Evaluating the Environmental Performance of the U.S. Next Generation Air Transportation System

Estimation of Noise, Air Quality, and Fuel-Efficiency Performance

2008 Portfolio Analysis Environmental Results

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The Main Environmental Effects

- **Noise:**

    - Relatively short time span for direct effects (seconds)
    - Relatively simple dose-response function
    - Goals expressed as average annual exposure level (dB DNL) over areas or people
    - Uncertainties: aircraft trajectory and state, meteorology

- **Air quality:**

    - Moderate scale for health effects (weeks to years)
    - Complex dose-response functions
    - Goals expressed as hourly to annual averages (pollutant density).
    - Uncertainties: aircraft trajectory and state, meteorology, atmospheric physics and chemistry, dose-response functions

- **Climate:**

    - Very long time scale for effects (years to centuries)
    - Very complex dose-response functions
    - Goals expressed as contribution to radiative forcing ($W/m2$; $W=J/sec$).
    - Uncertainties: aircraft trajectory and state, meteorology, atmospheric chemistry and physics, dose-response functions, inter-generational value discounting

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Goals of Environmental Analyses

- **Estimate environmental performance on a US-wide basis for for several NextGen scenarios considering fuel, emissions, and noise at the top several hundred airports ("LMI 310"):**
  - **Fuel**
    - **Total mass of fuel consumed / total distance flown (Tg/Bk)**
    - **Payload Fuel Efficiency (PFE) –**
    Total energy of fuel consumbed / (payload * Great Circle distance) (MJ/(kg*km))

  - **Local Air Quality and Green House Gas Emissions: HC, SO_x, NO_x, CO, CO_2**

  - **Noise**
    - **Population Exposed to Day/Night Average Noise Level (DNL)**
    - **Area Exposed (DNL)**

Goals of Environmental Analyses (2)

- **Assess NextGen ability to achieve JPDO Environmental Working Group (EWG) <u>interim</u> environmental goals***

  - **Noise goal: 4% reduction per year in the number of people exposed to ≥65 dB DNL**

  - **Fuel-efficiency goal: 1% improvement per year in efficiency, in terms of fuel/distance metric**

  - **PFE, GHG, and emissions goals: not yet specified**

- **Distinguish the effects of NextGen procedural and avionics improvements from NextGen engine and airframe improvements.**

* Current goals are defined for the FAA's Flight Plans and have been extended to time periods consistent with IPSA analysis.

Summary of IPSA NextGen Analysis Approach

- **Future demand scenarios are generated using FAA forecasts.**

- **Future baseline and NextGen airport capacities are estimated based on an airport-capacity constraints analysis and performed in coordination with FAA and Mitre for the years 2015 and 2025.**

- **NextGen performance related to capacity is evaluated using NAS-wide simulations.**

- **NextGen performance related to environment is evaluated based on the NAS-wide analysis using a suite of environmental modeling tools.**

- **Metrics of interest are derived from the NAS-wide analysis of throughput, delay, and environmental performance.**

Key Major Elements of Multi-stage Modelling Process

Impacts of multiple improvements modeled:

- **At 35 major airports, IMC capacity improvements in 2025 of 25% to 200%**

- **Sector capacity increases of 70-90%**

NextGen OI's

Operational Modelling and Analysis

Trajectories and schedules

Environmental Modelling and Analysis

Three additional improvements:

- **Fleet Evolution (with airframe/engine technology improvements)**
- **Required Navigation Performance (RNP)**
- **Continuous DescentArrivals (CDA); now Optimized Profile Descents (OPDs)**

Environmental Metrics and Comparison to Targets

Key Assumptions Regarding Performance Improvements

- **Demand Adjustment (Flight Trimming)**
  - Future demand is based on FAA's Terminal Area Forecast (TAF), but is 'constrained' to maintain reasonable levels of delay
  - Demand is 'trimmed' primarily from OEP airports which are primary contributors to delays
- **Airport Capacity Improvements**
  - Airport capacity improvements are based on bottom-up analysis of the operational improvements (OI's) and their operations impacts
  - Assumptions and analysis coordinated with FAA and Mitre and performed by IPSA
  - NextGen results in significant improvements in airport capacities (AAR/ADR) in all weather conditions (IMC/MVMC/VMC)
- **En Route Airspace Capacity Improvements**
  - En route airspace capacity improvements are based on prior government and industry research as well as IPSA analyses
  - NextGen capabilities such as improved traffic flow management and dynamic airspace capabilities result in increased en route capacities both NAS-wide and in congested airspace
- **Weather-related ATM Improvements**
  - NextGen capabilities related to mitigating the impact of bad weather are primarily captured through improved ATC/ATM/TFM capabilities.
  - Improved ATC capability in weather, to mitigate weather impact on airspace.
  - Improved airport or terminal area weather capabilities, to mitigate weather impact on airport capacity.

