Addressing Aircraft Noise in the United States: Part II Mitigation Solution Development

To: 22nd Workshop of the Aeroacoustics Specialists Committee of the CEAS

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Outline

- **Economics and Environmental Impacts of Aviation**
- **Addressing the Aircraft Noise Challenge**
- **Summary**

Economic Benefits of Aviation

5.1% of U.S. GDP

10.6 Million
U.S. jobs

$1.6 Trillion
in U.S. economic activity annually

$59.9 Billion
of U.S. Trade Balance (exports-imports)

SOURCE: FAA Air Traffic Organization

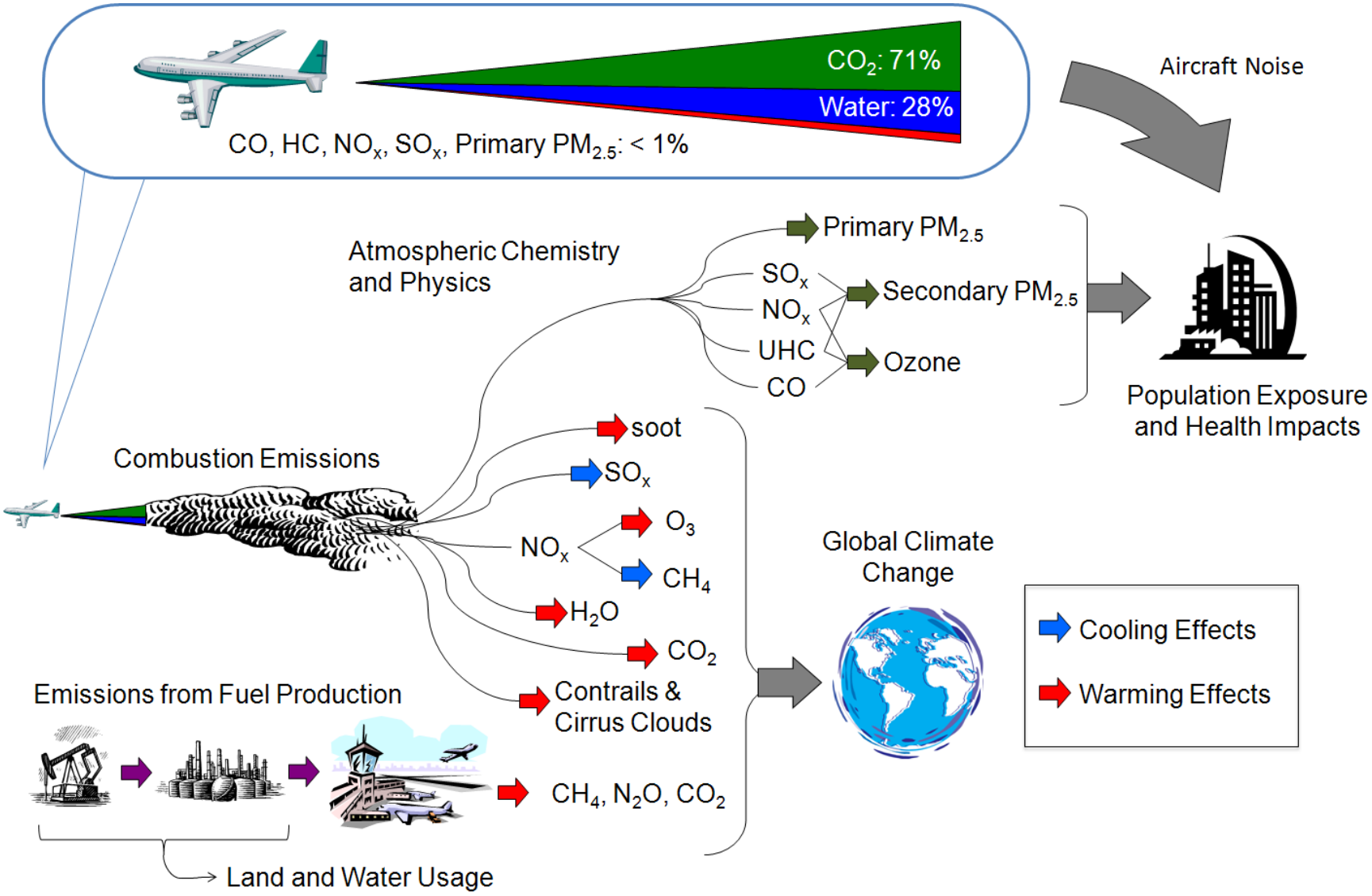
Aviation equipment (aircraft, spacecraft, and related equipment) is largest export sector in U.S. economy accounting for over 8% of total exports.

SOURCE: U.S. International Trade Commission

Benefits to Regional and Local Economies

- Aviation is a critical link for people, goods and services coming in and out of communities
- Access to aviation can be a vital reason that some companies use when choosing to locate offices, manufacturing and/or distribution facilities; and
- Passenger and cargo service can be crucial for community access and time-critical delivery services ranging from mail and packages to pharmaceuticals, biotech devices and computer components.

