Please note that this presentation was given during the United Nations Climate Change Conference (COP-15) in Copenhagen, December 7-18, 2009 for more information please visit http://www.cop15.state.gov/ .

GREENING U.S. AVIATION

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Aviation's Contribution to Society

- Aviation contributes more than $1.2 trillion each year to the U.S. economy and supplies more than 1 million jobs
- Aviation moves people and products all over the globe — quickly and safely. Aviation contributes to our quality of life — allowing us to visit friends and relatives, to travel, to experience new places, to connect the regions of the world

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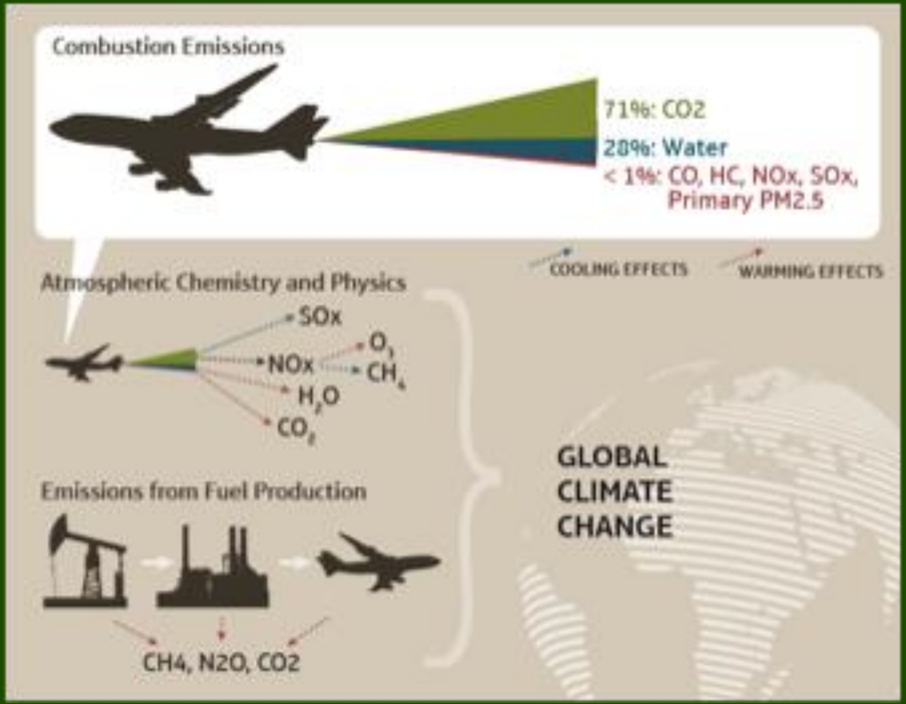
Aviation's Impact on Climate

- Aviation contributes ~3% CO_2 emissions; may grow globally to 5% by 2050 (IPCC)

The Record

- Between 1978 and 2008 U.S. airlines improved fuel efficiency from 2.92 Revenue Ton Miles/gallon to 6.11 Revenue Ton Miles/gallon, a 110% improvement
- 2.7 billion metric tons of CO2 savings equivalent to taking ~19.5 million cars off the road each year
- From 2000 to 2008:
  - Reduced absolute fuel burn and emissions by ~ 5.5%
  - Increased passengers and cargo by 17%



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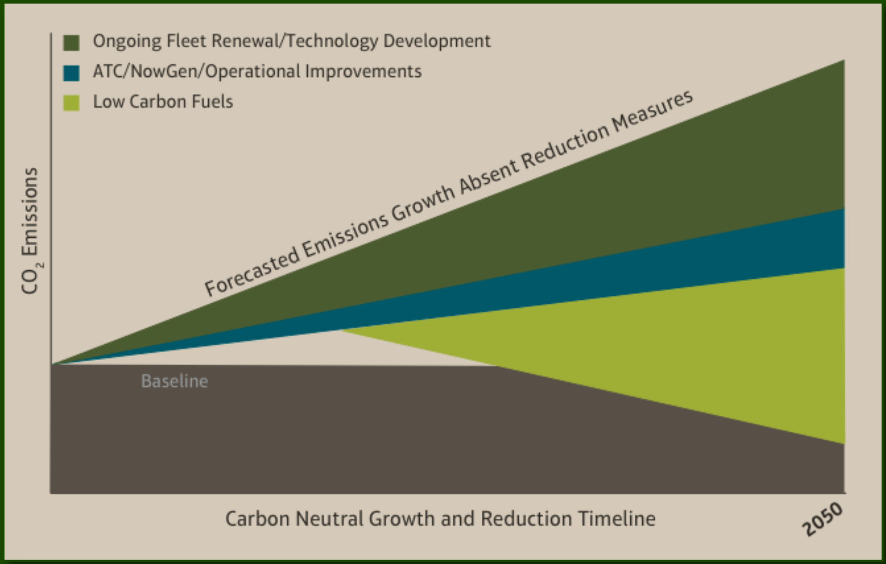
The Challenge:

