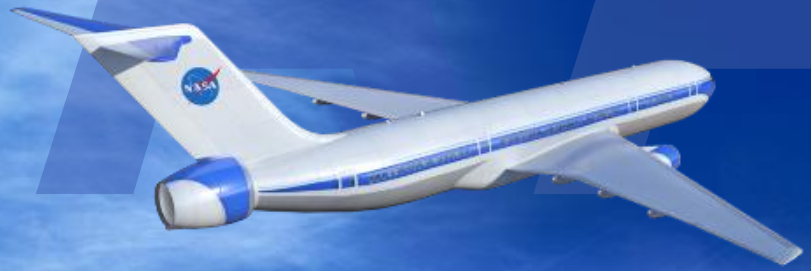
Noise Reduction Technology Implementation for a Quieter Subsonic Transport System



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SAE AeroTech Americas Congress
Pasadena, CA

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Acknowledgments

- The NASA Advanced Air Transport Technology (AATT) Project for supporting the NASA research in this presentation

- Kelly Shelts of the Aeroacoustics Branch, NASA Langley

Outline

- Historical Progress of Aircraft Noise
  - Current Status of the Air Transportation System Regarding Aviation Noise
- Pathways for Noise Reduction Implementation
  - Insights into the Challenges
- NASA AATT Acoustics Research Overview
  - Technologies
  - Future Aircraft Configurations
  - Prospects for Electrification Impact
- Summary

