

# Mitigating Aviation Contribution to Climate Change Through Integrated R&D and Solution-Based Approach

**Venue:** U.S. Department of Transportation  
Climate Adaptation and Mitigation  
Workshop Meeting

**By:** Dr. Mohan Gupta  
Asst. Chief Scientist  
Office of Environment and Energy  
Federal Aviation Administration

**Date:** February 26, 2015



Federal Aviation  
Administration



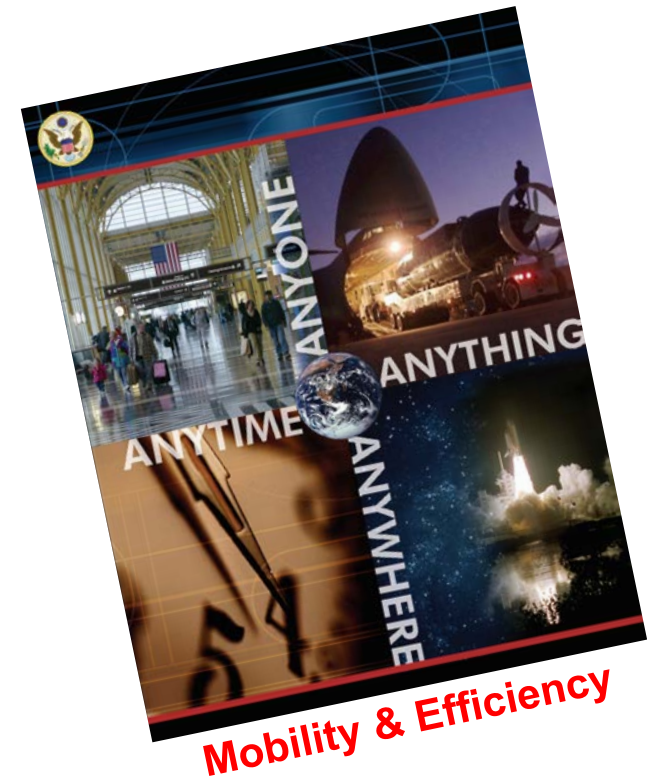
# Outline

- **Aviation: Mobility, Economy and the Environment**
- **Aviation Emissions and Climate Change**
- **Integrated Mitigation Solutions**
  - NextGen Five Pillar Approach
- **Closing Observations**



# Aviation: Mobility, Economy and the Environment

- Helps generate more than 5% of U.S. GDP and more than 10 million U.S. jobs; driving about \$1 Trillion in Economic Activity  
[Source: FAA Air Traffic Organization]
- In 2013, Exports by air accounted for 27% of the total *value* of U.S. exports and 22% of the total *value* of imports (all-time highs of \$430.9B and \$509.4B, respectively)  
[Source: US Census Bureau]



