Aircraft Technology Modeling and Assessment Projects

Presented to: REDAC E&E Subcommittee

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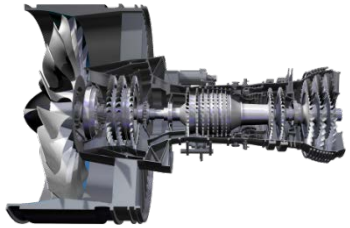
High Level Objectives

Assess the potential of aircraft technologies to meet our aviation environmental goals

- **Model aircraft technologies at a physics-based level**
- **Assess technology combinations**
- **Identify fleet-wide benefits**



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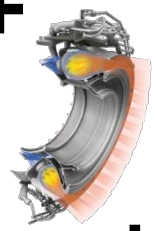

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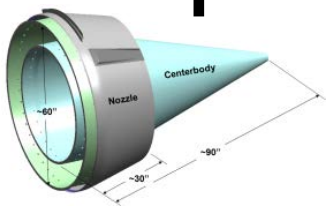


Regional Jet

Single-Aisle

Twin-Aisle

Large Twin-Aisle

Very Large Aircraft

Subsystem Technology Impacts → **Technology Effects on Vehicle** → **Fleet Level Implications**

Projects Supporting This Objective

✓ **PARTNER Project 36 – CLEEN I Tech Assessment**

- Effort with GT to model the CLEEN I technologies and assess their benefits
- Funded 2010-2014
- Completed vehicle and fleet level assessment of majority of the CLEEN I technologies.
- Public final report released February 2016.

✓ **PARTNER Project 43 – Analysis of Mission Specification Changes**

- Effort with GT, MIT, Stanford to assess fuel burn reductions resulting from changes in future aircraft design from mission specification changes
- Funded 2011-2013

Projects Supporting This Objective (Contd.)

ASCENT Project 10 – Broad Assessment of Scenarios

- Effort with GT, Purdue, and Stanford to examine a broad set of future aircraft technology scenarios and technology's ability to meet our goals for fuel burn, emissions, and noise from aviation
- Gather expert opinion on assumptions that drive demand, fleet evolution, and technology
- Funded August 2014 through May 2017
- Used as a vehicle to complete CLEEN I technology modeling and provide final update to assessment

ASCENT Project 37 – CLEEN II System Level Assessment

- Effort with GT to model the funded CLEEN II technologies and assess their benefits
- Initiated 8/2015