Historical Progress of Aircraft Noise

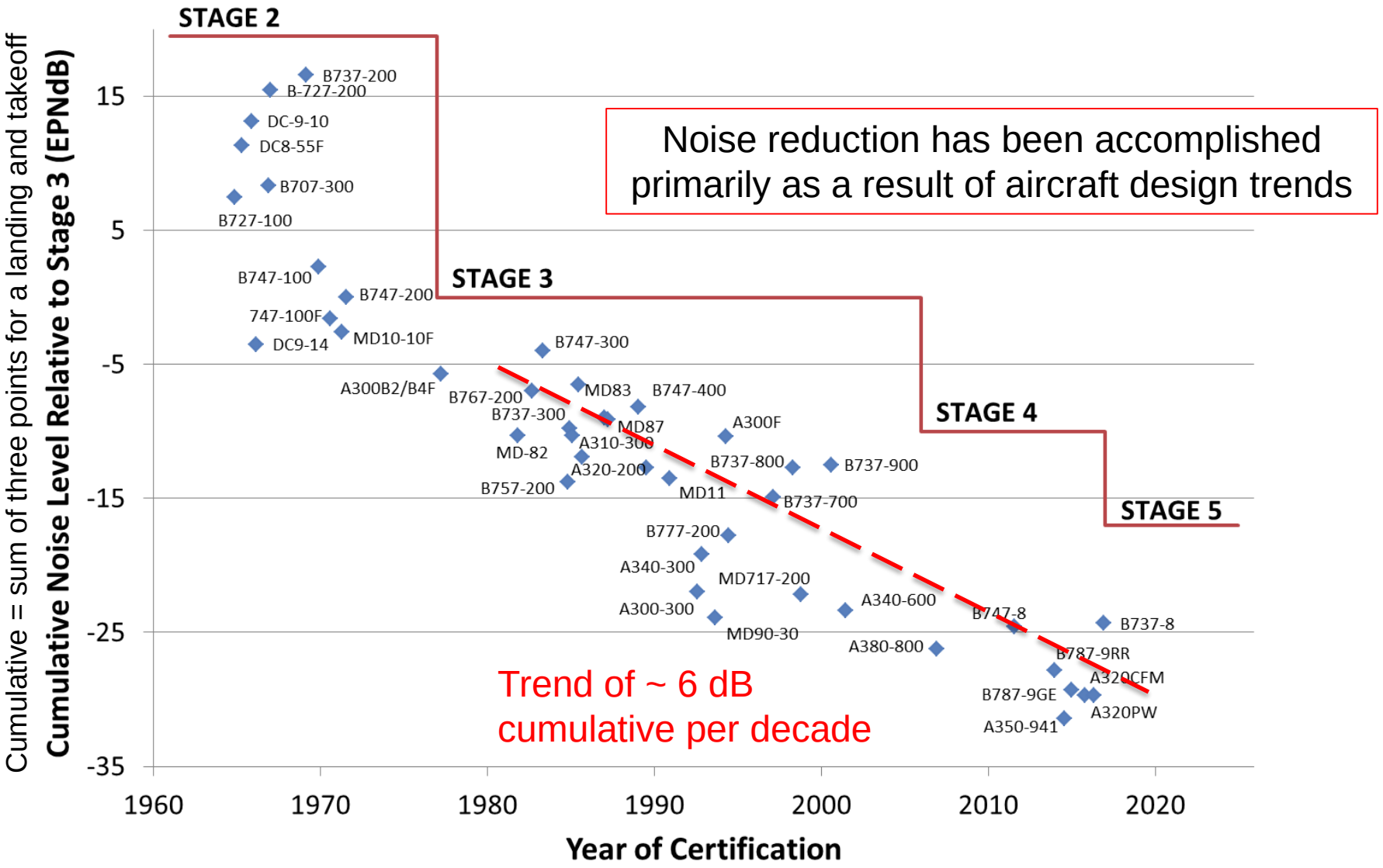


Figure reproduced from James Hileman, "Addressing Aircraft Noise in the United States: Part II Mitigation Solution Development," September 6, 2018 to the 22nd Workshop of the Aeroacoustics Specialists Committee of the CEAS.

Observations on Noise Certification Levels

Researcher viewpoint:

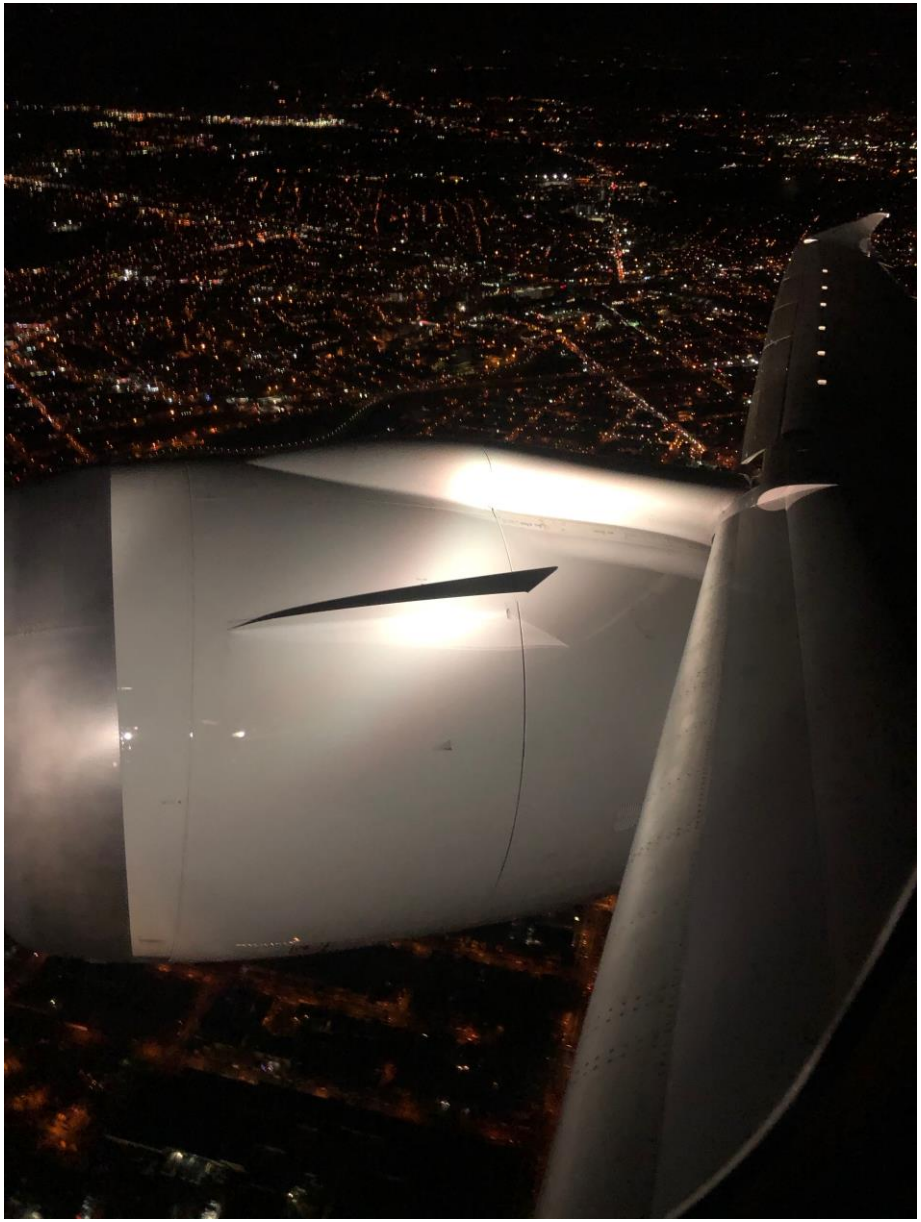
- Future levels established largely by the design trend and the availability of ready technology
- Largely a lagging level rather than a leading or goal level