- *Enable increased mobility while reducing climate impacts in absolute terms.*



The Solution - U.S. five-pillar approach

- Mature New Aircraft Technology
- Accelerate Operational Changes
- Develop Alternative Fuels
- Examine Policies and Market Based Measures
- Advance Scientific Understanding, Improve Environmental Analysis Capability

Our Plans

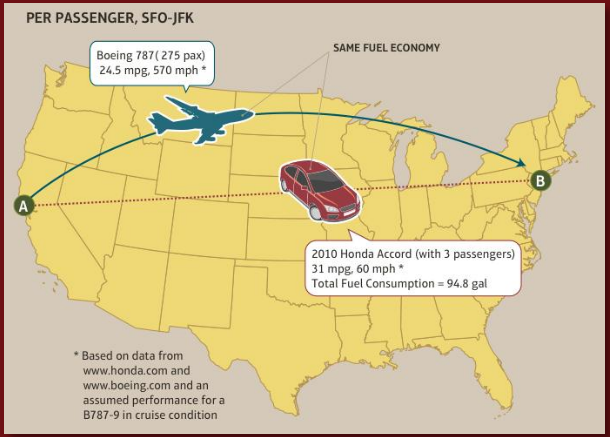
- Aggressive efficiency improvements of at least 2% per year
- Carbon neutral growth by 2020, absolute reductions by 2050
- Aircraft and engine CO_2 and other emissions standards

Aircraft Technologies

How will future aircraft mitigate their environmental impact while enabling continued growth?

WHAT HAVE WE ACHIEVED RECENTLY?

- Over the past 30 years, fuel burn improvements of approx. 60% achieved through aircraft technologies
- Key advances from aerodynamic, propulsion, and structural improvements
- Significant environmental gains: continuous reductions in absolute number of people exposed to objectionable noise, significant reductions in NO_x, other harmful emissions
- Significant reductions in fuel burn and CO_2 emissions
- Fully loaded B787 SFO-JFK yields similar fuel efficiency of a 2010 Honda Accord (with three passengers) at almost 10 x the speed



WHAT ARE WE DOING NOW?

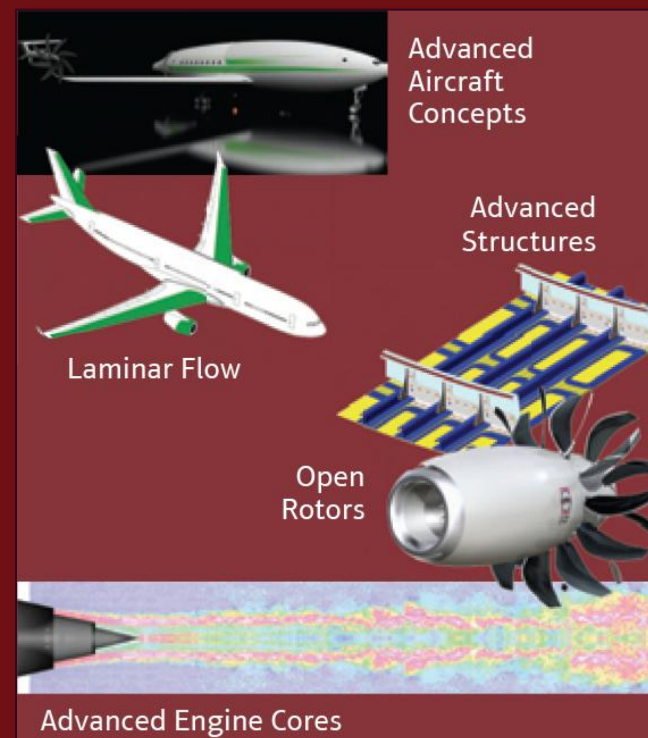
- Fostering significant technology advancements for next generation aircraft: all composite structures, ultra-high-bypass-ratio engines, advanced aerodynamics
- Addressing near-to-far term aviation efficiency and environmental goals consistent with the U.S. National Plan for Aeronautics R&D
- Looking ahead and pursuing research and development to simultaneously tackle all sources of commercial aircraft environmental impact

