Noise Reduction Technology Implementation for a Quieter Subsonic Transport System

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Outline

• Historical Progress of Aircraft Noise
  o Current Status of the Air Transportation System Regarding Aviation Noise

• Pathways for Noise Reduction Implementation
  o Insights into the Challenges

• NASA AATT Acoustics Research Overview
  o Technologies
  o Future Aircraft Configurations
  o Prospects for Electrification Impact

• Summary
Noise reduction has been accomplished primarily as a result of aircraft design trends.

Trend of ~ 6 dB cumulative per decade.

Figure reproduced from James Hileman, “Addressing Aircraft Noise in the United States: Part II Mitigation Solution Development,” September 6, 2018 to the 22nd Workshop of the Aeroacoustics Specialists Committee of the CEAS.
Observations on Noise Certification Levels

**Researcher viewpoint:**
- Future levels established largely by the design trend and the availability of ready technology
- Largely a lagging level rather than a leading or goal level

**Over time:**
- 260% increase in US passenger enplanements from 1975 to 2015
- SeaTac alone saw +38% in daily operations from 2013 to 2018
- US enplanements forecast to grow 2-4% annually out to 2039 (FAA Aerospace Forecast Fiscal Years 2019-2039)
- Human perceptions adjust to new levels
Impact of Growth and Aviation Noise – Current State

- Tension between benefits of growth and negative noise impacts
- Major hurdles to new airport construction or expansion
- Airports work with limited options to mitigate noise
Impact of Precision Navigation

- RNAV (Area Navigation) Departures – September 2005
- North Texas Metroplex – September 2014

From Sandy Lancaster, “Aviation Noise Management and Innovation An Airport Perspective,” presentation to the NASA Acoustics Technical Working Group, April 10, 2018

Precision navigation has **only increased** community noise concerns
Recent Airport and Community News

In Medford, noise complaints are going through the roof.
By John Laidler, Globe Correspondent. September 6, 2019, 11:00 PM

Airline faces criminal charges for violating Long Beach noise ordinance.
The city prosecutor's office filed charges against Mesa Airlines.

‘The noise is unbelievable’: St. Louis airport noise triple since 2017.

Colorado’s aviation industry opposes noise bill
Michael Karluk, Colorado Politics
Jan 7, 2020

LAX Announces Incentive Program for Commercial Airlines to Fly Quieter
By City News Service - Published January 21, 2020 - Updated on January 22, 2020 at 4:57 pm

Los Angeles International Airport officials announced a program Tuesday designed to encourage commercial airlines to operate as quietly as possible to cut down on airport noise in surrounding communities.
The Fly Quieter program will evaluate airlines annually on their compliance with LAX noise-abatement procedures and their use of quieter aircraft and new technology. They will also be evaluated on their engagement with local community groups and stakeholders.
“…noise remains a predominant aviation environmental concern of the public, one of the principal environmental obstacles to expanding airport and airspace capacity, and the one that has used the most mitigation resources…”

Airport Expansion Example

London Heathrow Airport
New Third Runway

- Goal to increase capacity of London’s busiest airport
- Noise was a key issue

“…delivering over £200bn to the British economy and 180,000 jobs while reducing noise for local residents compared to today.”

- Heathrow CEO John Holland-Kaye

Sources:
http://news.bbc.co.uk/2/hi/uk_news/politics/7722164.stm
https://metro.co.uk/2018/06/05/heathrow-airport-will-get-third-runway-cabinet-give-green-light-plan-7605871/
For fuel burn reduction, stakeholder alignment is direct.

For noise reduction, alignment is not direct or clear.
International Civil Aviation Organization (ICAO) in 2004 adopted three major environmental goals: To limit or reduce the…

a. number of people affected by significant aircraft noise;
b. impact of aviation emissions on local air quality; and
c. Impact of aviation greenhouse gas emissions on the global climate.

Source: https://www.icao.int/environmental-protection/Pages/default.aspx
Accessed February 5, 2020
Possible Pathways for Source Noise

• Introduction on the Next Evolutionary Aircraft Product
  o Past successes

• Retrofit of In-Service Aircraft
  o Proposed example

• Revolutionary Future Aircraft
  o Overview of NASA’s Research
Introduction on the Next Evolutionary Aircraft

- Design/technology primarily for noise – very few examples:
  - Duct liners
  - Increased rotor stator spacing
  - Swept stators
  - Spliceless liners
  - Conventional and PAA chevrons

- Noise reduction must “buy it’s way on an aircraft”

- Insertion can happen relatively quickly, however, impact at the fleet level takes ~10+ years

- Few opportunities of new aircraft introduction
NASA/Boeing QTD2: PAA Chevron Concept to Flight in Two Years 2003-2005

Propulsion Airframe Aeroacoustic (PAA) integration effects was the innovative approach

Boeing LSAF Wind Tunnel Testing

2004

2003 – 2004

Concept Exploration/CFD

2005

QTD2 Flight Test

2011

B747-8 Product

Quiet Technology Demonstrator 2 (QTD2)

1 AIAA 2005-3083, 2006-2436
2 AIAA 2006-2438, 2006-2439
3 AIAA 2006-2467,2006-2434, 2006-2435
NASA/Boeing QTD3 Flight Test: Low Drag and Multidegree of Freedom (MDOF) Acoustic Liner

737 LEAP-1B Inlet Liner Flight Test (Summer 2018)

MDOF Liner Core
- 3.2 component and 0.7 aircraft cumulative EPNdB benefit
- High level validation of liner design procedure

Slotted Facesheet Perforations
- 30% drag reduction*
- Manufactured with existing tooling
- More drag reduction is possible

AATT Project demonstrated ability to leverage discipline expertise and facility investments

*relative to conventional liner, Ref. AIAA 2019-2763
Retrofit

• Impact at the fleet level is much faster from retrofitting existing aircraft.