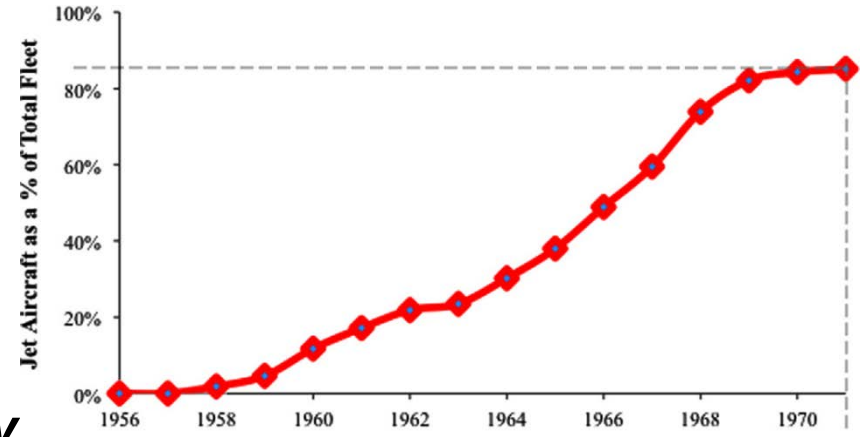
Environmental Impacts of Aviation



Addressing the Aircraft Noise Challenge

- **Understanding the Impact of Noise**
  - Noise impacts: annoyance, sleep, cardiovascular health and children's learning[1,2]
  - ***Improving modeling capabilities***
  - Evaluating current aircraft, helicopters, commercial supersonic aircraft, unmanned aerial systems, and commercial space vehicles
- **Outreach**
  - Increase public understanding
  - Community outreach
- **Mitigation**
  - Land use planning
  - ***Vehicle operations***
  - ***Airframe and engine technology***
  - ***Aircraft architecture***

Aircraft Technology Requires Time to Enter the Fleet



Diffusion of first generation jet aircraft into the airline fleet: 15 year diffusion dynamic[3] (Data source: ATA Annual Reports 1958–1980)

1. FICAN: Research Review of Selected Aviation Noise Issues https://fican1.files.wordpress.com/2018/04/fican_research_review_2018.pdf
2. ICAO CAEP Environmental Report: Aviation Noise Impacts: State of the Science: http://www.icao.int/environmental-protection/Pages/env2016.aspx
3. Hileman et al. 2013 http://dx.doi.org/10.1016/j.paerosci.2013.07.003/

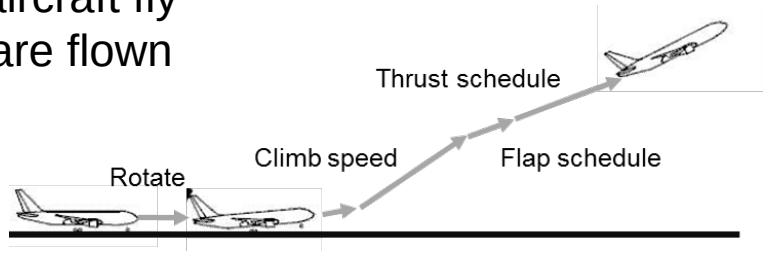
Aircraft Operations

Opportunities for noise reduction:

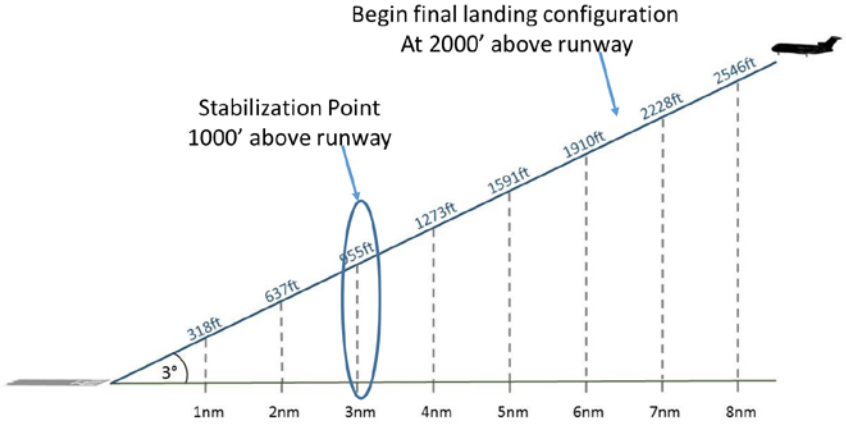
- In the U.S., Airlines determine *what* aircraft fly and *when*
- There might be opportunities to change *where* aircraft fly (through precision navigation) and *how* aircraft are flown

Concepts being evaluated:

- **Route changes**
- **Thrust / speed management**
  - Noise abatement procedures
  - Manage thrust and configuration to lower noise on takeoff and approach
- **Vertical profile**
  - Continuous climb operations
  - Continuous descent arrival
  - Modified approach angles
  - Staggered or displaced landing thresholds
- **Introduction of systematic dispersion**