Methods for Terminal-area Trajectories

- **High-fidelity approach used at top 35 airports incorporates 30 days of radar data and detailed representation of traffic patterns and variability.**

- **Algorithmic approach used to generate lower-fidelity trajectories at other airports, with some representation of variability.**
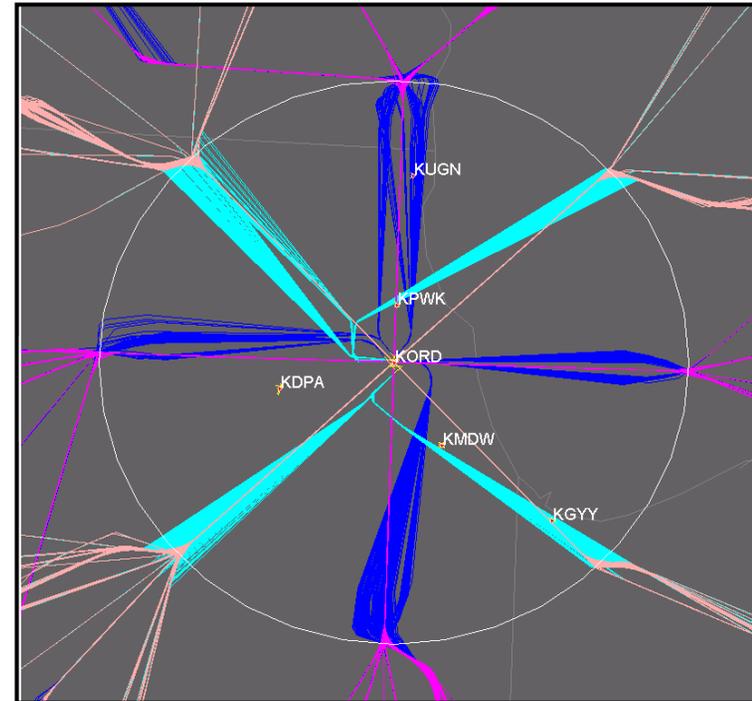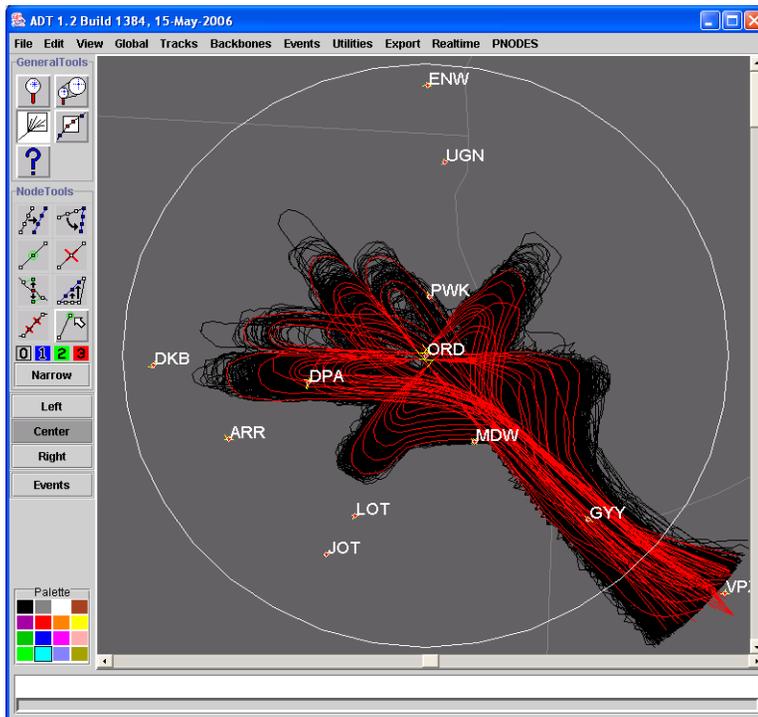
Projected Environmental Performance Improvements