PARTNER 36 – CLEEN I Assessment

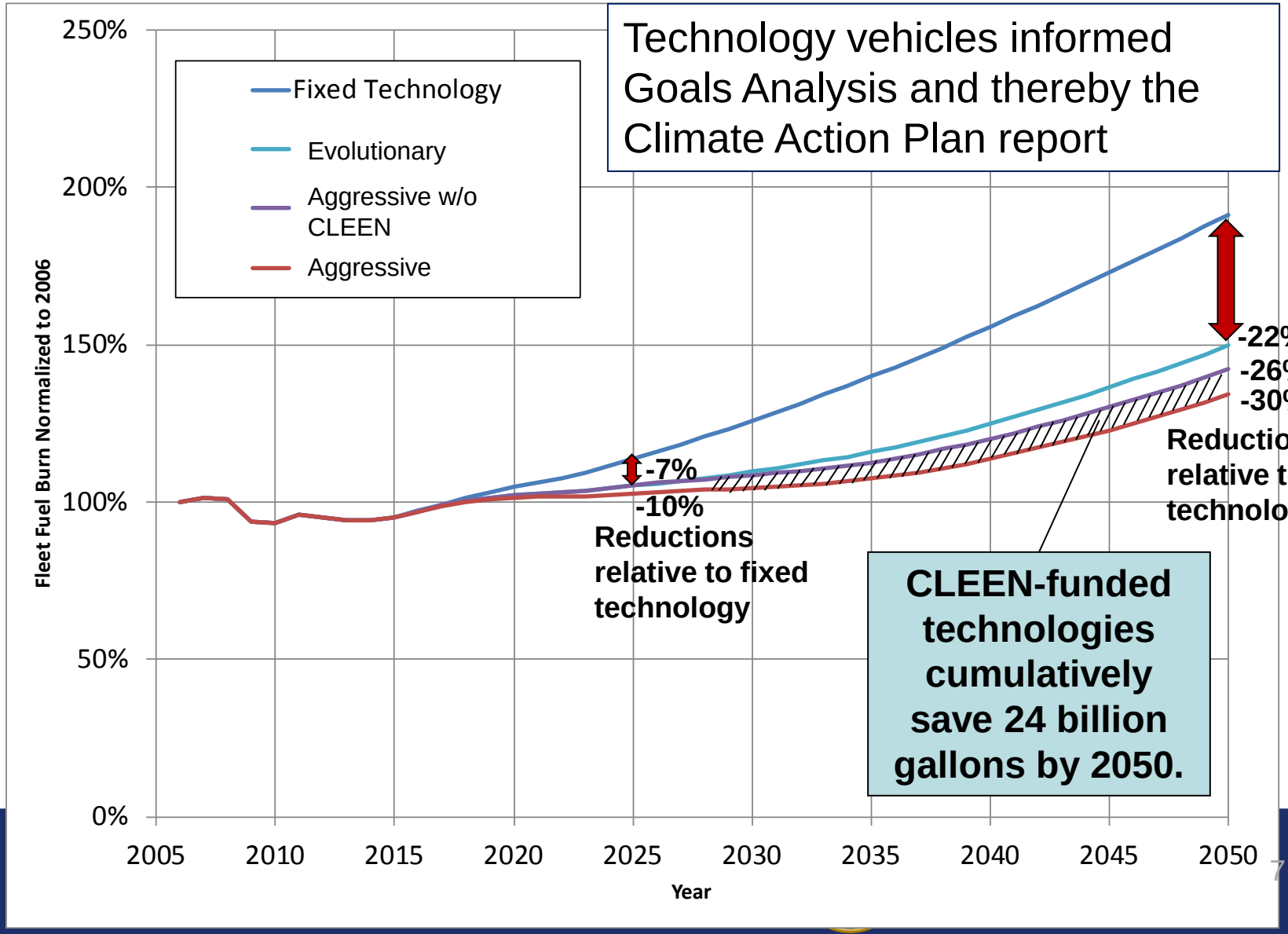
- Georgia Tech exchanged proprietary data with CLEEN companies to accurately represent their technologies at the subsystem and vehicle level
- Vehicle-level assessments of technologies as applied across size classes (kept limited rights)
- Fleet-level assessments of the CLEEN technologies benefits, as well as complementary likely N+1 and N+2 technologies
- Technology vehicles informed NextGen Goals Analysis and Climate Action Plan report
- Public final report released February 2016
- Final update to results conducted under ASCENT 10 – final CLEEN technologies captured and fleet-level noise assessment added – **SHOWN HERE**