Takeoff Profile



Approach Profile

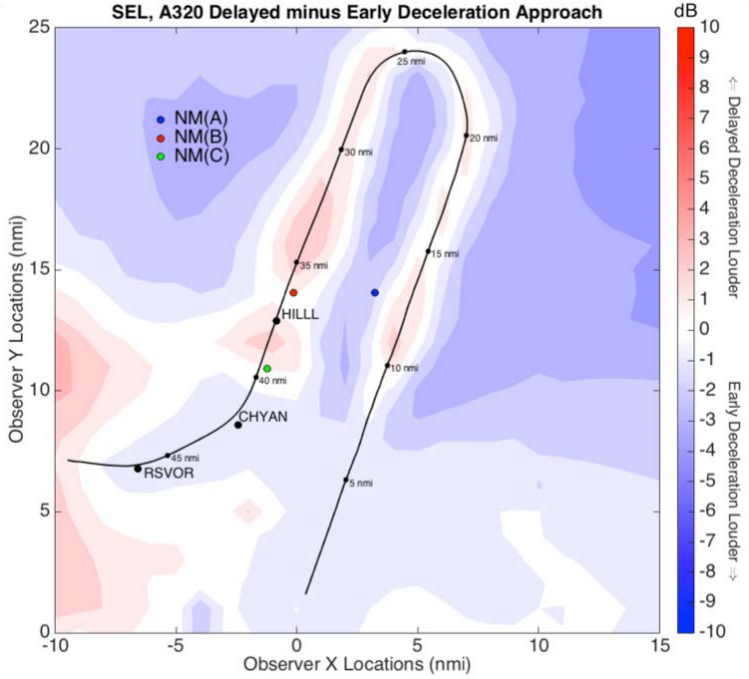
Modeling Operational Improvements

Enhanced air traffic evaluation framework

- Seeking better integration of noise into flight procedure design
- Current analytical approach focused on engine noise
- New framework also considers airframe noise
- Could enable analytical evaluation of procedure concepts at lower DNL
- Being developed by MIT through ASCENT Projects 23 and 44

Case study to test framework

- Using FAA-Massport MOU as a case study to test framework
- Developing and evaluating procedures with noise reduction potential



More Information:
ASCENT Project 23 website: https://ascent.aero/project/analytical-approach-for-quantifying-noise-from-advanced-operational-procedures/

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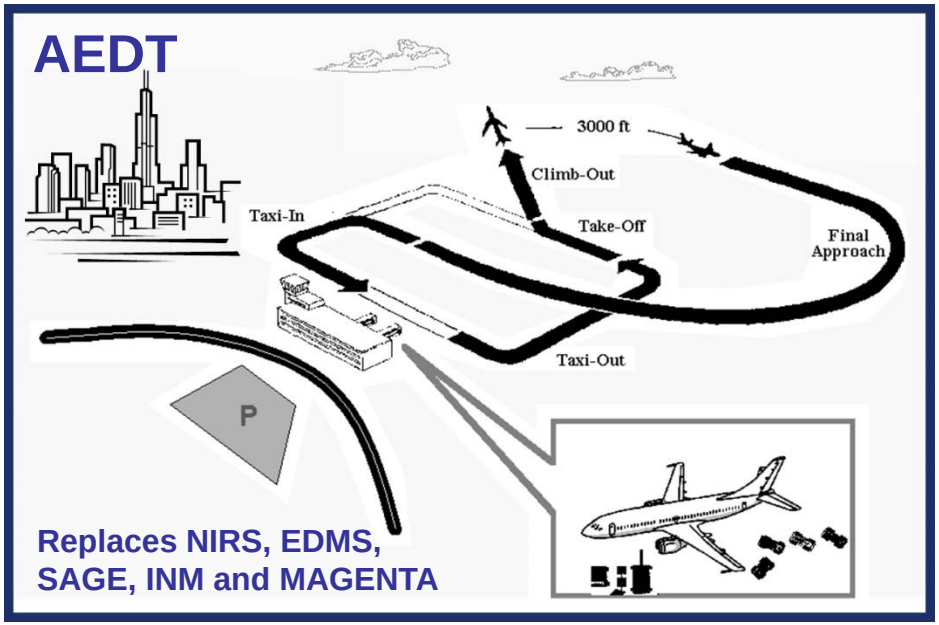
Modeling Noise

Aviation Environmental Design Tool (AEDT)

