planning
  - Such an approach should be (U. Schumann et al., AEC Roadmap 2019 Presentation):
    a. Effective: The impact must be large enough to counter increasing aviation CO_2 effects,
    b. Feasible: Must be tested,
    c. Verifiable: Best by observations,
    d. Robust: Risk of negative climate impact must be small,
    e. Affordable: Best without fuel consumption increases.
  - Feasibility with no fuel burn impacts shown by recent model studies (Avila et al., Transportation Research Interdisciplinary Perspectives 2 (2019) 100033; Teoh et al., Environ. Sci. Technol., February 2020)
  - Some warming contrails may not be avoided but AIC warming impacts could be reduced significantly





Avila et al., Transportation Research Interdisciplinary Perspectives 2 (2019) 100033

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Motivation

- **<u>OBSERVATION</u>: In the absence of FAA guidance…**
  - FAA EPS and contractors were applying General Conformity thresholds to Federal Actions in attainment areas.
    - The effects of this approach are:
      - Set up a false defacto guidance of how to do NEPA air quality analyses in attainment areas
      - Wrongfully applied nonattainment regulations to attainment areas.
      - Artificially limits aviation growth in attainment areas
- **<u>NEED</u>: New FAA Screening Criteria is needed that is applicable to Federal Actions in attainment areas**

What's the difference?

Nonattainment
De Minimis Thresholds (tons/year)

Criteria Pollutant	Nonattainment Classification		*De Minimis* Threshold (Tons/Year)								
			CO	NH_3	NO_2	NO_x	Pb	$PM_{2.5}$	PM_{10}	SO_2	VOC
CO	All		100	-	--	-	-	-	-	-	-
NO_2	All		-	-	100	-	-	-	-	-	-
O_3	Marginal and Moderate	Outside OTR	-	-	-	100	-	-	-	-	100
		Inside OTR	-	-	-	100	-	-	-	-	50
	Serious		-	-	-	50	-	-	-	-	50
	Severe		-	-	-	25	-	-	-	-	25
	Extreme		-	-	-	10	-	-	-	-	10
Pb	All		-	-	-	-	25	-	-	-	-
$PM_{2.5}$[1]	All		-	100	-	100	-	100	-	100	100
PM_{10}	Moderate		-	-	-	-	-	-	100	-	-
	Serious		-	-	-	-	-	-	70	-	-
SO_2	All		-	-	-	-	-	-	-	100	-