Technology Scenario Definitions

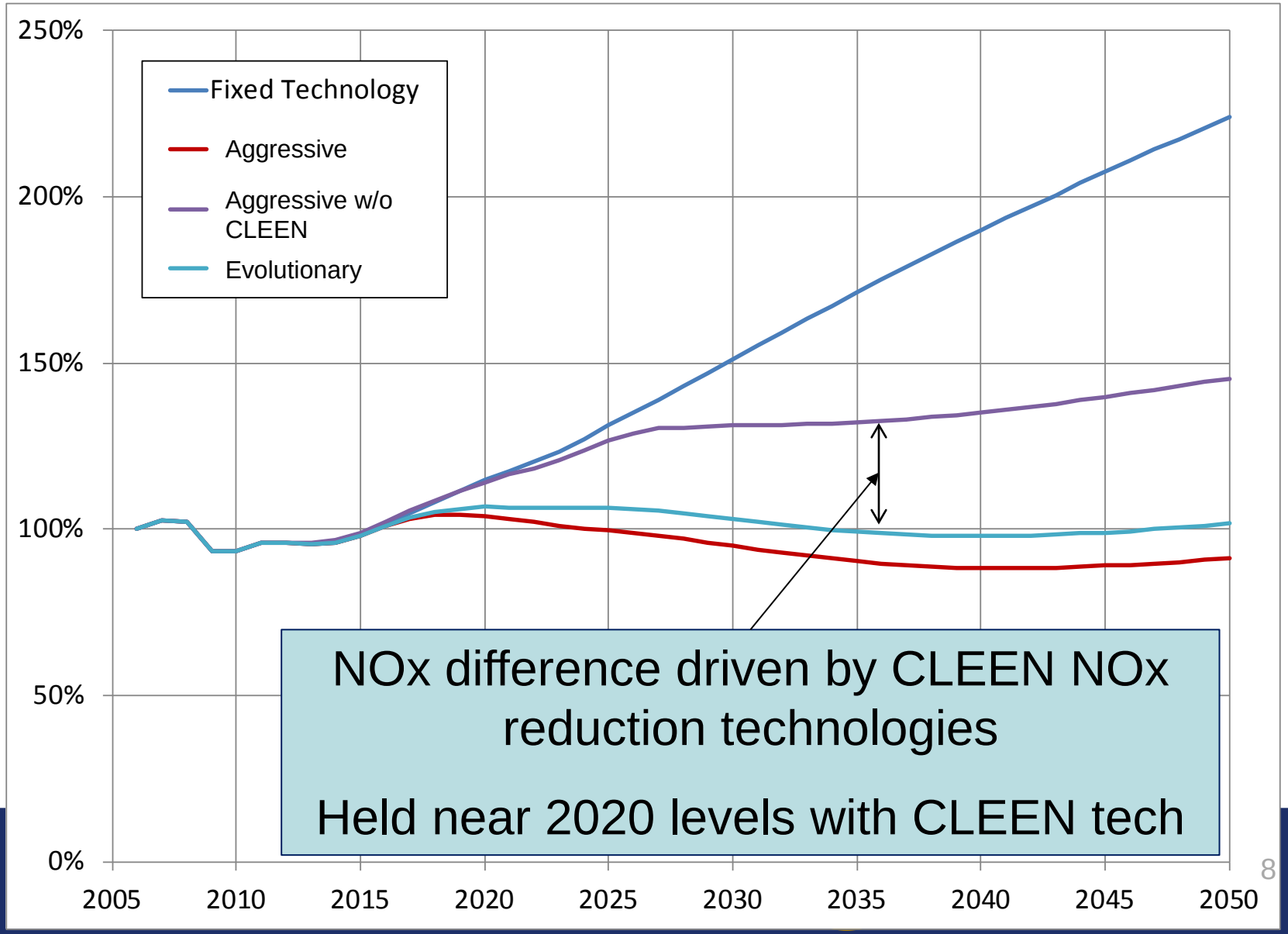
- Before defining specific technology packages FAA & GT jointly developed four scenarios
- Each scenario subdivided into N+1 and N+2 vehicles/technologies
- Vehicles phased into fleet using retirement and deployment schedule assumptions

Scenario	Description
Fixed Technology (Reference)	Continue to replace retired aircraft with best-in-class current in-production; use current in-production through 2050 for new aircraft
Evolutionary	'Normal' technology evolution Conservative inclusion of CLEEN technologies in N+1
Aggressive	Represents higher rate of technology development Includes all CLEEN Techs in N+1
Aggressive w/o CLEEN	Identical to aggressive with all CLEEN technologies removed – (Can be compared to Aggressive to identify CLEEN impact)