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

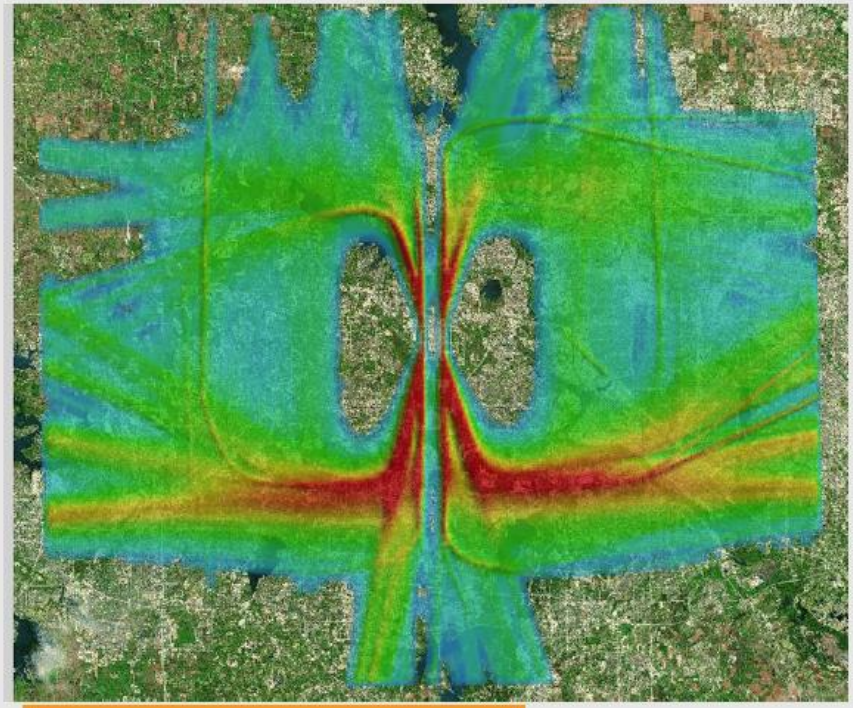
Impact of Growth *and* Aviation Noise – Current State