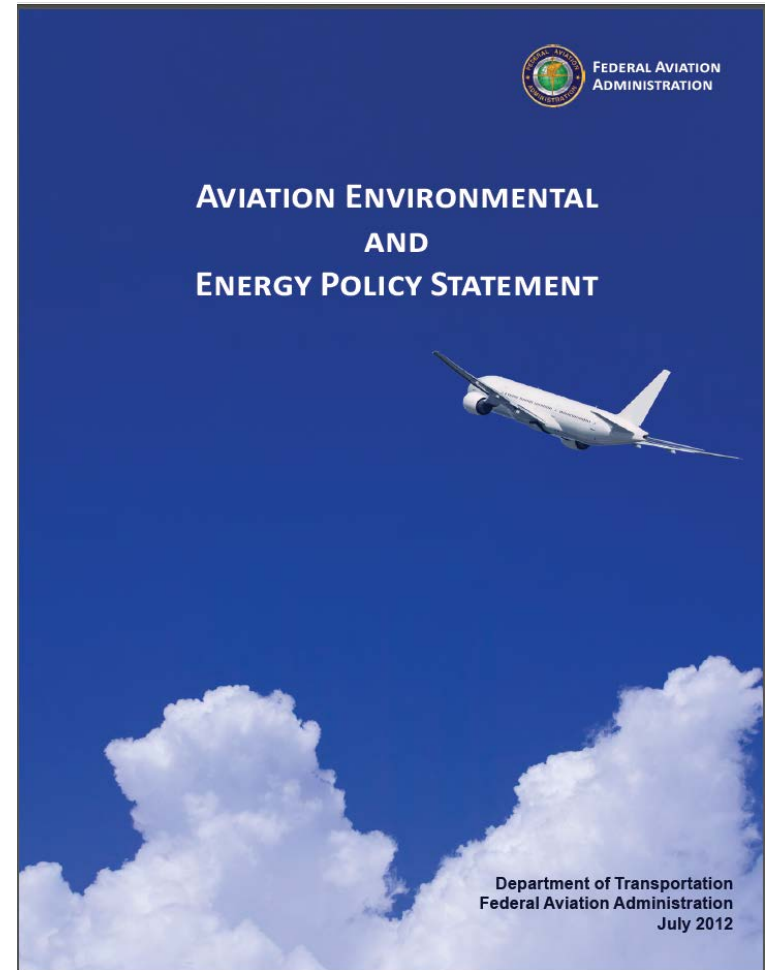
# Vision and Principles

## Vision:

*Environmental protection that allows sustained aviation growth*

## Guiding Principles:

1. Limit and reduce future aviation environmental impacts to levels that protect public health and welfare.
2. Ensure energy availability and sustainability.



***Need increased mobility with reduced environmental impacts and enhanced energy availability and sustainability***

# Environment & Energy Goals

Aspect	Goal
<b>Noise</b>	Reduce the number of people exposed to significant noise around U.S. airports in absolute terms, notwithstanding aviation growth, and provide additional measures to protect public health and welfare and our national resources.
<b>Air Quality</b>	Achieve an absolute reduction of significant air quality health and welfare impacts attributable to aviation, notwithstanding aviation growth.
<b>Energy</b>	Improve National Airspace System (NAS) energy efficiency and develop and deploy alternative jet fuels for commercial aviation.
<b>Climate</b>	Limit the impact of aircraft CO2 emissions on the global climate by achieving carbon neutral growth by 2020 compared to 2005, and net reductions of the climate impact from all aviation emissions over the longer term (by 2050).



# Climate Action Plan

- USG has set an ambitious overarching goal of achieving carbon-neutral growth for U.S. commercial aviation by 2020, using 2005 emissions as a baseline
- Plan is based upon NextGen five-pillar approach
- Plan identifies current progress and planned actions being taken toward meeting carbon-neutral growth goal



•U.S. Aviation GHG Emissions Reduction Plan available at:

•[http://www.faa.gov/about/office\\_org/headquarters\\_offices/apl/enviro\\_policy\\_guidance/policy/media/Aviation\\_Greenhouse\\_Gas\\_Emissions\\_Reduction\\_Plan.pdf](http://www.faa.gov/about/office_org/headquarters_offices/apl/enviro_policy_guidance/policy/media/Aviation_Greenhouse_Gas_Emissions_Reduction_Plan.pdf)



**Federal Aviation  
Administration**

# FAA Approach and Strategy

## Approach

- Characterize the Problem and Assess Risk
- Develop Mitigation Solutions
- Manage System-wide Environmental Performance

Significant Increase in Capacity & Mobility

- Challenges**
- Noise
  - Air Quality
  - Climate
  - Energy
  - Water Quality

## Strategy: Integrated NextGen Five-Pillar Environmental Approach

- **P1: Improved Scientific Knowledge and Integrated Modeling**
- **P2: New Aircraft Technologies**
- **P3: Sustainable Alternative Aviation Fuels**
- **P4: Air Traffic Management Modernization and Operational Improvements**
- **P5: Policies, Environmental Standards, and Market Based Measures**