	N+1 (2015) CONVENTIONAL CONFIGURATION RELATIVE TO 1998	N+2 (2020-25) UNCONVENTIONAL CONFIGURATION RELATIVE TO 1998	N+3 (2030-35) ADVANCED CONCEPTS RELATIVE TO 2005
NOISE	-32 dB cum below Stage 4	-42 dB cum below Stage 4	-71 dB cum below Stage 4
LTO NOX EMISSIONS (BELOW CAEP 6)	-60%	-75%	better than -75%
AIRCRAFT FUEL BURN	-33%	-50%	better than -70%

WHAT ARE WE DOING NEXT?

- Environmental and energy drivers are shaping future aircraft and propulsion system design
- National Plan for Aeronautics R&D laying foundation for next three generations of aircraft: N+1 (2017), N+2 (2025), N+3 (2035)
- NASA and FAA accelerating technologies:
  - CLEEN: Continuous Lower Energy Emissions and Noise
  - ERA: Environmentally Responsible Aviation
- Dramatic changes may be needed to support a carbon-neutral system

The combination of advanced engine technologies and dramatic changes in the airframe configurations are key contributors to a carbon-neutral commercial aviation system.



Operations

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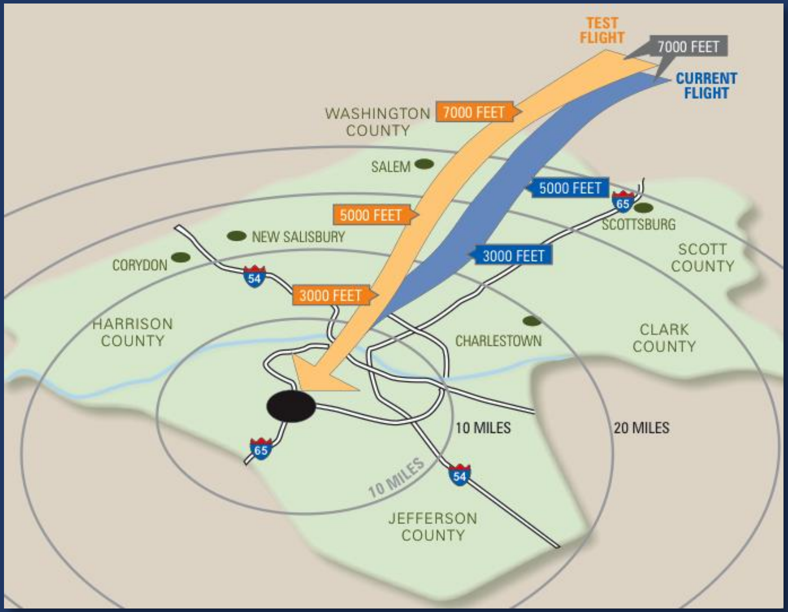
What role can operations play in limiting aviation's environmental impact?

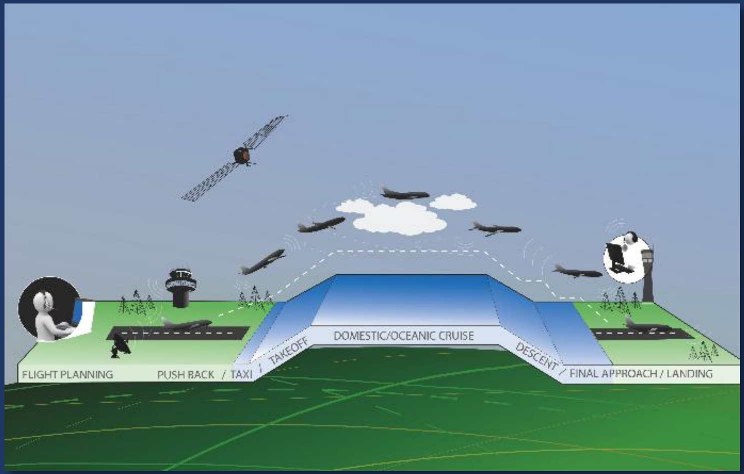
WHAT HAVE WE ACHIEVED RECENTLY?