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

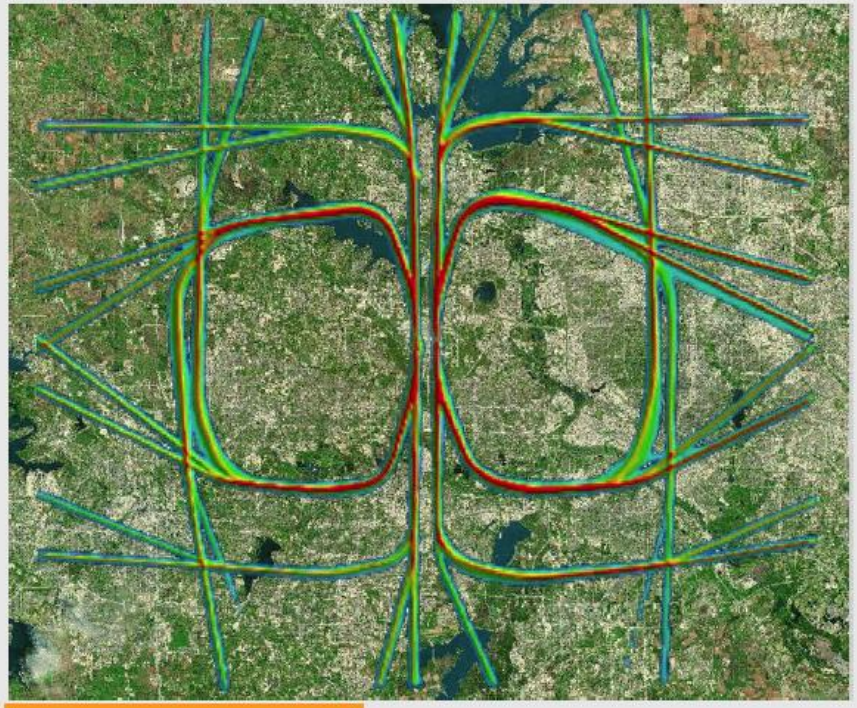


Impact of Precision Navigation

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



NON-RNAV DEPARTURES



RNAV DEPARTURES

DFW

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 co
going through the ro

By John Laidler Globe Correspondent, September 6, 2019, 11:0

'The noise is unbelievable': SI
triple since 2

The Washington Post
Democracy Dies in Darkness

Appeals court rules against D.C.

NEWS > CRIME + PUBLIC SAFETY

Airline faces crimina
violating Long Beach
noise ordinance

The city prosecutor's office fi
charges against Mesa Airlines

The City of Long Beach reveals the new monument
Beach Airport (LGB) on Monday, June 17, 2019. The
rich aviation history and was inspired by the DC-3 ai
visitors to LGB and increase the airportÕs presence
(Photo by Ana P. Garcia, Contributing Photographer)

Colorado's aviation industry opp
noise bill

Michael Karlik, Colorado Politics
Jan 7, 2020

U.S. Rep. Joe Neguse (D-Boulder) responds to testimony by C
U.S. House of Representatives Select Committee on the Climat
2019, in Boulder. The hearing was titled "Colorado's Roadmap
and Local Leaders" and was held at CU Boulder's Wittemyer C
Colorado Politics

Andy Colwell

Colorado's aviation industry association on Tuesday
bill from U.S. Rep. Joe Neguse that would expand
operations in the name of noise reduction.

LAX Announces Incentive Program for Commercial Airlines to Fly Quieter

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.

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 Constrained Growth

"…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…"

Page 3, "Aviation Environmental and Energy Policy Statement," Department of Transportation, Federal Aviation Administration, July 2012.
https://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/ accessed February 18, 2020.