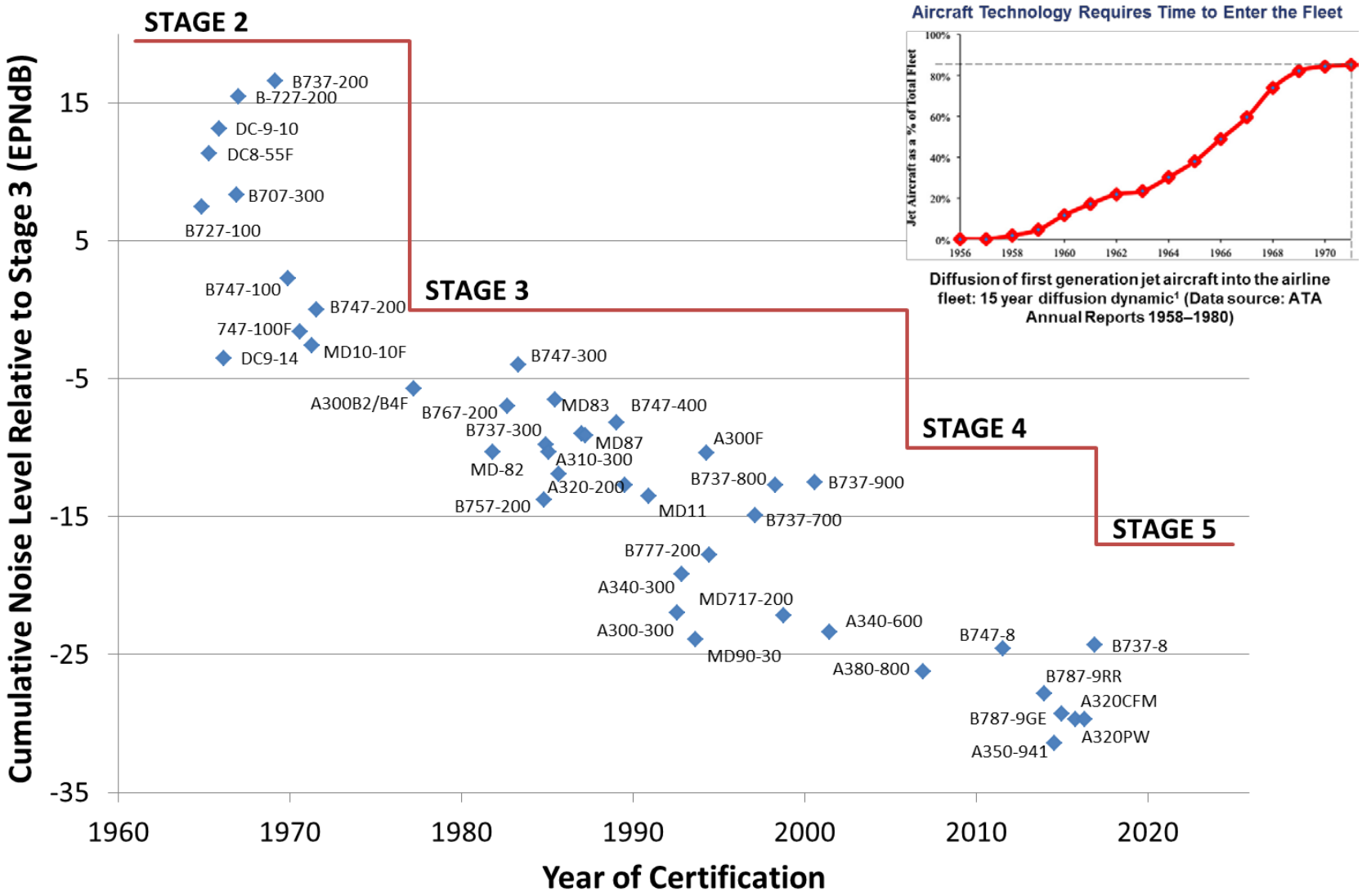
- Computes noise, fuel burn and emissions simultaneously
- Can analyze airport, regional, national, and global scales
- Required for all regulatory actions



AEDT Development Plan

- Current version of tool, AEDT2d
- Developing AEDT3a with planned release in 2018
  - Seeking to improve abilities at lower DNL
  - Improving takeoff weight and thrust modeling
  - Improving aircraft performance module
- Laying ground work to incorporate airframe noise more explicitly in AEDT4 with a post 2020 release

Commercial Aircraft Noise Evolution



Diffusion of first generation jet aircraft into the airline fleet: 15 year diffusion dynamic[1] (Data source: ATA Annual Reports 1958–1980)

Noise Reduction through Technology

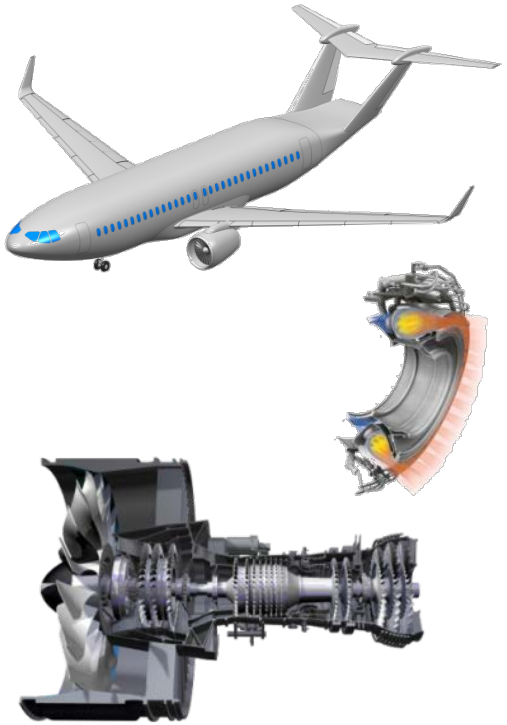
- Noise improvements have come with fuel efficiency gains
- Increased engine bypass ratio

- Simplified high lift systems

Continuous Lower Energy, Emissions & Noise (CLEEN)

- FAA led public-private partnership with 50-50 cost share from industry
- Reducing fuel burn, emissions and noise via aircraft and engine technologies and alternative jet fuels
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies

	Phase I	Phase II
Time Frame	2010-2015	2016-2020
FAA Budget	~$125M	~$100M
Noise Reduction Goal	25 dB cumulative noise reduction cumulative to Stage 5	
NO_X Emissions Reduction Goal	60% landing/take-off NO_X emissions	75% landing/take-off NO_X emissions
Fuel Burn Goal	33% reduction	40% reduction
Planned Entry into Service	2018	2026



CLEEN Details

Awardees:

- **Aurora Flight Sciences (Phase II only)**
- **Boeing**
- **Delta Tech Ops, America's Phenix, MDS Coating Technologies (Phase II only)**
- **General Electric (GE) Aviation**
- **Honeywell Aerospace**
- **Pratt & Whitney**
- **Rohr, Inc. / UTC Aerospace Systems (Phase II only)**
- **Rolls-Royce**