CORNERS OF THE TRADE SPACE	N+1 (2015 EIS) Generation Conventional Tube and Wing (relative to B737/CFM56)	N+2 (2020 IOC) Generation Unconventional Hybrid Wing Body (relative to B777/GE90)	N+3 (2030-2035 EIS) Generation Advanced Aircraft Concepts (relative to user defined reference)
Noise	- 32 dB (cum below Stage 4)	- 42 dB (cum below Stage 4)	55 LDN (dB) at average airport boundary
LTO NOx Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%**	-40%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

** An additional reduction of 10 percent may be possible through improved operational capability

* Concepts that enable optimal use of runways at mutiple airports within the metropolitan areas

EIS = Entry Into Service; IOC = Initial Operating Capability

N+1 Conventional

N+2 Hybrid Wing/Body

N+3 Generation

Scenarios for 2008 Round of Analysis

• *2006 Baseline* – **A scenario based on actual traffic levels for 13 July 2006 and containing approximately 95,000 flights.**

• *2025 Without NextGen, Lower Feasible Demand* – **A scenario with unconstrained demand projected to 2025 based on the FAA's Terminal Area Forecasts (approximately 150,000 flights) and trimmed to a feasible level based on demand/capacity limits of 1.2 quarter-hourly and 0.9 hourly. The resulting feasible demand is approximately 125,000 flights.**

• *2025 Without NextGen, Higher Feasible Demand* – **The same as Scenario II, but trimmed to a feasible level based on increased airport capacity. The resulting feasible demand is approximately 135,000 flights.**

• *2025 With NextGen, Higher Feasible Demand, No New Technology* – **The same as Scenario III, but including NextGen operational improvements for airports, en route, and terminal.**

• *2025 With NextGen, Higher Feasible Demand, Significant New Technology* – **The same as Scenario IV, but with the addition of new engine/airframe technology at the N+1 level.**

• *2025 With NextGen, Higher Feasible Demand, Very Significant New Technology* - **The same as Scenario IV, but with the addition of new engine/airframe technology at the N+2 level.**

Operations and Airports Included in Environmental Metrics

- The 2006 baseline and 2025 scenarios (as modelled in ACES) served over 1500 airports and ranged from 95K flights to 135K flights in 2025. Total IFR and VFR flights were evenly split.

- Fuel per unit distance and payload-based fuel metrics were computed using nearly 90% of the IFR operations. Calculations for both metrics are based only on flights with PFE from 0.002 to 0.1 MJ/(kg*km).

- Higher fidelity noise for the top 34 "OEP" airports accounted for nearly 70% of the IFR operations.

- Using the Area Equivalency Method, noise-contour areas were computed for over 1200 airports accounting for ~95% of the total operations.

- Local Air Quality including HC, NOx, SOx, and CO computed for 294 of the LMI 310 airports and included almost 90% of the IFR operations.