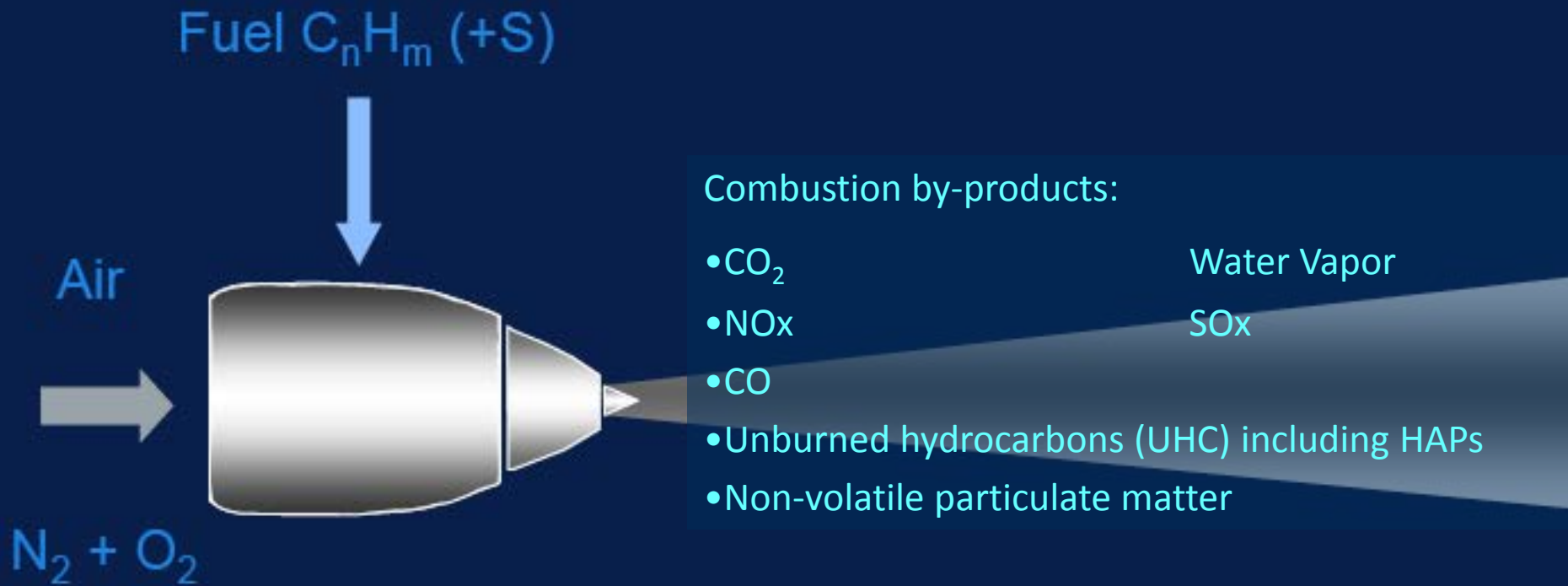


## Overarching Direction

- Develop a goals-focused research program that leads to solutions for aviation E&E challenges
- Evaluate progress towards goals
- Modify the plan as needed



# Aircraft Combustion Emissions



## Some key points:

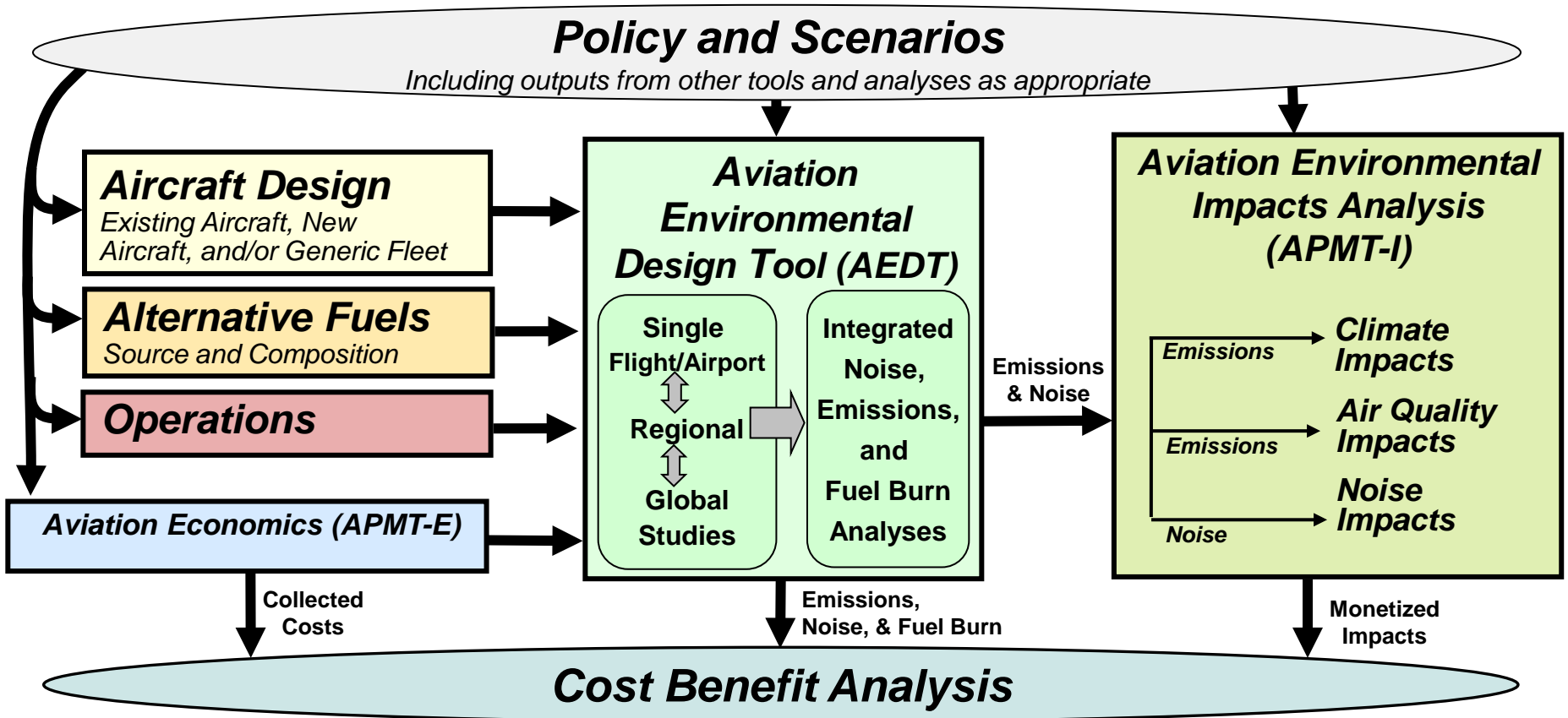
- Aircraft emissions are inherently four-dimensional (space & time) in nature
- Vertical extent of aviation emissions ranges from surface to cruise altitude
- Connect international boundaries with local, regional and global issues
- Emissions evolution from plume to global scale
- Environmental impacts: Air quality, climate change and public health
- Aircraft non- $CO_2$  emissions are increasing while background emissions are decreasing
  - Aviation demand is projected to increase at the rate of 2.2%/year over the next 20 years (FAA Forecast, 2014)