Phase I Technologies:

- **9 Technologies focused on**
  - Revolutionary Engine Design
  - Engine redesign
  - Wing technologies
  - Flight Management System Improvements
  - Improved Combustors

Phase II Technologies:

- **14 Technologies focused on**
  - Fuselage redesign
  - Engine redesign
  - Wing technology
  - Flight Management System improvements
  - Improved combustion

CLEEN Technology and Benefits:

Demonstrated technologies that reduce noise, emissions and fuel burn

Boeing

Adaptive Trailing Edge
~ 2% fuel burn reduction
~ 1.7 EPNdB cum reduction to Stage 4 in some single and twin aisles

Adaptive Trailing Edge

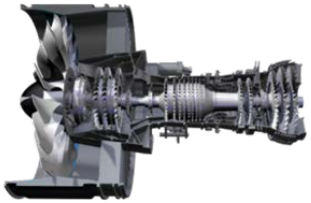
Ceramic Matrix Composite (CMC) Acoustic Nozzle
~ 1% fuel burn reduction
~2.3 EPNdB cumulative noise reduction to Stage 4

Ceramic Matrix Composite Nozzle

Pratt & Whitney

Geared Turbofan Technologies
CLEEN techs expand design space for engine with ~ 20% fuel burn reduction,
> 20 EPNdB cumulative noise reduction to Stage 4

Ultra-high Bypass Ratio Geared Turbofan



CLEEN Technology and Benefits:

Demonstrated technologies that reduce noise, emissions and fuel burn

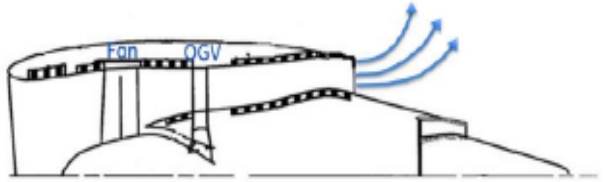
General Electric

Open Rotor
~26% reduction in fuel burn (re: 737-800)
~15-17EPNdB cumulative noise reduction to Stage 4

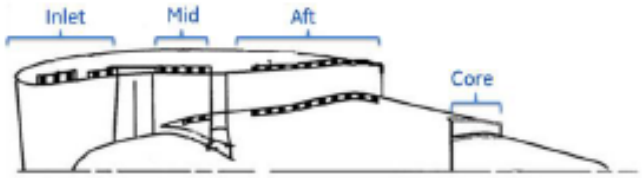
Novel Acoustic Liner Technology
~ 2 EPNdB cumulative noise reduction to Stage 4

Fan Noise Source Strength Reduction
~1 ENLdB cumulative noise reduction to Stage 4

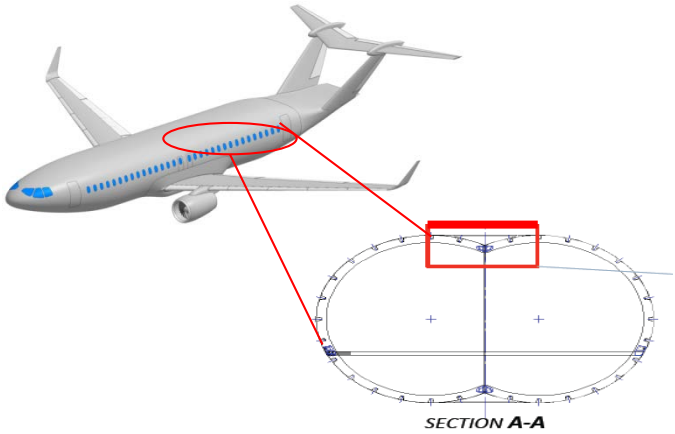
Fan Source Strength Reduction



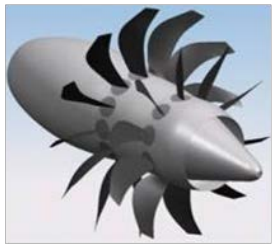
Novel Acoustic Liners



D8 Aircraft Fuselage



Open Rotor Engine



Aurora

D8 aircraft fuselage

~29% fuel burn reduction

~16 EPNdB cum noise margin to Stage 4

Assessment of CLEEN Technologies

- **Georgia Tech**
  - Modeled most, but not all, Phase I and II CLEEN Technologies
  - Evaluating impact on fuel burn and noise out to 2050
  - Evaluation of Phase I captured in two technical reports


PARTNER

Partnership for Air Transportation Noise and Emissions Reduction
An FAA/NASA/Transport Canada-sponsored Center of Excellence

Environmental Design Space Assessment of Continuous Lower Energy Emissions and Noise (CLEEN) Technologies

PARTNER Project 36 Final Report

prepared by
Dimitri Mavris, Jimmy C. Tai, Christopher Perullo

March 2016

- **22 billion gallons of cumulative jet fuel saved**
  - **1.7 million cars off road between 2025 and 2050**
- **Contribute to a 14% <u>decrease</u> in the land area exposed to DNL 65 dB and greater**