Results: Fleet fuel efficiency (fuel/distance)
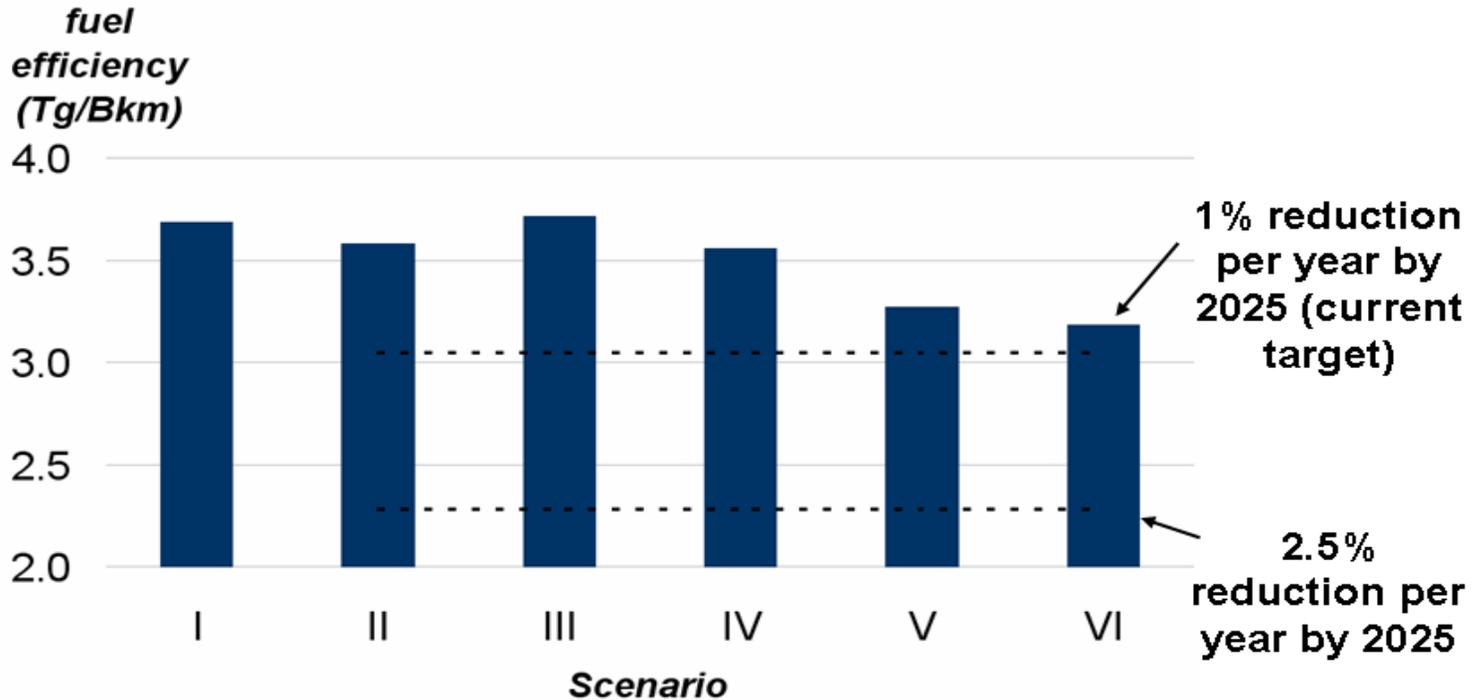
- The similarities between *2025 base most* and *2025 nextgen least* suggest that by implementing NextGen operational improvements (but not introducing new airframe/engine technologies) allows fuel efficiency to remain constant while supporting ~11% more flights.
- Evolving the fleet to either N+1 and N+2 projected technology levels beginning in 2016, does not reach the current goal of 1% reduction per year.

Results: Payload Fuel Efficiency (energy/(mass*GCdist))
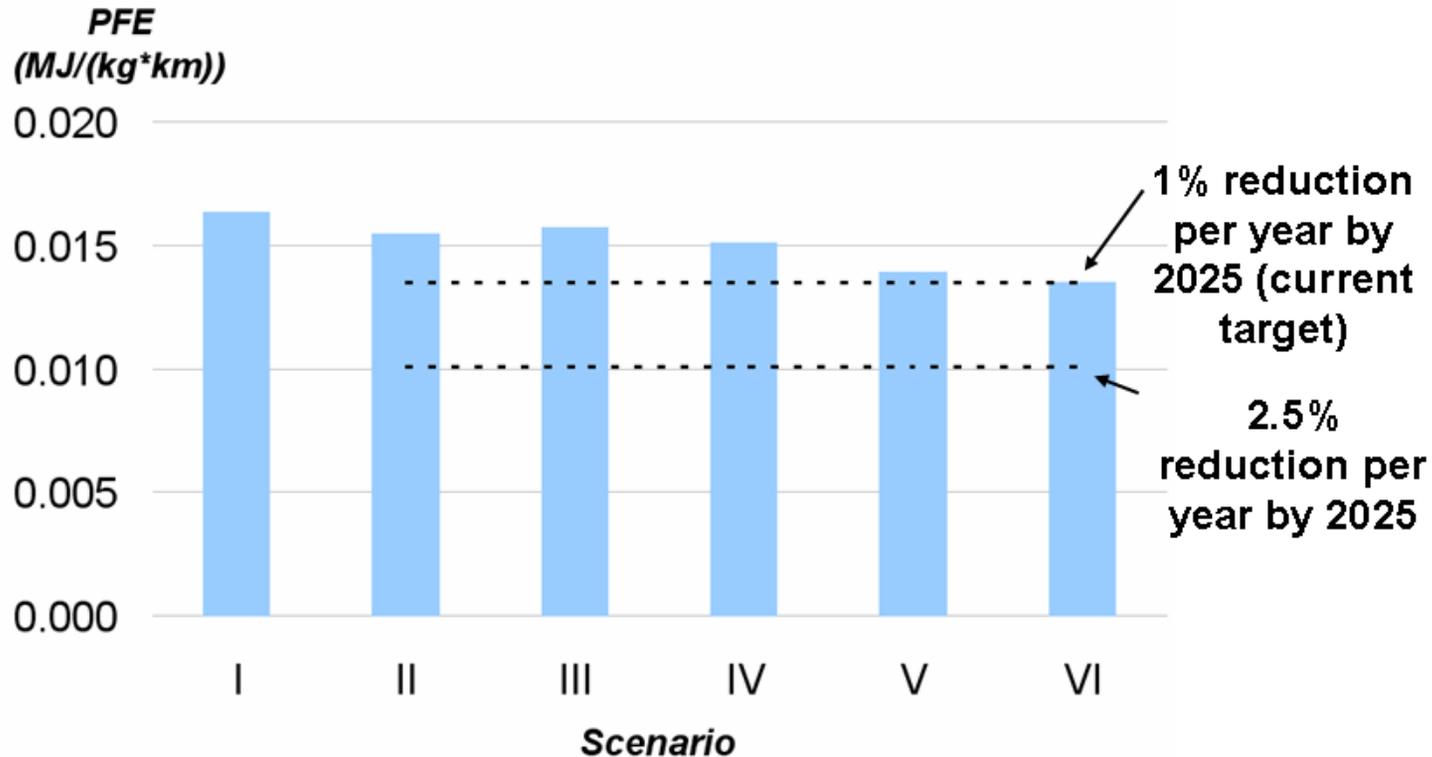
- Calculations are based only on flights with PFE from 0.002 to 0.1 MJ/(kg*km).