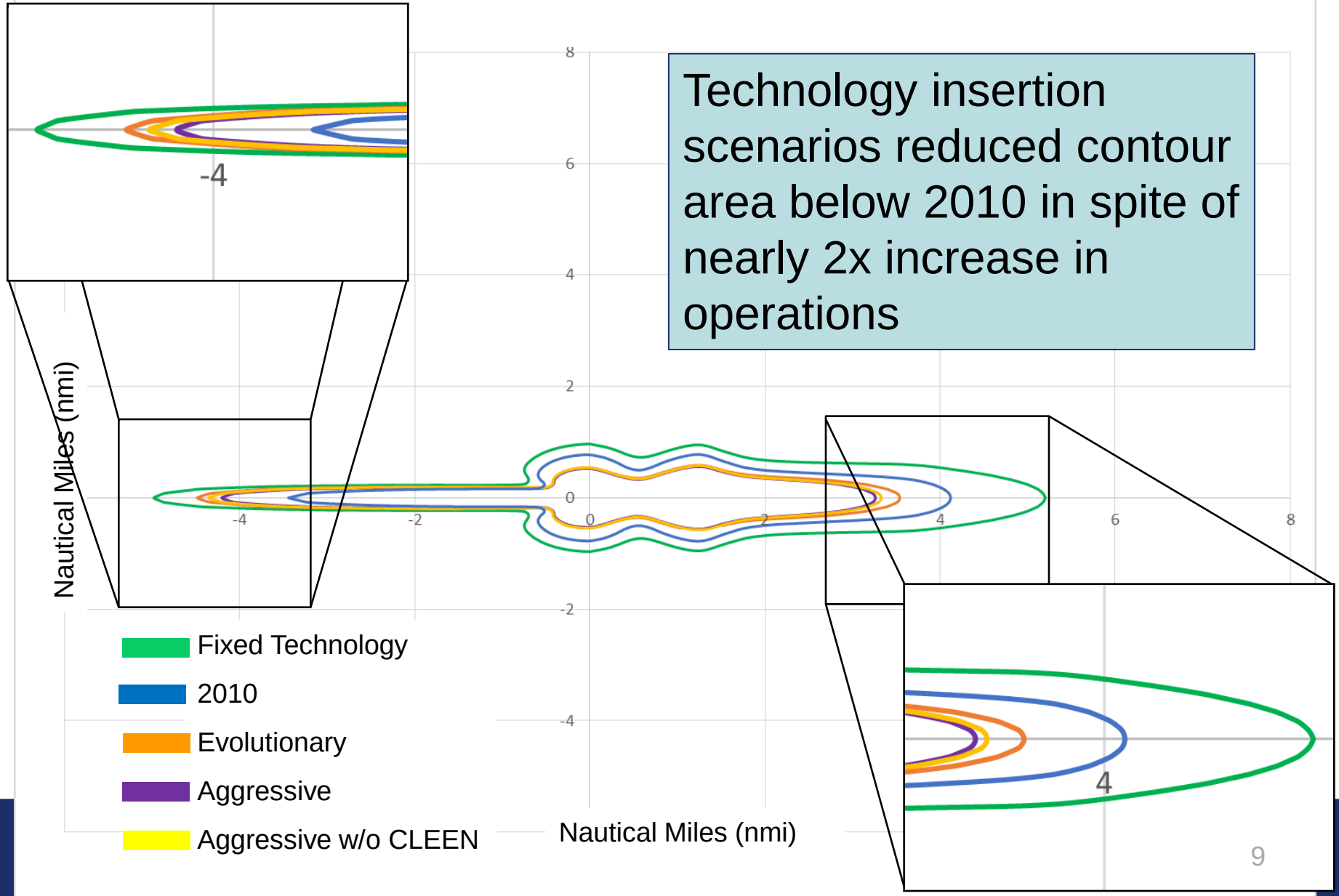
Fleet Fuel Burn Results



Fleet LTO NOx Results



Fleet Noise Results - 2050 65 DNL Contour



PARTNER 43 – Mission Specification Changes

Motivation: Potential exists for fuel burn reductions resulting from changes in future aircraft design with different mission specifications

Objectives: Evaluate the potential of this approach to reduce fuel burn and aviation's environmental impact

- Quantify the system-level impacts of mission specification changes in future aircraft including:
  - Range / Payload capabilities
  - Cruise speed / altitude
  - Wing span
- Understand impact on airline operations / economics
- System-level cost / benefit analyses
- Impact on infrastructure, NAS operations, and relationship with NextGen ConOps

PARTNER 43 Conclusions

- Reduced cruise Mach # has the potential to reduce fuel burn for all aircraft classes (5%-10%)
- Reduced design range has significant fuel burn reduction effect (5-10%+) in the longer range aircraft but it is not very effective in shorter range (RJ, SA) vehicles
- Span increases are ineffective for SA, LTA, VLA, and provide only modest improvements for STA and RJ. Significant improvements (>10%) from span increases require unconventional configurations.
- Combinations of Mach, range, and span can further increase benefits.