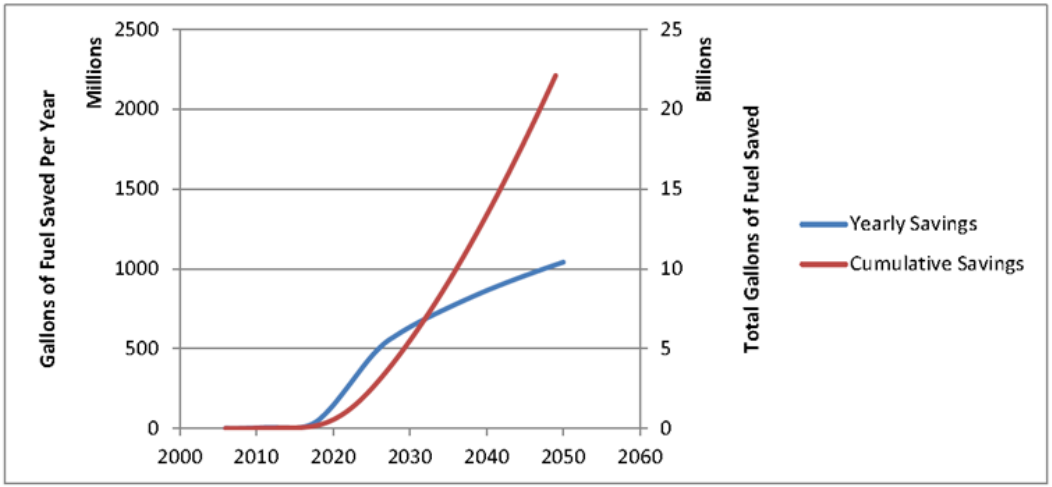


FIGURE 40: POTENTIAL FUEL BURN SAVINGS PROVIDED BY CLEEN TECHNOLOGIES MODELED IN THIS STUDY

https://ascent.aero/documents/2018/07/ascent-010-2015-annual-report.pdf/

http://partner.mit.edu/sites/partner.mit.edu/files/PARTNER-Project-36-final-report.pdf

Aircraft Evolution – 1947 to Today

- Every large jet aircraft today is a descendant of the Boeing B-47[1]

- Need a change in aircraft configuration to “solve” the aircraft noise challenge

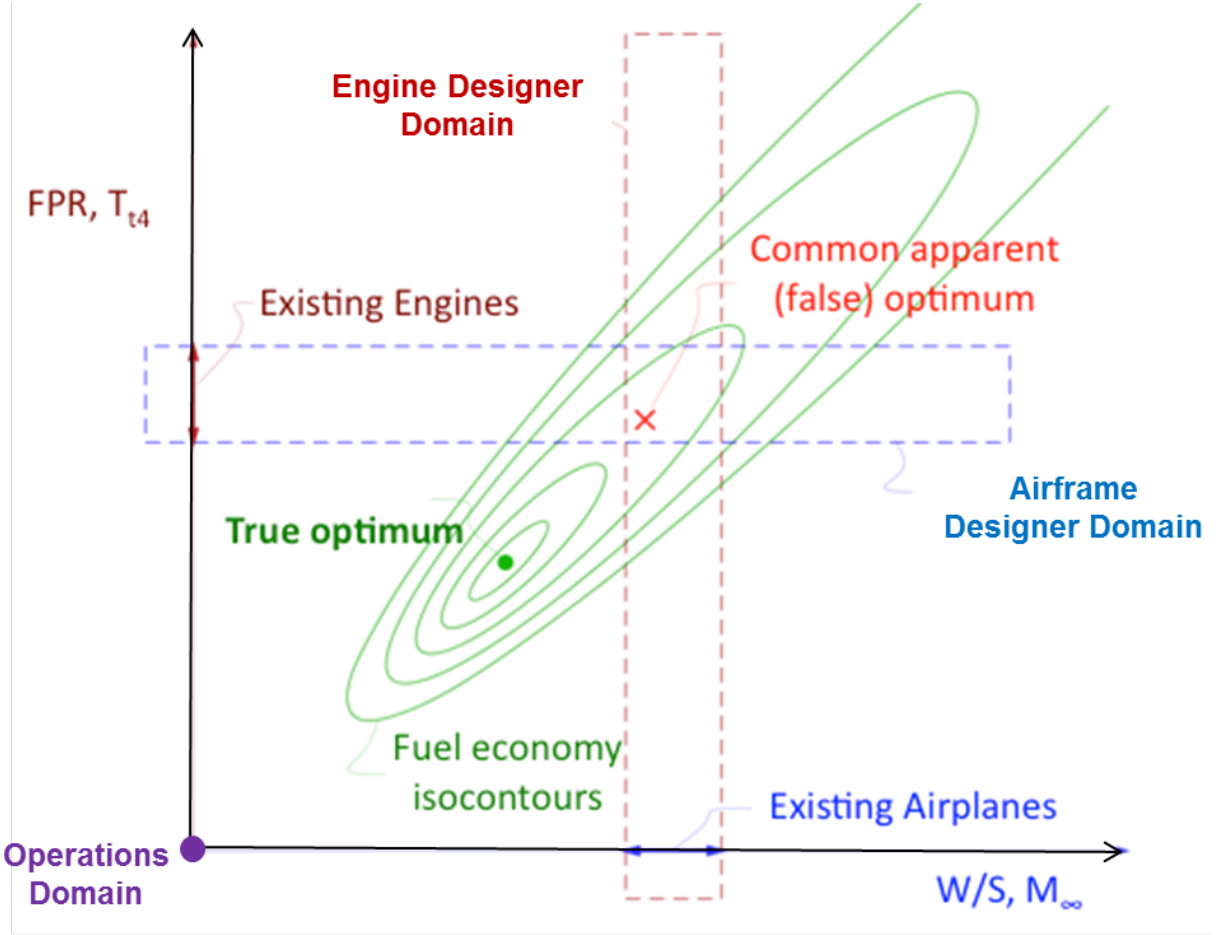
The Jet as Art by Jeffrey Milstein[2]