- By evolving the fleet to an N+2 projected technology level beginning in 2016, the current target of 1% reduction per year is reached.

Results: Population Exposed to Noise (65 dB DNL)
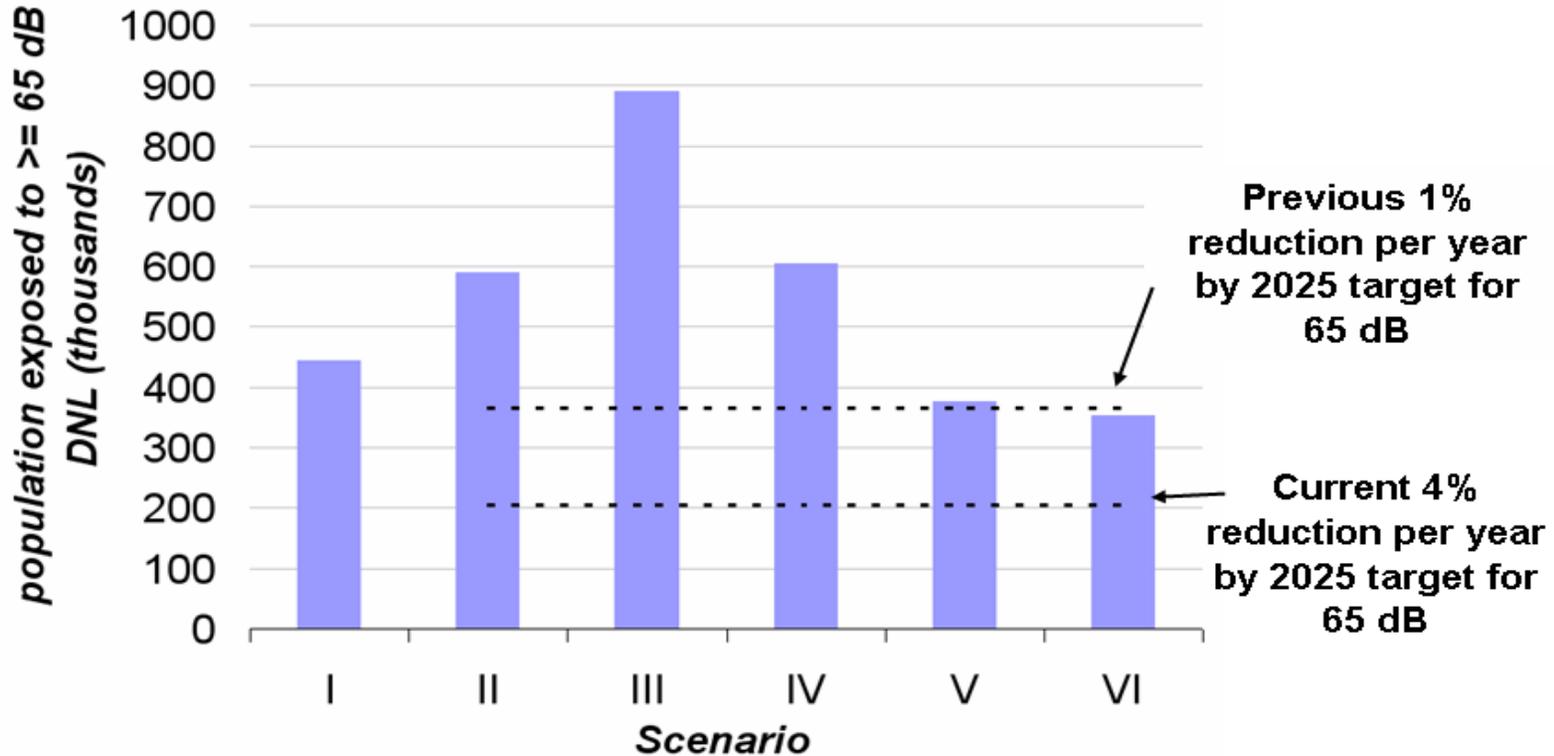
- **Similarities between scenarios II and IV suggest that by implementing NextGen operational improvements, principally RNP and CDA, (but not introducing new airframe/engine technologies) increases population exposed to significant noise by 2% while supporting ~11% more flights.**
- **By evolving the fleet to N+2 projected technology levels beginning in 2016, the previous goal of 1% reduction per year in population exposed to significant noise is reached, but the newer 4%/year goal is not.**