# Tools and Analytical Capability: Inventory and Analysis

## Pillar 1



### Tools Applications

- CAEP analyses
- Domestic Annual Performance Reporting
- Goals analysis

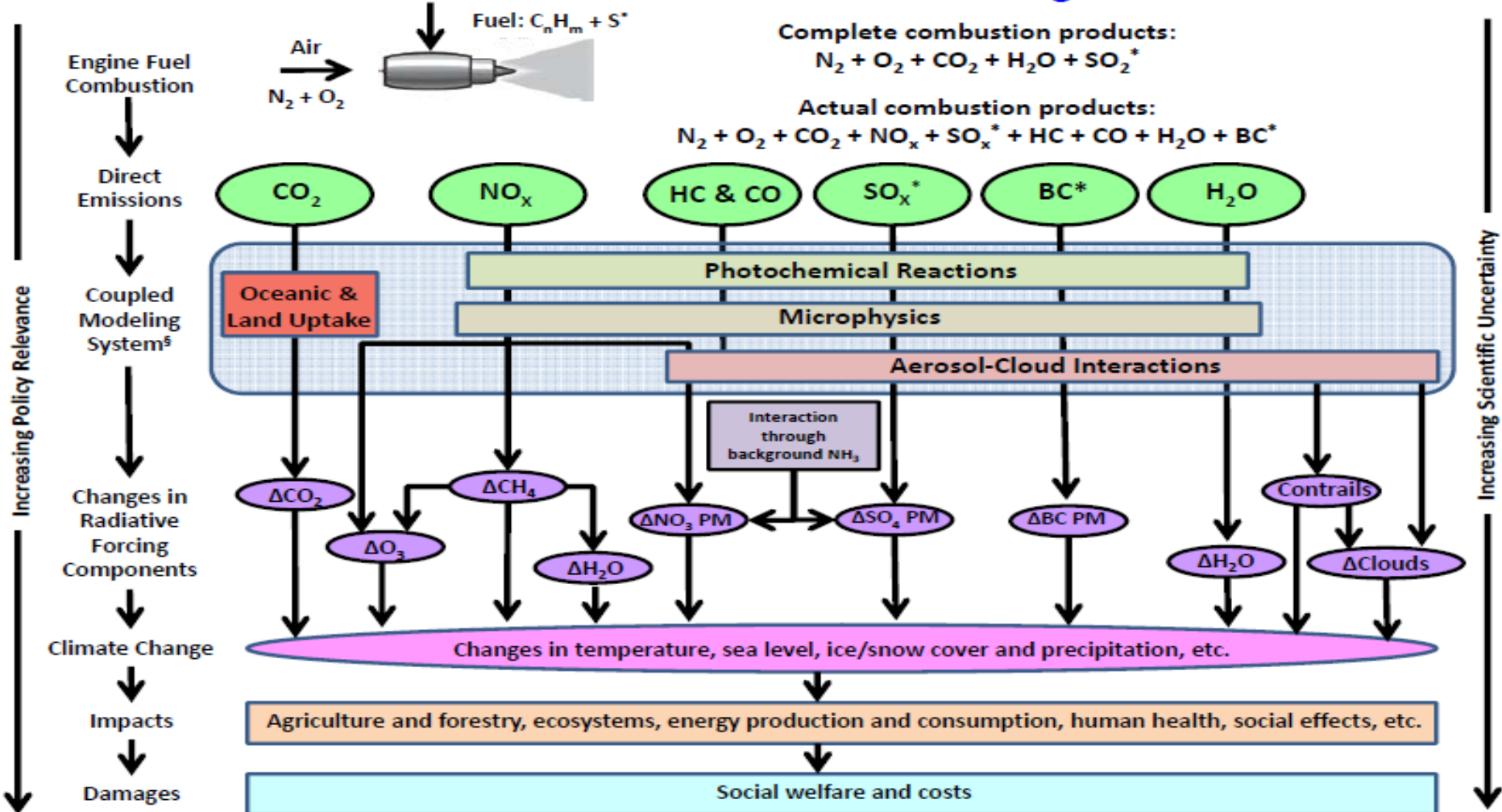
- NextGen benefit analysis
- Technology Assessment
- Airspace and airport design & planning
- Compliance and regulatory analyses