Source:
1. http://www.boeing.com/history/products/b-47-stratojet.page
2. http://www.jeffreymilstein.com/index/aircraft.html#grid

Integrated Design Solutions

A step change in noise reduction will only be achieved if it is accompanied by a step change in fuel burn while ensuring safe operation

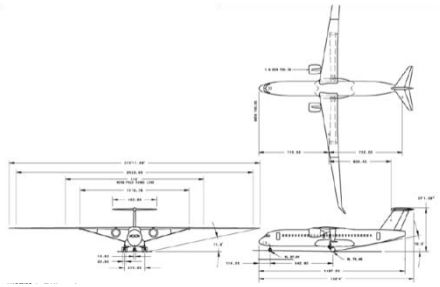
Need globally-optimized airframe / engine / operations to get a step change in environmental performance relative to today

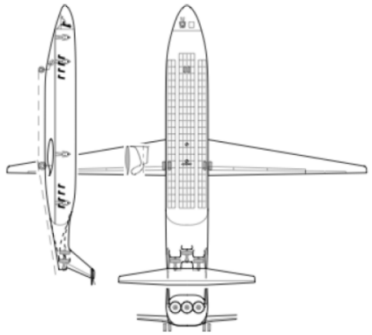


Graphic courtesy of Mark Drela, MIT

A Step-Change in Environmental Performance

- A step change in noise reduction will only be achieved if it is accompanied by a step change in fuel burn while ensuring safe operation
- Need to integrate engine, airframe and operations
  - Change configuration to allow larger bypass ratio engines
  - Shield engine noise with lifting fuselage
  - Flush mount engines to allow for boundary layer ingestion
  - Reduce cruise Mach with unswept wings
- Multiple Programs:
  - CMI Silent Aircraft Initiative
  - NASA Environmentally Responsible Aviation and N+3 Projects
  - NASA New Aviation Horizons Initiative





Flight demonstrations are needed to mature new concepts. This is critical to solving the noise challenge facing aviation.

More Information:
- NASA ERA: http://www.aeronautics.nasa.gov/isrp/era/index.htm
- NASA SFW Project: http://www.aeronautics.nasa.gov/fap/sfw_project.html
- CMI SAI: http://silentaircraft.org/

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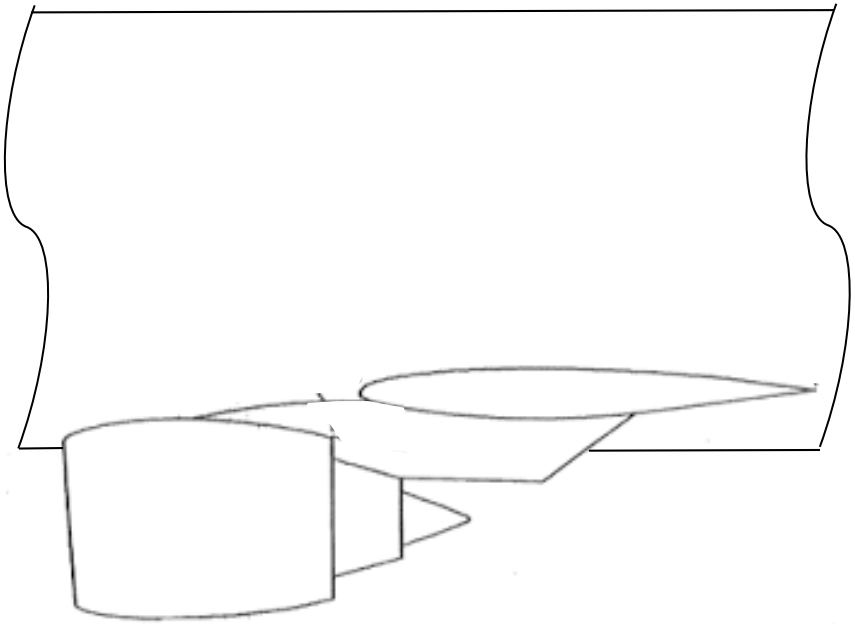
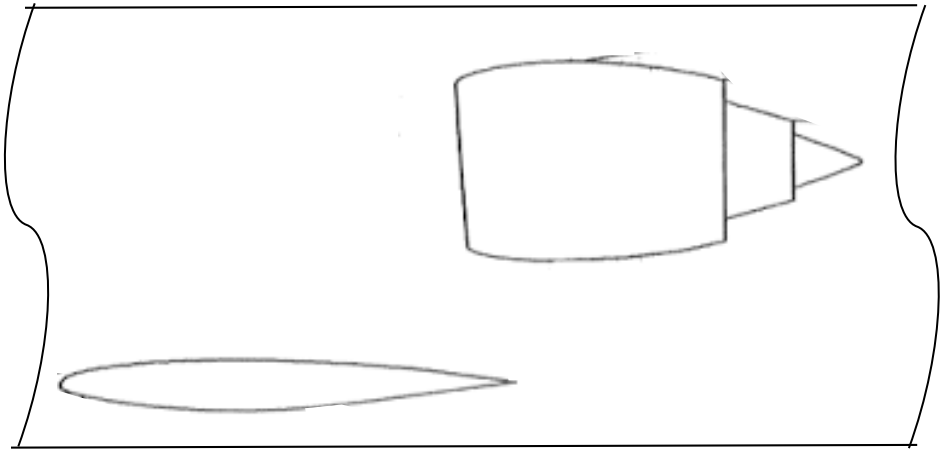
A Thought for Consideration