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* Population is held constant with the US 2000 Census

Changes in LAQ Emissions Inventories (below 3Kft)
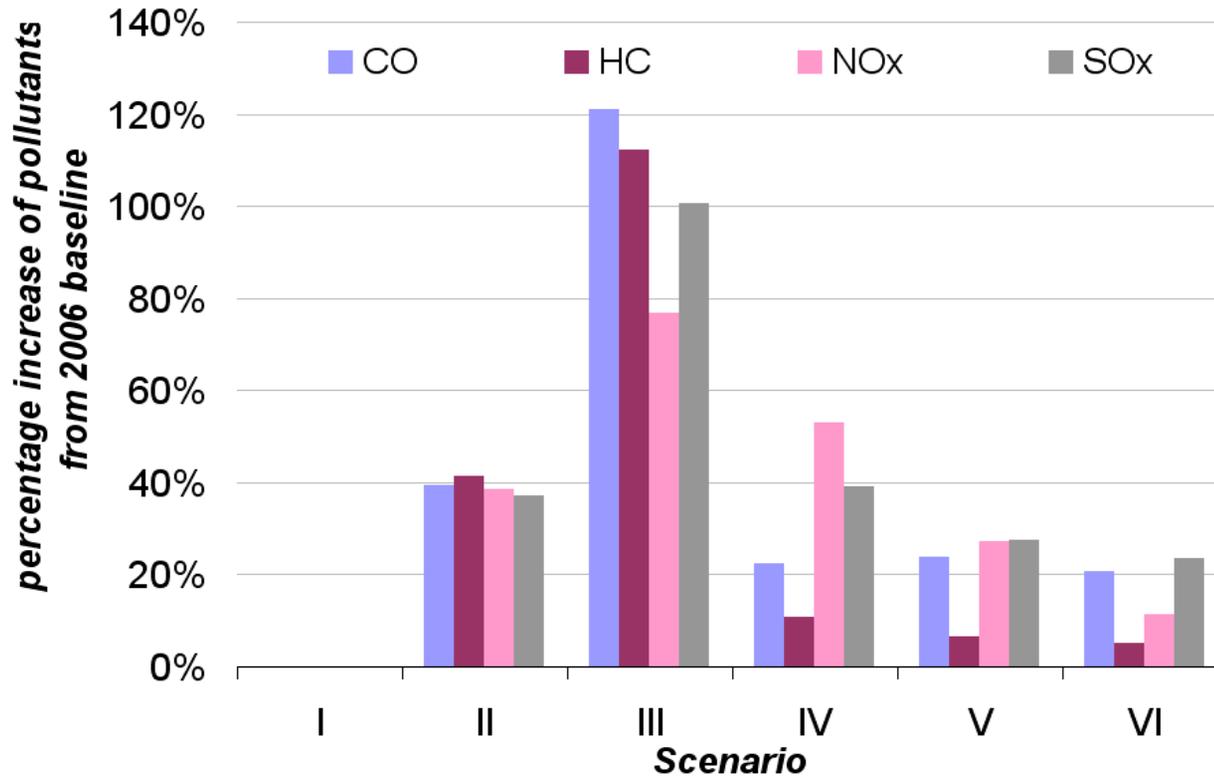
- **113 of the 294 LMI airports processed are in counties that are currently considered non-attainment areas and an additional 51 airports are in counties that are currently considered maintenance areas (based on U.S. NAAQS criteria.**
- **In scenario II, 70% of these 164 airports had increases in all pollutants while the *2025 nextgen n+2* has 54%.**