- *Reducing fuel burn and noise impacts*
- Reduced Vertical Separation Minimum (RVSM) implemented across United States
  - Allows aircraft to fly at more optimal altitudes
  - Increases airspace capacity and reduces congestion
- Continuous Descent Approaches (CDAs) implemented at selected airports
  - Cost-effective near- and medium-term reductions in
    - Noise and emissions
    - Fuel burn and flight time



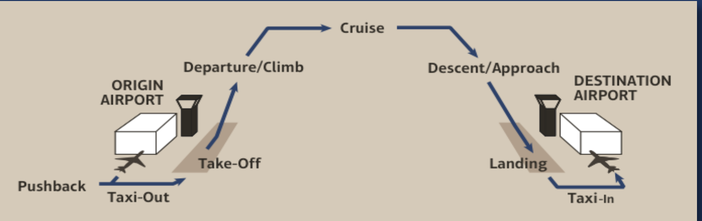
WHAT ARE WE DOING NOW?

- ***Mitigations in every flight phase***
- Surface
  - Limiting build up of queues on the airport surface
  - Gate-hold strategies
  - Taxi route planning, including the use of perimeter taxiways
  - Operational procedures such as tow-outs and single engine taxi
- Departure
  - Continuous climb departures
- Cruise
  - En route traffic optimization
  - Cruise climb
  - Additional cruise lanes
- Approach
  - Optimal Profile Descents (OPDs)—successor to CDAs
  - RNAV& RNP enabling more precise and predictable departure, cruise, approach



WHAT ARE WE DOING NEXT?

- "Gate-to-gate" 4D trajectory optimization enabled by the Next Generation Air Transportation System (NextGen)
  - Balancing capacity and environmental performance
  - Integrating advanced technologies, airspace and procedures



	PUSHBACK	TAXI-OUT	TAKE-OFF	DEPARTURE/ CLIMB	CRUISE	DESCENT/ APPROACH	LANDING	TAXI-IN
POTENTIALLY NEAR TERM	Basic Pushback Management Strategies (e.g. N-control)[1]	Single Engine Taxi	Engine Take-off Power Optimization	Continuous Climb Departures in a Terminal Area	Optimal Cruise Altitude & Speed Assignment, e.g. Cruise Climb	Continuous Descent Approaches in a Terminal Area	Displaced Thresholds	Single Engine Taxi
POTENTIALLY MEDIUM TERM	Advanced Pushback Management Strategies[2]	Optimal Taxi Routing with no/ minimal Holding[2]	Runway Allocation for Optimal Taxi Routing[2]	Optimal Continuous Climb Departures to Cruise	Wind Optimized Ground Track at Optimal Cruise Altitude & Speed[3,4]	Continuous Descent Approaches from Cruise[3]	Steeper Glideslope Angles Runway Allocation for Optimal Taxi Routing[2]	Optimal Taxi Routing with no/ minimal Holding[2]

1 Proposed to be tested in PARTNER/Lincoln Lab field trial
2 Under development in Lincoln Lab Arrival/Departure Management Tool (A/DMT) project
3 Part of NextGen/SESAR objectives
4 Part of AIRE & ASPIRE objectives for oceanic operations

We are undertaking a comprehensive assessment of the total environmental impact of operational measures

Alternative Fuels

Can alternative fuels provide aviation with a sustainable source of energy to power both the fleet of today and that of tomorrow?

WHAT HAVE WE ACHIEVED RECENTLY?

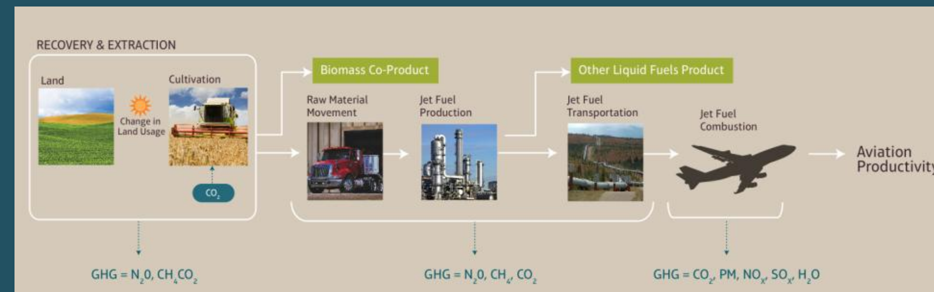
- Developed advanced biofuels that are safe for aviation and could be grown in a sustainable manner
- Gained approval of a new synthetic jet fuel specification — Fisher-Tropsch alternatives now covered and hydroprocessed renewal jet fuel approval expected soon
- Flew multiple times on these fuels