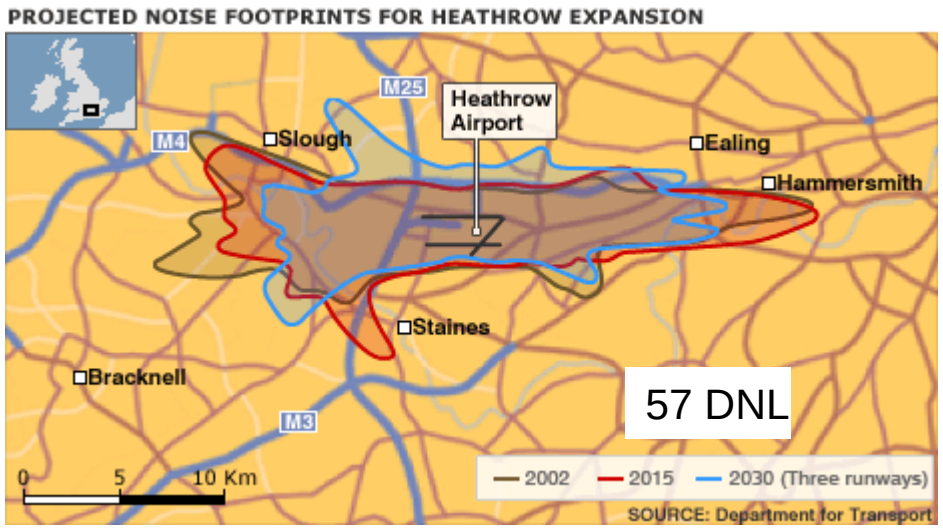
Airport Expansion Example

London Heathrow Airport New Third Runway

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

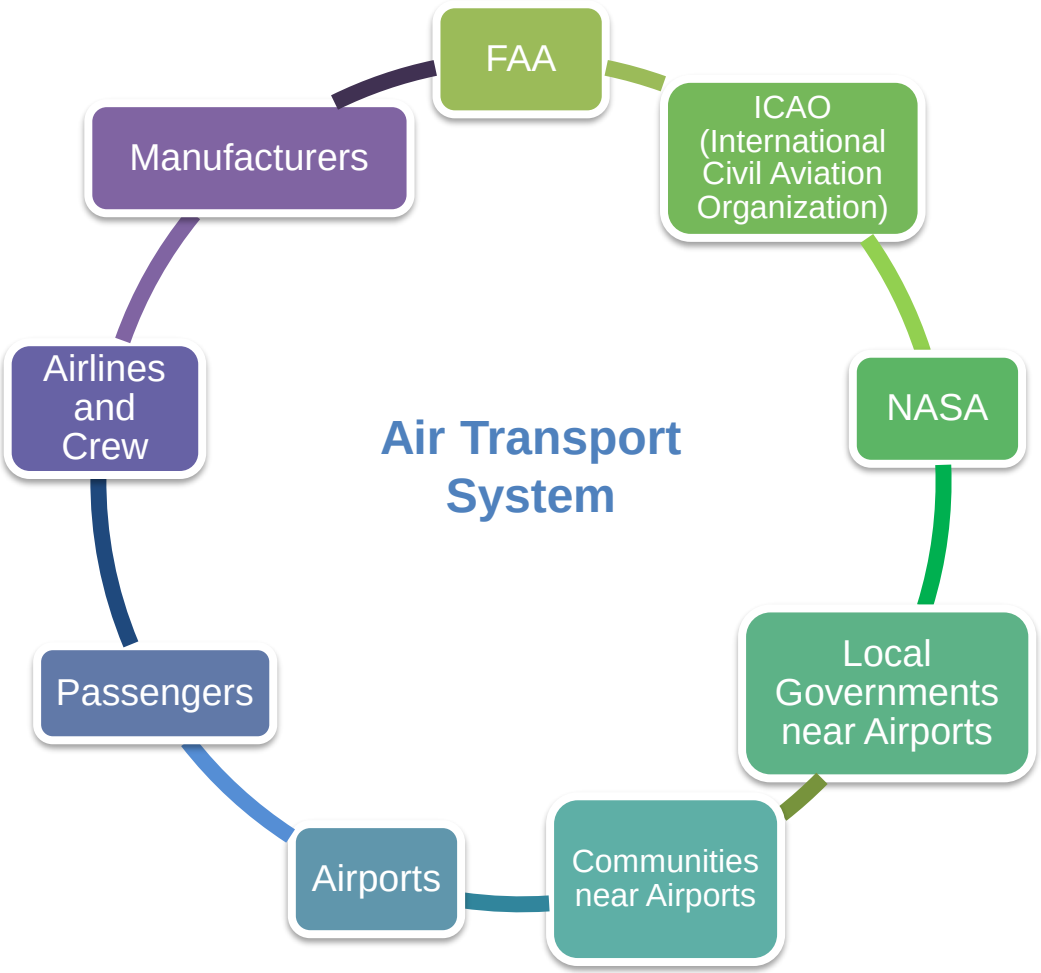
"…delivering over £200bn to the British economy and 180,000 jobs while reducing noise for local residents compared to today."