Net "Product" Compared to Fuel or CO2
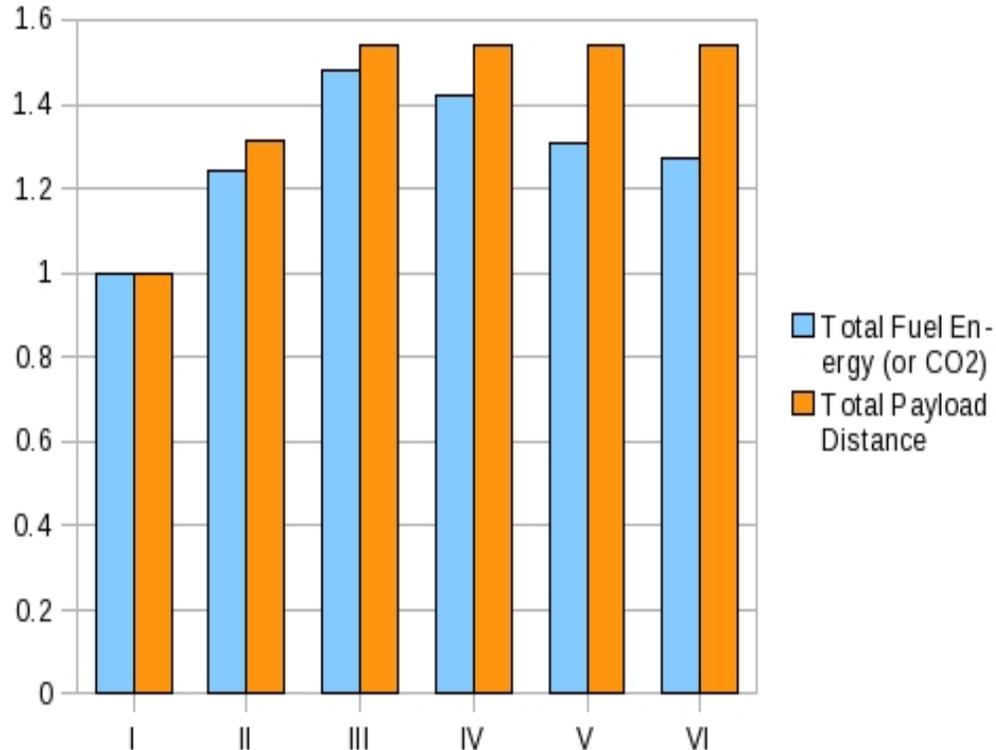
- **NextGen operational capabilities and fleet evolution (not including advanced technological improvements) enable attainment of approximately 50% more air-transport "product" (flown distance or payload distance) with about 40% more expenditure of fuel (compare Scenario IV to I).**

- **With the addition of advanced technologies, this can be attained with only about 30% more expenditure of fuel (compare Scenarios V and VI to I).**

Summary of 2008 Round of Analysis

- Major environmental metrics have been calculated on a US-wide basis for several 2025 scenarios and compared with a 2006 baseline.

- Environmental performance was compared to interim goals for fuel efficiency and noise.

- Noise and fuel-efficiency targets are not achieved in 2025 for scenarios without NextGen.

- NextGen operational improvements (without new engine/airframe technology) enable sustained environmental performance with additional flights, but none of the environmental targets are achieved.

- New engine/airframe technologies:
  - Enable improvement in overall system fuel efficiency and, for the PFE metric, the N+2 projections achieve the current goal of 1%/year improvement (relative to the base year).
  - Enable original noise goal (65 dB DNL) of 1%/year reduction to be achieved in 2025, but current goal of 4%/year reduction is not achieved.