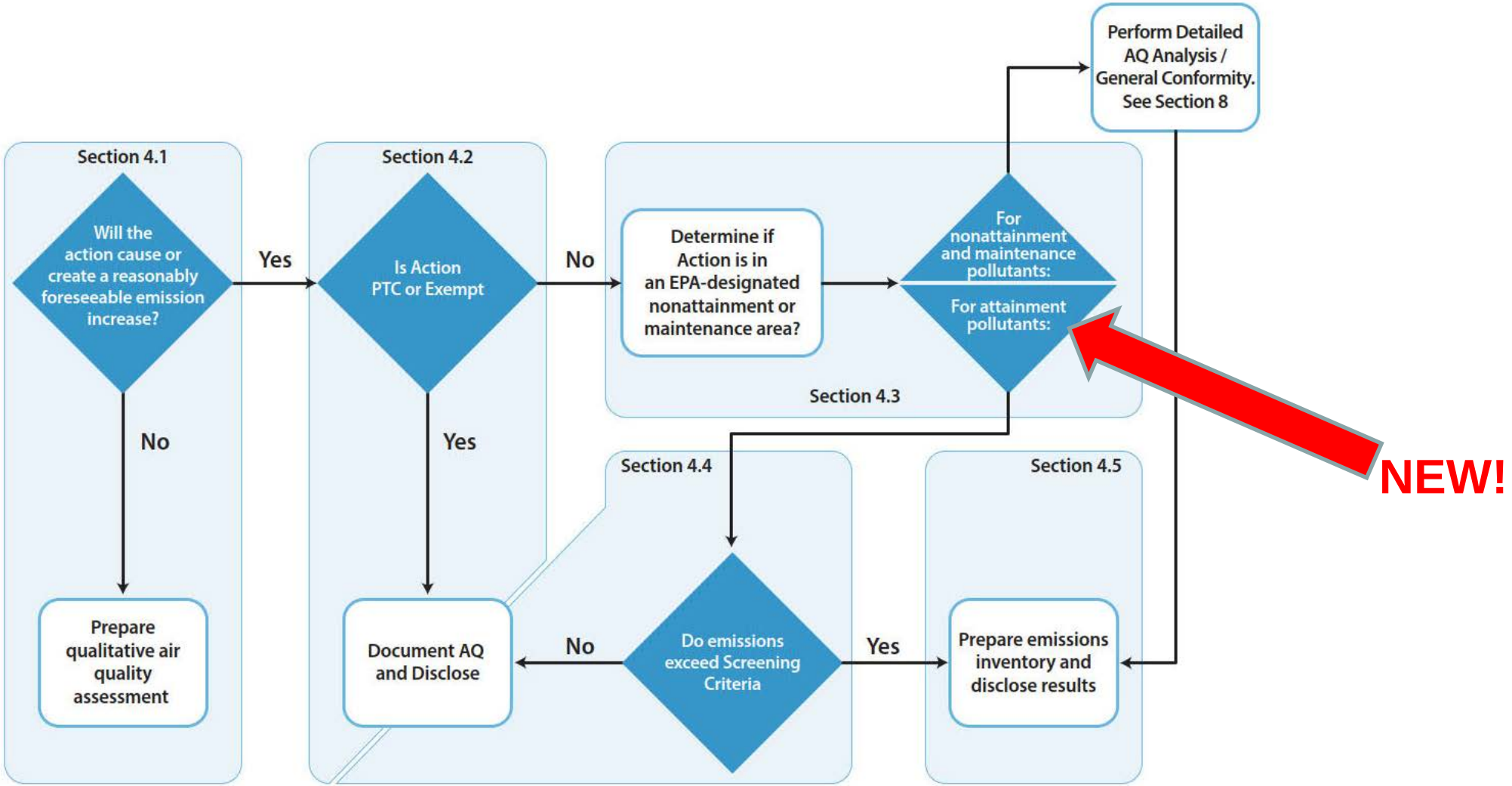
Source: 40 CFR 93.153(b)(1).
Notes: OTR = Ozone Transport Region.
[1] NO_x is evaluated as a $PM_{2.5}$ precursor unless federal/state/local regulation deems it is not significant to $PM_{2.5}$ nonattainment in an area(s). VOC and NH_3 are only evaluated as $PM_{2.5}$ precursors if federal/state/local regulation deems it is significant to $PM_{2.5}$ nonattainment in an area(s).

Attainment
Threshold (tons/year)

- **250 tons/year for each regulated pollutant***

*** Pb not included. Threshold is based on EPA's Prevention of Significant Deterioration regulations.**

Guidance Flow Chart



Proposed Screening Criteria

- **Will the FAA action cause an increase in project aircraft operations of more than 14,000 movements per year for an airport outside the OTR? If the project is in an OTR and more than one third of the increase involves GA aircraft, the above question should be revised to 5,000 from 14,000.**
- **Will the FAA action cause a projected annual increase of aircraft delay exceeding 340,000 minutes?**
- **Will the FAA action cause an additional 25 million VMT from on-road vehicles per year?**
- **Will the FAA action result in the use of more than 125 construction vehicles or GSE during a year, or if the project is in the OTR, 50 construction vehicles or GSE during a year?**

Next Steps

- **New screening tool for Federal Actions in attainment areas will be included in latest revisions to FAA Air Quality Handbook guidance document.**
  - Undergoing final edits.
  - AGC review pending.
  - Post to FAA public website

Summary

- **Have a comprehensive emissions research portfolio**
- **Research is ongoing to inform:**
  - Cruise-climb NOx and nvPM Modeling
  - nvPM Ambient Conditions Corrections Development
  - Improved Dispersion Modeling for Compliance
  - Airport Impacts Monitoring
  - Source Apportionment of Ambient Pollutant Measurements
- **A Potential Contrails Research Plan was presented**
  - Not trivial
  - Develop robust tools and methods to accurately forecast warming contrails
  - Reduce warming impacts
- **AQ Screening Criteria for Federal Actions in Attainment Areas**

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