-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/
https://www.heathrowexpansion.com/airports-commission/airports-commission-verdict-jobs-economic-benefits-less-noise/

Comments on Stakeholder Interconnections

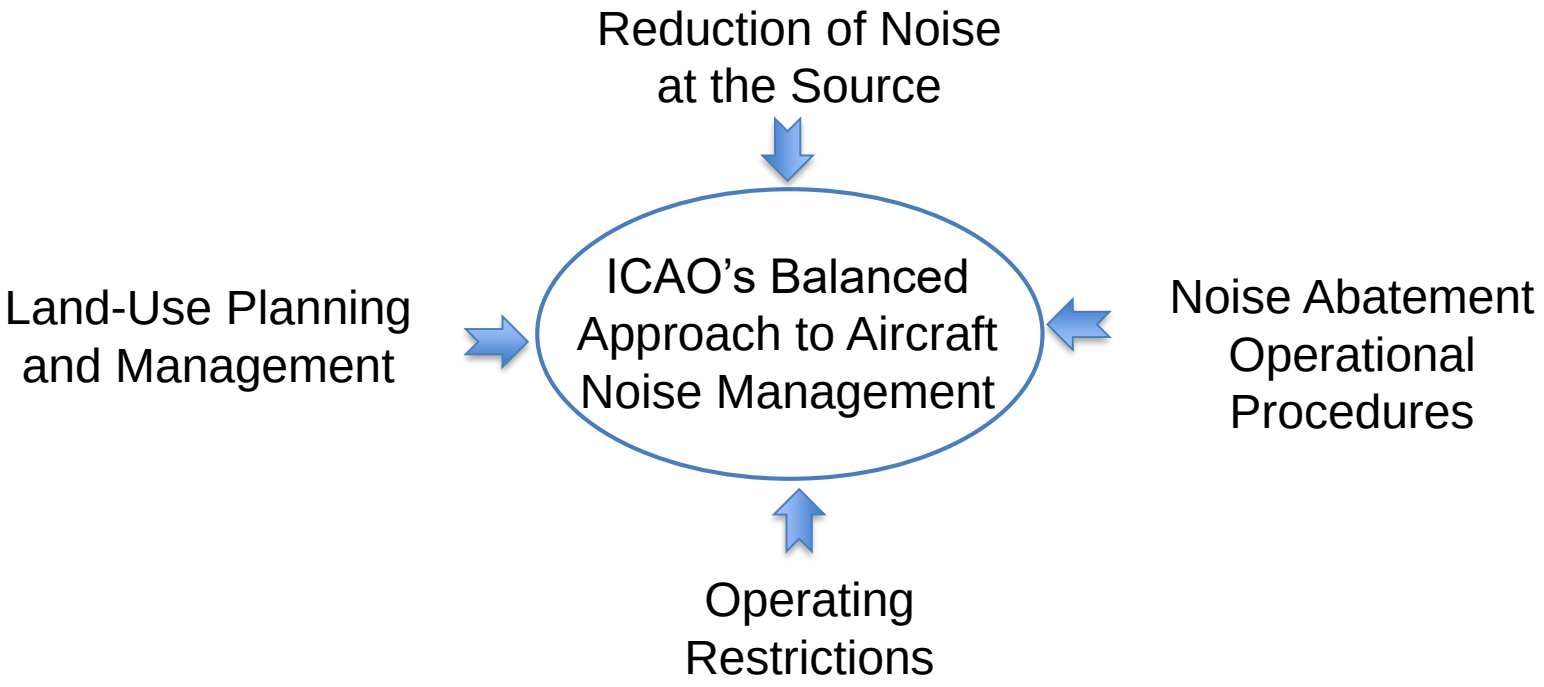


- For fuel burn reduction, stakeholder alignment is direct
- For noise reduction, alignment is not direct or clear