• Winglet retrofit example – offered by Aviation Partners Boeing on range of 737, 757 and 767 aircraft. Annual savings of 130,000 gallons per aircraft for a 737-800.¹

• Fedex B727 Hushkits to comply with Stage 3 Noise – full noise compliance without compromising thrust or specific fuel consumption.²

Airlines are the upfront purchasers and need a benefit to justify the investment.

Quiet Nacelle Retrofit for Boeing 737NGs

- New Quiet Nacelle Retrofit:
  - Spliceless MDOF liner
  - Chevron nozzle
  - Low-drag liner facesheet and possible lighter weight

- The NASA Aircraft Noise Prediction Program (ANOPP-Research) used to estimate a cumulative 2.8 EPNdB reduction.

- Significant fleet-level impact with ~7000 aircraft in service.
Overview of NASA’s Acoustics Research

• Implementation of noise reduction is both needed for the air transportation system and is also very challenging

• Highlights of the NASA AATT Project’s acoustics portfolio including revolutionary subsonic transport aircraft concepts
NASA AATT Noise Reduction Technologies

Soft Stator\(^1\)

1.0 EPNdB cumulative reduction at aircraft level\(^3\)

Over-the-Rotor (OTR) Treatment\(^2\)

- Noise reduction of 2 to 4.5 dB for sub-components of fan noise\(^2\)
- Aerodynamic performance loss estimated\(^2\) between 0 and 0.5%

Liner in-between grooves

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\(^1\)Jones and Howerton, AIAA Paper 2016-2787
\(^3\)Guo, et al. AIAA Paper 2018-3126
NASA AATT Noise Reduction Technologies

Slat Cove Filler\(^1\)
Low Weight & Complexity

Slat Gap Filler\(^1\)
Low Weight, Moderate Complexity

- 4 EPNdB reduction goal for total airframe noise is achievable
- Deployable

High Lift – Common Research Model Test in the 14x22 Subsonic Wind Tunnel 2020\(^1\)

Propulsion Airframe Aeroacoustic (PAA) and Aircraft System Noise Flight Test on Boeing 787 ecoDemonstrator

NASA/Boeing Research, In Progress

For a range of flight conditions and aircraft configurations
• Measure from over 1200 microphones on the ground and aircraft

Measure PAA effects:
• Reflection of engine noise by the airframe to microphones below
• Shielding of engine noise to microphones above wing

Expected Impacts:
▪ Improved understanding of transport noise
▪ Quantification of full scale PAA effects
▪ Best evaluation of ANOPP to date
▪ Lead to improvements in ANOPP
Revolutionary - Mid-Fuselage Nacelle (MFN) with Far Term Technology Roadmap

MFN 40.2 EPNdB cumulative margin below Stage 4 predicted, Ref. AIAA-2018-3126
Revolutionary Aircraft Concept - Transonic Truss Braced Wing

Opportunity
- Increases aspect ratio (to ~23) for reduced drag

Challenges
- Structures
- Aeroelastics

- NASA-funded Boeing concept development (2008-present)
- AATT Assessments
  - Concept design and predicted fuel burn and emissions
  - System noise with unique airframe and PAA integration effects predicted using ANOPP-Research – *additional opportunity*
Prospects for Electrification Noise Impacts

- Electric-propulsion aircraft are in their infancy, with focus on taxi, commuter, and regional aircraft.

- Reduced noise is a commonly cited benefit of electric propulsion, few quantitative studies exist.

- For large commercial aircraft, combustor/core noise is a relatively small contributor.

- Electric propulsion does not directly affect the dominant sources.
Transformational - HWB Concept with Far Term Technology Roadmap

- Propulsion design space expanded:
  - Distributed electric motors.
  - Hybrid systems separating turboelectric generators from electric drive motors.

Low noise possible through configuration change,
Electrification could enable low noise \( IF \) designed for noise from beginning

**HWB 50.9 EPNdB cumulative margin below Stage 4, Ref. AIAA-2017-3193 With gas turbine engines**
Summary – The Challenge of Aviation Noise

- Annoyance impacts and constraint on growth are penalties borne by all stakeholders
  - The whole system is paying now

- Noise penalty impacts are distributed among the stakeholders with little direct linkage between investment and benefit
  - Yet, whole system would benefit

- This fundamental disconnect hinders the investment needed to increase insertion of noise reduction technology
Summary – Effective Technology Development Approaches

• Increasing the available portfolio of noise reduction technology would stimulate all insertion paths:
  o Justifies the setting of lower regulatory noise levels
  o More likely to be proactively implemented by industry
  o More possibilities for retrofitting

• Emphasize:
  o Healthy discovery portfolio
  o Focused development:
    ❑ Feasibility
    ❑ Neutral to favorable weight, fuel burn, and other impacts
    ❑ Less complexity
  o Flight/engine testing, both test bed and X-plane:
    ❑ Accelerate maturation (system integration and manufacturing proof-of-concept)
    ❑ Key tool to explore and develop unique information and innovative approaches
    ❑ Driver of creativity and timeline

• Aircraft configuration does offer revolutionary noise reduction
Certification Noise Conditions for Transport Aircraft

1) Flight Operation/ Trajectory Simulation
2) Source Noise Modeling
3) Noise Propagation to Observers
4) Ground observer noise time history
5) Time Integration to EPNL

50 Hz to 10 kHz