This is not an exhaustive list of applications.



# Aviation Climate Impacts – A Schematic Diagram

## Pillar 1



\*100% Alternative Jet fuels will have no sulfur related emissions and have lower black carbon (BC) emissions; other emissions could be lower (e.g.,  $NO_x$ )  
<sup>5</sup>Accounts for radiative, chemical, microphysical and dynamical couplings along with dependence on changing climatic conditions and background atmosphere

# Continuous Lower Energy, Emissions and Noise (CLEEN) II

## Pillar 2



- CLEEN II: 2015-2020 (\$100M FAA Funding)**

- Reduce aircraft fuel burn, emissions and noise through technology & advance alternative jet fuels
- Develop and demonstrate (TRL 6-7) certifiable aircraft technology
- 1:1 minimum cost share requirement
- More information available at:

[http://www.faa.gov/about/office\\_org/headquarters\\_offices/apl/research/aircraft\\_technology/cleen/](http://www.faa.gov/about/office_org/headquarters_offices/apl/research/aircraft_technology/cleen/)

### CLEEN vs. CLEEN II Program Goals

	CLEEN	CLEEN II	
Noise (cum below Stage 4)	-32 dB	-32 dB	and/or reduces the noise contour area in absolute terms
LTO NOx Emissions (below CAEP 6)	-60%	-75%	and/or reduces absolute NOx production over the aircraft's mission
Aircraft Fuel Burn	-33%	-40%	and/or supports the FAA's goal to achieve a net reduction in climate impact from aviation

**Also, focuses on advance use of “drop-in” renewable alternative fuels**



# Continuous Lower Energy, Emissions and Noise (CLEEN)

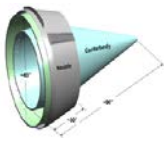
## Pillar 2

- 5 year effort to accelerate technology maturation
- Reduces aircraft fuel burn, emissions and noise
- 50% cost share; total FAA budget: ~\$125M



### Boeing

- Ceramic Matrix Composite Nozzle
- Adaptive Trailing Edge



### Rolls-Royce

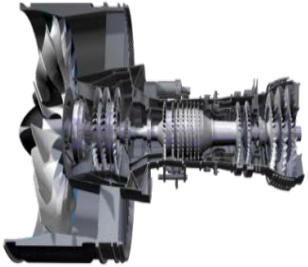
- Ceramic Matrix Composite Blade Tracks
- Dual-Walled Turbine Airfoils