Pathways for Noise Reduction Implementation

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
  - Past successes
- Retrofit of In-Service Aircraft
  - Proposed example
- Revolutionary Future Aircraft
  - 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[2]

2004

2005

QTD2

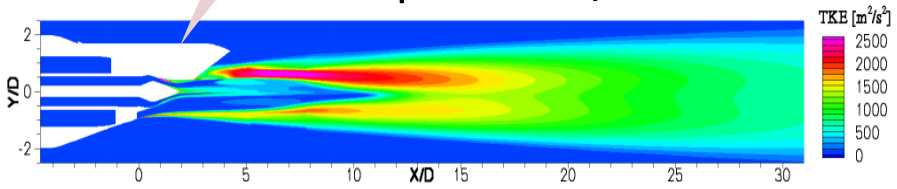
Flight Test[3]

2011

B747-8 Product

2003 – 2004

Concept Exploration/CFD[1]



Quiet Technology Demonstrator 2 (QTD2)

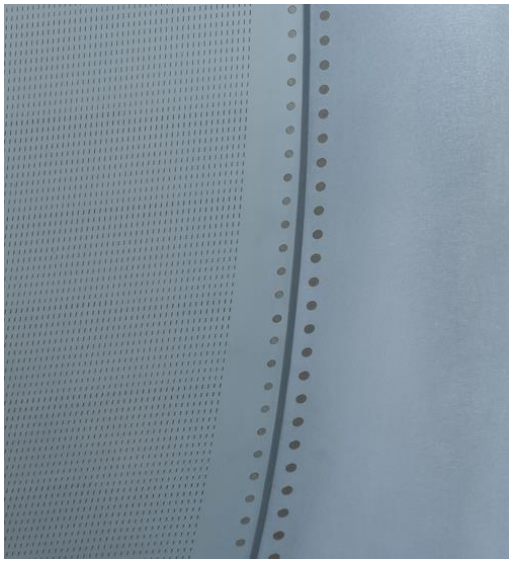
[1] AIAA 2005-3083, 2006-2436
[2] AIAA 2006-2438, 2006-2439
[3] AIAA 2006-2467,2006-2434, 2006-2435

NASA/Boeing QTD3 Flight Test: Low Drag and Multidegree of Freedom (MDOF) Acoustic Liner

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

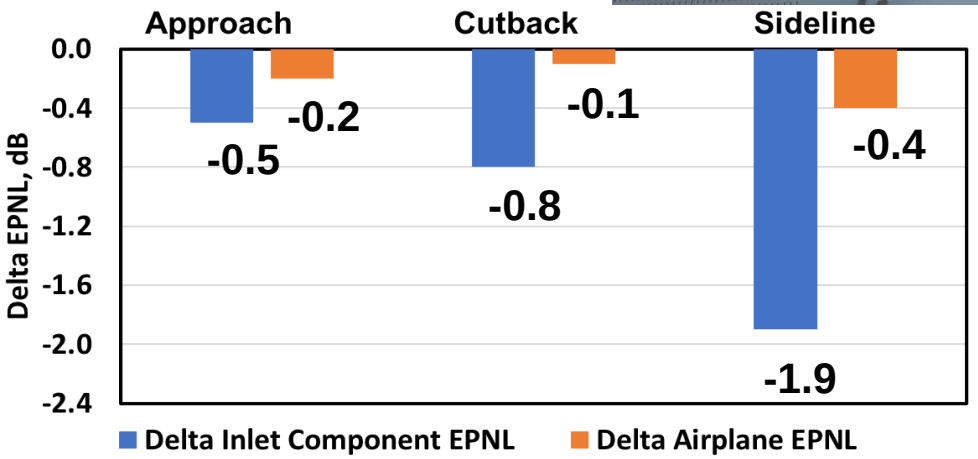
Slotted Facesheet Perforations

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



MDOF Liner Core

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



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.