Use wing for shielding on tube-wing aircraft





Changing engine location could:

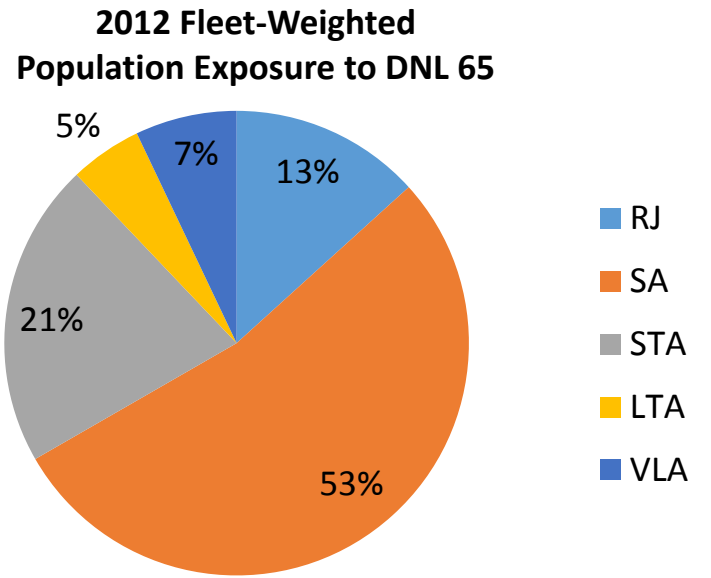
- **Provides forward fan noise shielding and enable larger diameter engines with lower fan pressure ratio thus lower aft engine noise**
- **Potentially assist aerodynamic performance**
- **Increase maintenance costs, increase cabin noise, and block passenger line of sight**

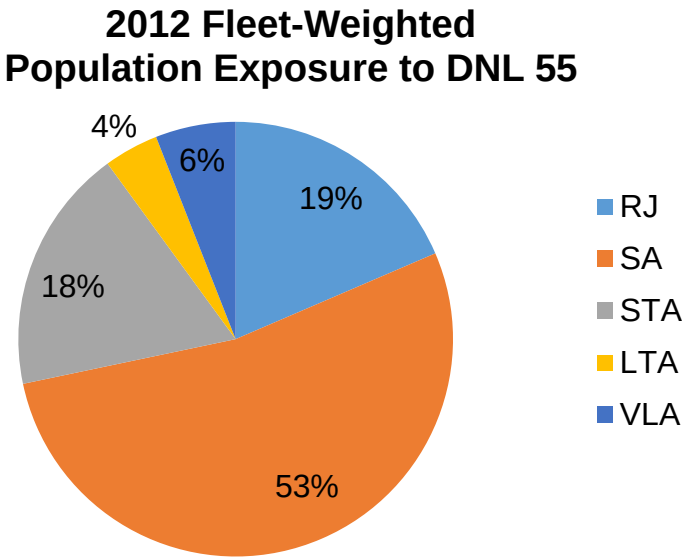
U.S. Noise Exposure by Aircraft Class

- Combined noise energy with population exposure to generate distribution of system-wide population exposure with respect to aircraft class
- Low noise single aisle aircraft could provide a substantial reduction in population exposure to noise

Example calculation for Regional Jet (RJ):

$$FWPE_{RJ} = \sum_{i}^{airports} PopExposed_i * \frac{NoiseEnergy_{RJ,i}}{NoiseEnergy_{Tot,i}}$$





Data Source: FAA Office of Environment and Energy

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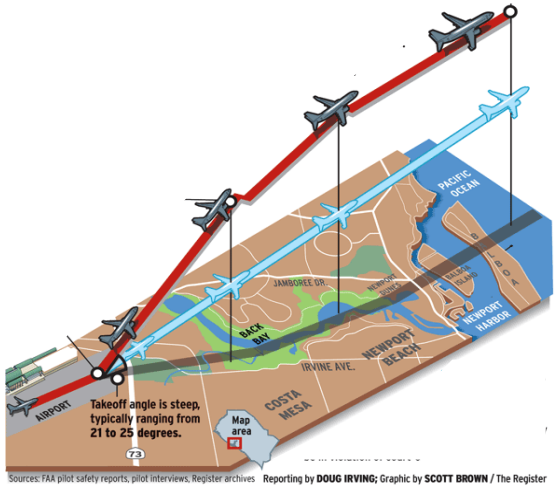
Closing Observations

- Despite considerable reductions, noise remains a constraint on aviation growth
- Utilizing a comprehensive approach to address aircraft noise challenge
- Research program is being executed to better understand noise impacts
- Examining potential means to reduce noise from the current fleet through operational procedure concepts
- Technology advancements are needed to achieve aircraft noise reduction
- A step change in environmental performance is needed – magnitude of challenge is well suited to a public-private partnership



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