ASCENT 10 Overview

Objective: Define range of scenarios that bound the demand for future aviation activity and assess the effects of different fleet composition and aircraft technology on fuel burn, emissions, and noise from aviation

- Evaluate broad set of future scenarios out to 2050, showing potential benefits of technology on fuel burn, emissions, and noise
- Provide modeling and assessment mechanism for aircraft technology
- Support NextGen Goals Analysis, other analyses

Approach:

1. Develop a set of harmonized fleet assumptions for use in future fleet assessments;
   - Workshops/consensus building among academia, government, industry
2. Model advanced aircraft technologies and advanced vehicles expected to enter the fleet through 2050; while
   - Leveraging, heavily previous modeling work in CLEEN, NASA programs – and filling gaps as necessary for scenarios developed in (1)
3. Perform vehicle and fleet level assessments based on input from the FAA and the results of (1) and (2).

Studies are performed by each university team using in-house expertise and tools in complementary areas.

Workshop Approach

- ✓ **Fleet Workshop 1 – *May 14, 2015***
  - Goal: Determine what defines a world view or scenario
  - Feedback on descriptors (variables, ranges, and importance)
  - Bring forward initial worldviews for comment
- ✓ **Fleet Workshop 2 – *August 27, 2015***
  - Goal: Gather information to select specific worldviews/scenarios of interest
  - Feedback on technology insertion opportunities and their timing, aircraft life, production rates
  - Feedback on proposed worldviews and scenarios
- ✓ **Technology Workshop(s) 1 – *June 10-11, 2015***
  - Goal: Identify technology maturation and availability for a broad range of technology areas (e.g. wing design, engine core noise)
  - Feedback on examples of 1st/2nd/3rd generation technologies
  - Provide specific examples of technologies for feedback
- ✓ **Technology Workshop 2 – *February 16, 2016***
  - Goal: Consensus on technology evolution scenarios
  - Feedback on specific technology impacts and maturation rates

Participants thus far: The U.S. Air Force, Airports Council International – North America, Booz Allen Hamilton, Boeing, Department of Transportation Volpe Center, Embraer, FAA Office of Environment and Energy, FAA Office of Aviation Policy & Plans, General Electric, Georgia Tech, Honeywell, Lufthansa, Mitre, NASA, Pratt & Whitney, Purdue, Rolls-Royce, Stanford, Textron Aviation and Virginia Tech.

Accomplishments and Next Steps

- **Have used workshop feedback to generate key scenarios and their assumptions**
  - Obtained input on factors that drive demand, fleet evolution
  - Established technology assumptions in many individual technical domains
  - Mapped these areas together into cohesive future scenarios
- **Scenarios include:**
  - Current trends in demand and fleet evolution, with deltas provided by technology development
  - Environmental bounding scenarios – driving parameters at limits
  - High demand scenarios – delta effects of technologies
  - Low demand scenarios – delta effects of technologies
  - Noise limiting scenarios (hypothetical)
- **Will share scenarios and supporting assumptions publicly for leveraging in other government, industry, or academic analyses**
- **Beginning analysis of scenarios with our team's tools:**
  - Vehicles: EDS, SUAVE
  - Fleet: GREAT, FLEET
- **Planned to complete analysis and reporting by May 2017**

ASCENT 37 – CLEEN II Assessment

Following similar model to PARTNER 36:

- Exchange of proprietary data with CLEEN II companies to accurately represent their technologies at the subsystem and vehicle level
- Vehicle and fleet-level assessment of CLEEN II and other complementary technologies impacts to fuel burn, emissions, and noise
- Will leverage ASCENT 10 scenario development for demand, fleet evolution assumptions
- More involvement by FAA with in-house use of tools. Divide and conquer modeling with GT to cover 8 companies.

Progress:

- Georgia Tech has established necessary NDAs with companies for data exchange
- Conducted initial modeling discussions with each CLEEN II company, planning types of data to be exchanged, availability, timeline
- Results are being used to map out the next 4 years of effort

Summary

- Technology assessment efforts are well coordinated and linked
  - ASCENT 10's scenarios will inform CLEEN II assessment, Goals Analysis and Climate Action Plan
- Work is developing and improving analytical tools
- Analyses are advancing our understanding of how technologies reduce noise, fuel burn, emissions and their impacts
- Work is helping us understand the potential of aircraft technologies to meet our aviation environmental goals