### Honeywell

- Lighter weight, higher temp engine

### Pratt & Whitney

- Ultra-high Bypass Ratio Geared Turbofan



### General Electric

- Flight Management System / Air Traffic Integration
- Flight Management System / Engine Integration
- Twin Annular Premixing Swirler (TAPS) II Low NOx Combustor
- Open Rotor Engine



# CLEEN's Milestone Demonstrations

## Pillar 2



GE TAPS II Core Engine Test (TRL 6)



GE Open Rotor Wind Tunnel Tests (TRL 5)



Boeing Adaptive Trailing Edge

Ground Demonstration (TRL 6) Flight Demonstration (TRL 7)



Boeing Ceramic Matrix Composite Nozzle Ground Test (TRL 6)

GE Trajectory Synchronization Simulation (TRL 6)



Dec  
Jan

Jul  
Sep

Jan  
Mar

May

Jul

2011

2012

2013

2014



RR CMC Turbine Blade Track Engine Ground Testing



P&W Fan Rig Wind Tunnel Test



Boeing CMC Exhaust Nozzle Flight Test on 787 ecoDemonstrator (TRL 7)



Federal Aviation Administration

# Sustainable Aviation Energy

## Pillar 3

### Uniqueness of Aviation in terms of Energy:

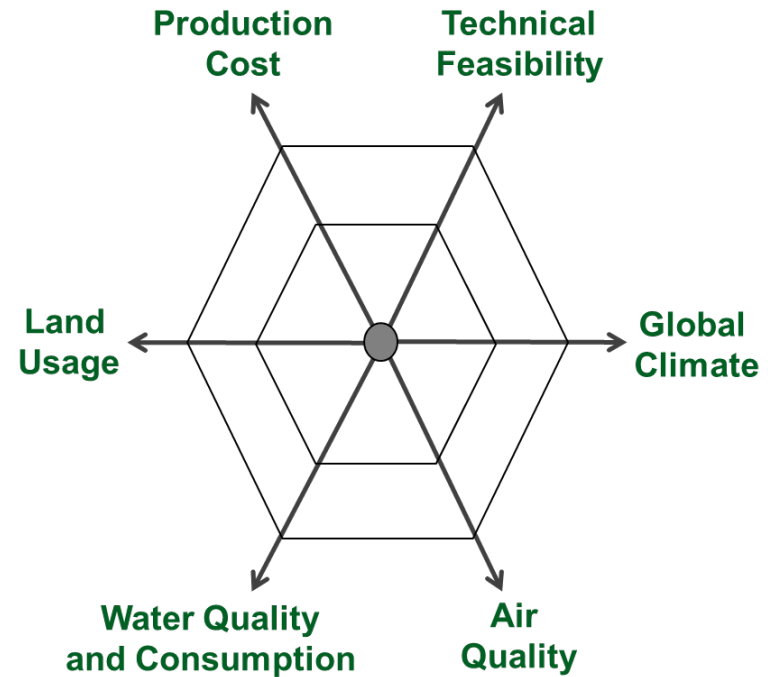
- Large existing infrastructure of vehicles designed for jet fuel.
- For safety and energy efficiency, aviation requires hydrocarbon-based fuels. Batteries, alcohols and biodiesel (FAME) will not work with current fleet.
- Focus is on 'drop-in' fuels

### Potential Benefit:

- Reduce emissions that impact global climate change and air quality.
- Expand and diversify energy supplies.
- Economic development.

### Challenge:

- *Develop environmentally and economically sustainable feedstocks and production methods for commercial production*



# Commercial Aviation Alternative Fuels Initiative (CAAFI)

## Pillar 3

- Public-Private coalition for commercial aviation to engage the emerging alternative fuels industry
- Enable development of alt jet fuels
- Four teams for key issues
  - Environment Team
  - Certification-Qualification Team
  - R&D Team
  - Business Team
- State and Regional Support
- International Cooperation



# FAA Alternative Jet Fuel Activities

## Pillar 3

- **Testing**

- Support Cert/Qual testing
- Improve Cert/Qual process
- Emissions measurements

- **Analysis**

- Environmental sustainability
- Techno-economic analysis
- Future scenarios

- **Coordination**

- Interagency
- Public-Private
- State & Regional
- International

Till date, 3 alternative jet fuels have been approved by the ASTM International. Several other fuel candidates are currently being evaluated.



