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

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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)

**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

- **CO\textsubscript{2}:** 71%
- **Water:** 28%
- CO, HC, NO\textsubscript{x}, SO\textsubscript{x}, Primary PM\textsubscript{2.5}: < 1%

Aircraft Noise

Population Exposure and Health Impacts

Atmospheric Chemistry and Physics

- Primary PM\textsubscript{2.5}
- Secondary PM\textsubscript{2.5}
- SO\textsubscript{x}
- NO\textsubscript{x}
- UHC
- Ozone

Combustion Emissions

- Soot
- SO\textsubscript{x}
- NO\textsubscript{x}
- CH\textsubscript{4}
- H\textsubscript{2}O
- CO\textsubscript{2}

Global Climate Change

- Cooling Effects
- Warming Effects

Emissions from Fuel Production

Contrails & Cirrus Clouds

Land and Water Usage

- CH\textsubscript{4}, N\textsubscript{2}O, CO\textsubscript{2}
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*

1. FICAN: Research Review of Selected Aviation Noise Issues
2. ICAO CAEP Environmental Report: Aviation Noise Impacts: State of the Science:
http://www.icao.int/environmental-protection/Pages/env2016.aspx

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

For more information on AEDT or to download it, please visit: https://aedt.faa.gov/
Commercial Aircraft Noise Evolution

![Diagram showing the evolution of commercial aircraft noise levels from 1960 to 2020, categorized into stages (1-5). The x-axis represents the year of certification, and the y-axis represents the cumulative noise level relative to Stage 3 (EPNdB). Each stage is marked with specific aircraft models and years.]

- **Stage 2**: B737-200, B727-200, DC-9-10, DC8-55F, B707-300, B727-100.
- **Stage 3**: B747-200, B747-200, 747-100F, MD10-10F, DC9-14.
- **Stage 4**: A300B2/B4F, B767-200, B777-300, MD83, B747-400, MD87, A310-300, A320-200, B737-300, B737-800, MD11, B737-900, B737-700.
- **Stage 5**: B777-200, A340-300, MD717-200, A340-600, MD90-30, B747-8, B737-8, B787-9RR, A320CFM, B787-9GE, A350-941, A320PW.
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

<table>
<thead>
<tr>
<th></th>
<th>Phase I</th>
<th>Phase II</th>
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<tbody>
<tr>
<td>Time Frame</td>
<td>2010-2015</td>
<td>2016-2020</td>
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<tr>
<td>FAA Budget</td>
<td>~$125M</td>
<td>~$100M</td>
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<tr>
<td>Noise Reduction Goal</td>
<td>25 dB cumulative noise reduction cumulative to Stage 5</td>
<td></td>
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<tr>
<td>NOX Emissions Reduction Goal</td>
<td>60% landing/take-off NOX emissions</td>
<td>75% landing/take-off NOX emissions</td>
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<tr>
<td>Fuel Burn Goal</td>
<td>33% reduction</td>
<td>40% reduction</td>
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<tr>
<td>Planned Entry into Service</td>
<td>2018</td>
<td>2026</td>
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For more information: http://www.faa.gov/go/cleen
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

For more information: http://www.faa.gov/go/cleen
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

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

**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

For more information: http://www.faa.gov/go/cleen
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

**Aurora**

**D8 aircraft fuselage**
- ~29% fuel burn reduction
- ~16 EPNdB cum noise margin to Stage 4

For more information: http://www.faa.gov/go/cleen
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

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

Source:
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/
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):

\[ FWPE_{RJ} = \sum_{i} PopExposed_i \times \frac{NoiseEnergy_{RJ,i}}{NoiseEnergy_{Tot,i}} \]

Data Source: FAA Office of Environment and Energy
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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