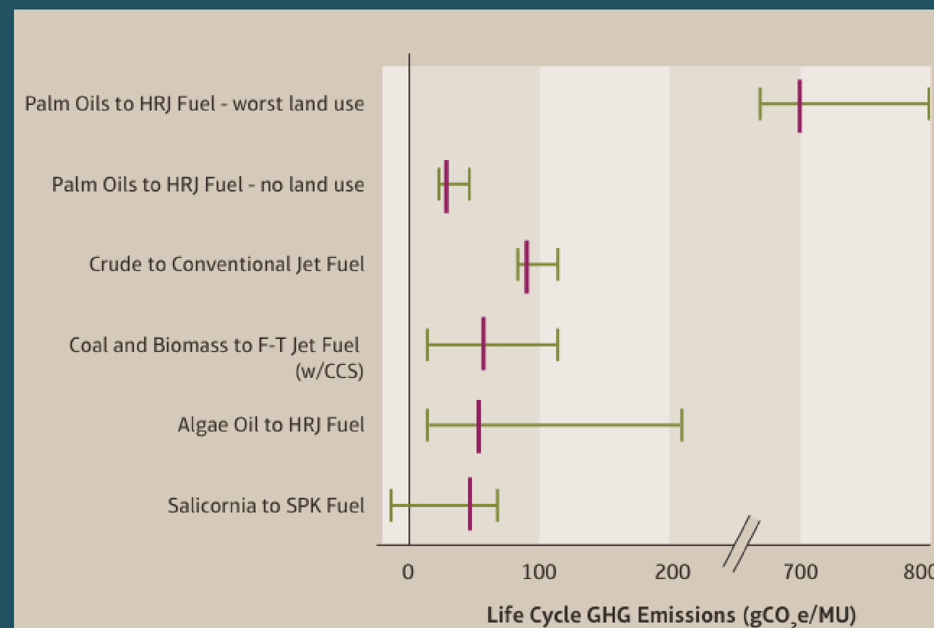
Commercial Aviation Alternative Fuels Initiative (CAAFI)

- Coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participant, and U.S. government agencies
- Leading development and deployment of alternative jet fuels for commercial aviation

WHAT ARE WE DOING NOW?

- Researchers characterizing well-to-wake lifecycle GHG emissions
- Purchasing fuels derived from camelina and algae for more extensive testing
- Considerable capital devoted to developing new biofuels
- Aviation industry purchasing fuels — synthetic diesel in Los Angeles International Airport for ground support equipment





WHAT IS COMING NEXT?

- Sustainable biofuels avoid competition for food and fresh water
- Advanced bio-based jet fuels from camelina may pave the way
- Bio-based synthetic fuels with coal and carbon capture and sequestration could reduce GHG emissions and be cost-competitive
- Salicornia to synthetic fuel could be grown in the desert with sea water
- Algae holds tremendous potential and it may not be that far away

Technology exists to create alternative jet fuels compatible with today's aircraft; fuel feedstocks being evaluated to determine their environmental sustainability.

Science & Decision-making

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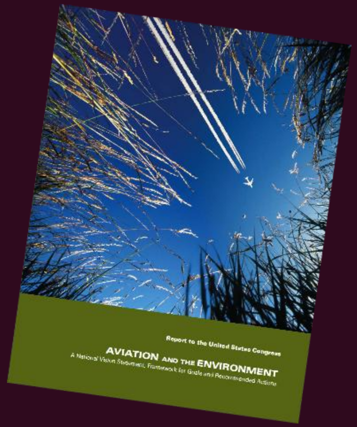
How will we decide which policies, technologies, fuels, and operational procedures best address societal needs for mobility and a clean environment?