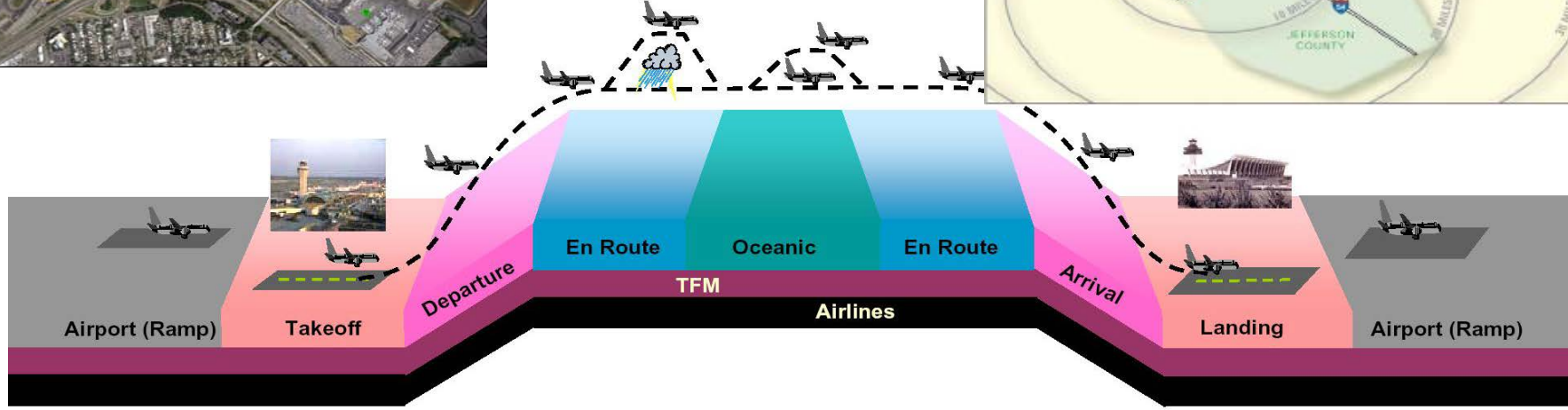
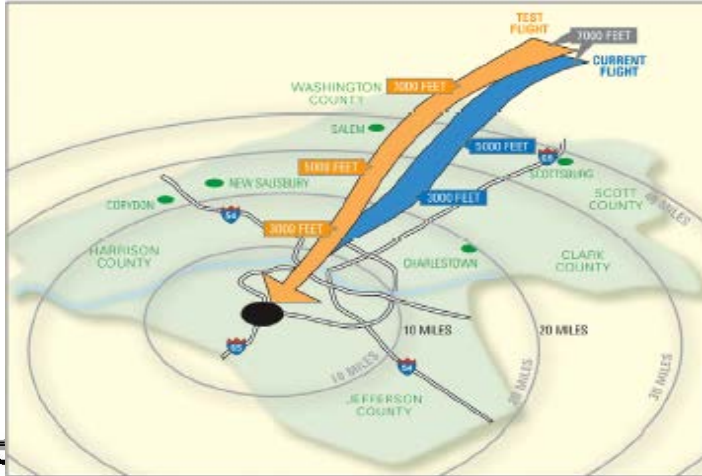


# Clean, Quiet and Energy Efficient Operational Procedures

## Pillar 4



Surface  
Terminal  
En-route



New air traffic management capabilities, and gate to gate and surface operational procedures will allow further reduction in aviation's environmental footprint and increase energy efficiency.



# Research Programs



## Center of Excellence (COE) Program

- Focused on university research



## Continuous Lower Energy, Emissions and Noise (CLEEN)

- CLEEN: 2010-2015
- CLEEN II: 2015-2020
- Reduce aircraft fuel burn, emissions and noise through technology & advance alternative jet fuels



## Additional Research Efforts

- DOT Volpe Transportation Center
- Contract mechanisms (e.g., SEMRS, PEARS)



# Closing Observations

- Aviation is an essential mode of transportation with extraordinary benefits for mobility and economy
- Aviation contribution to climate change is small but it is expected to increase with projected future demand and decline in emissions from other sectors (particularly for non-CO<sub>2</sub> emissions) – *unless appropriate actions are taken*
- Advancing the state of science and analytical capability to better characterize aviation climate impacts and to inform decision-making
- Pursuing a balanced, integrated and multi-faceted solution-based 5-pillar approach to reduce aviation emissions and their contribution to climate change