Understanding Environmental Constraints in a Common Capacity-related Metric

- **Algorithmic process reduces the flight schedule in order to meet noise and fuel-efficiency targets (or other targets).**

- **Net environmental constraint is expressed as the sum of all flights removed to meet the goals.**

- **Intent is <u>only</u> to estimate the size of trimmed schedules that would meet the stated environmental goals, <u>not</u> to develop schedule-reduction strategies.**

PFE-based Trimming

Combined Fuel and Noise Trimming
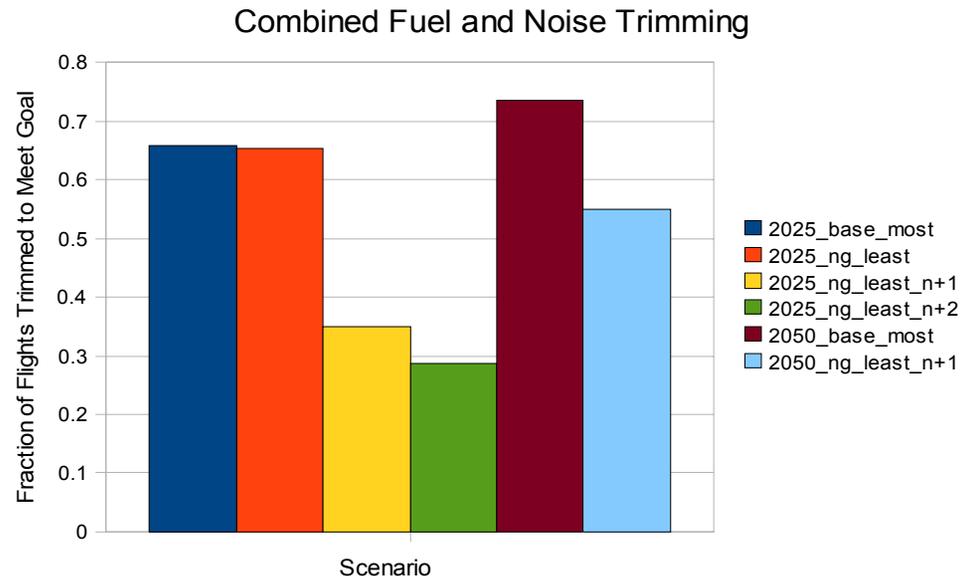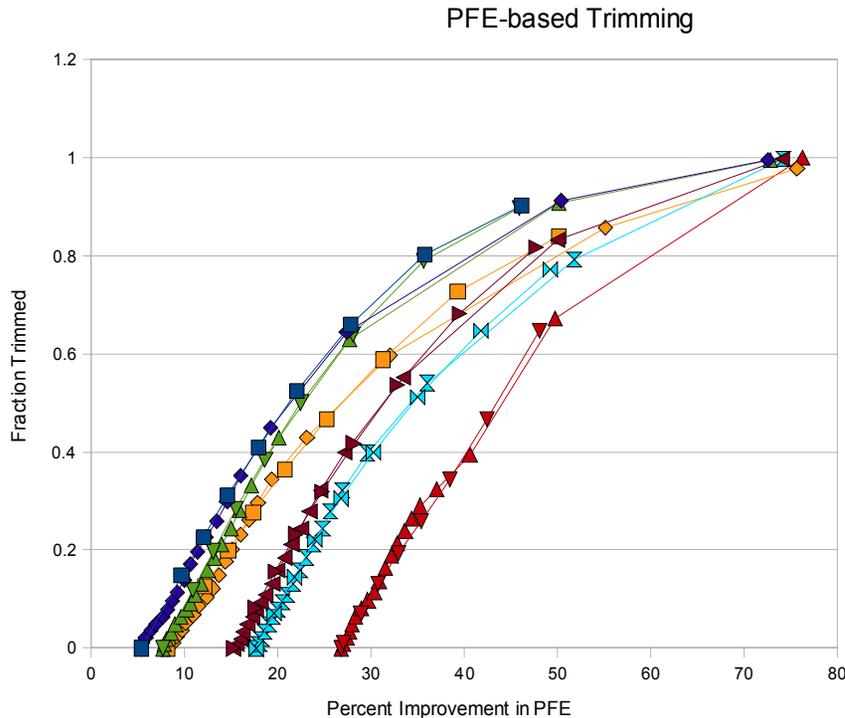
Next Steps

- **Expanded set of scenarios**

- **Refinement of fleet-insertion assumptions and analysis**

- **Sensitivity analyses**

- **Evolution of environmental goals?**

- **Additional new technologies: alternative fuels, ...**