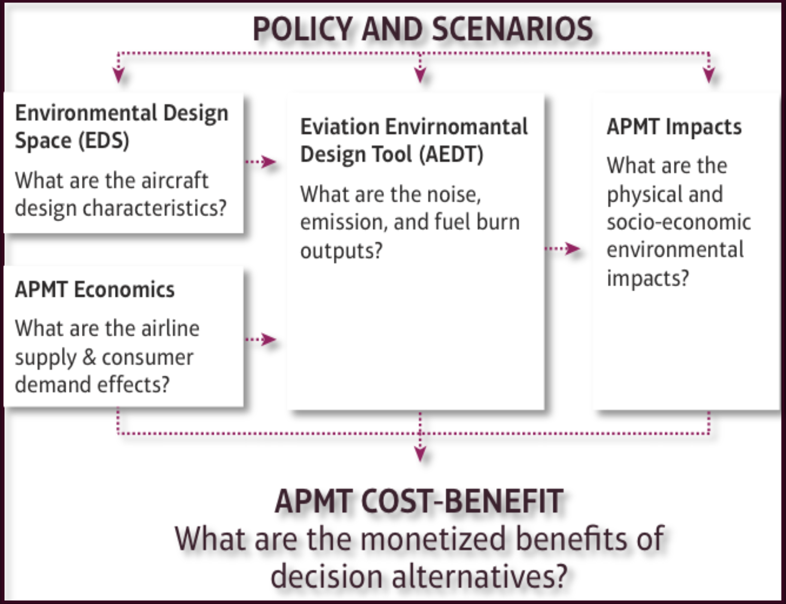
WHAT HAVE WE LEARNED?

- 2004: PARTNER Report to the U.S. Congress recommends U.S. vision for absolute reductions in significant aviation environmental effects
  - Recommendations for technology, operations, science, and tool development incorporated in U.S. National Aeronautics policy and FAA Flight Plan goals
- Subsequent work by more than 250 researchers has led to a dramatic improvement in understanding climate, air quality, noise impacts
- Policymakers now including explicit assessments of aviation health and welfare impacts in decision-making
- Climate impacts of aviation likely more significant than air quality or noise
- International collaboration has expanded our capabilities and knowledge



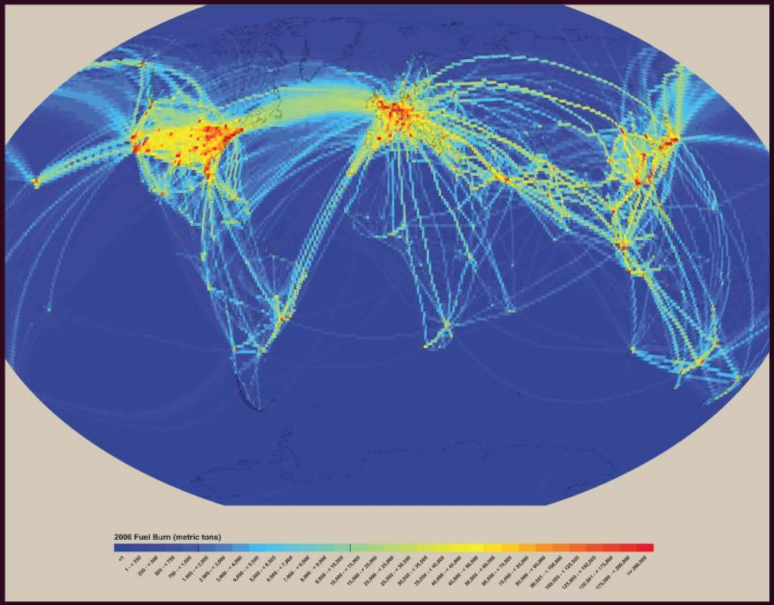
WHAT ARE WE DOING NOW?

- Enhancing aviation environmental tools for improved analysis capability
- Using climate simulations to understand aircraft impacts
- Developing and applying policy analysis tools that include CO_2 and non-CO_2 impacts
- Measuring alternative and conventional fuel engine emissions
- Studying coupled surface air quality and climate impacts
- Using our scientific understanding of impacts in analyses of
  - Metrics to support an aircraft CO2 emissions standard
  - Market-based measures
  - Advanced aircraft operational procedures
  - Increased stringency of engine NOx certification standards
  - U.S. Next Generation Air Transportation System implementation alternatives
  - Aircraft technology development options
  - Alternative fuels
  - Ultra low sulfur fuels



WHAT IS COMING NEXT?

- A significant increase in support of aviation climate impact research.
- Aviation Climate Change Research Initiative to fund a team of researchers from around the world.



We are advancing understanding, but not waiting; we are using our best methods to seek solutions now.