[1]http://www.aviationpartnersboeing.com/winglets_lbf.php (accessed Feb 7, 2020)
[2]http://www.fedex.com/us/hushkit/helpdecide/ (accessed Feb 7, 2020)

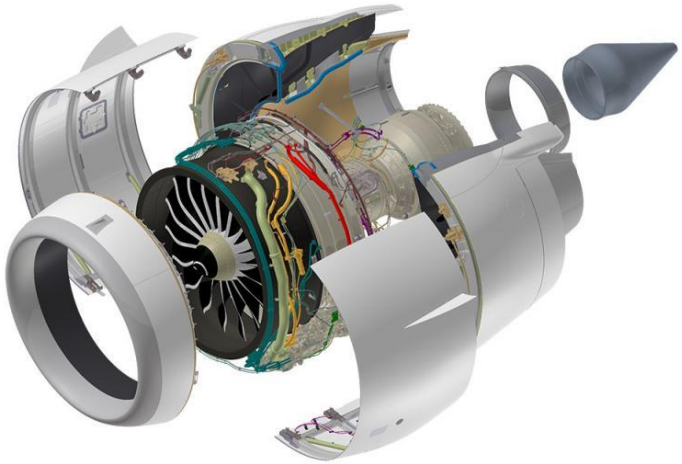
Quiet Nacelle Retrofit for Boeing 737NGs

- 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.

https://www.boeing.com/

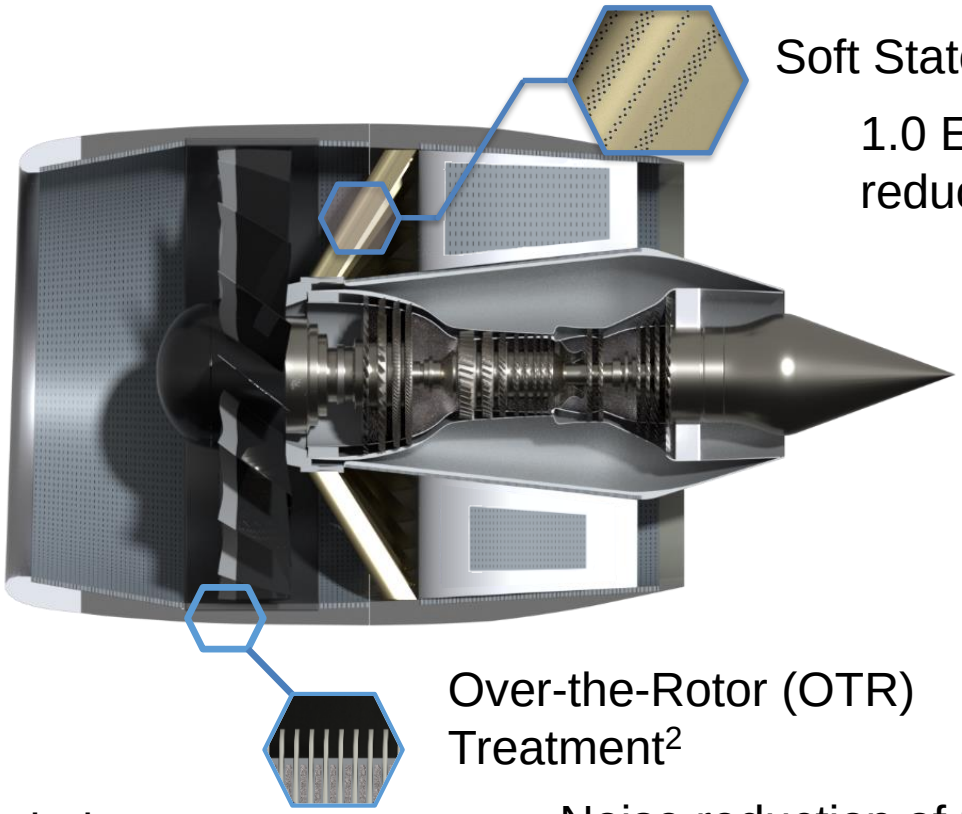

https://www.safran-nacelles.com/innovation-0

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]

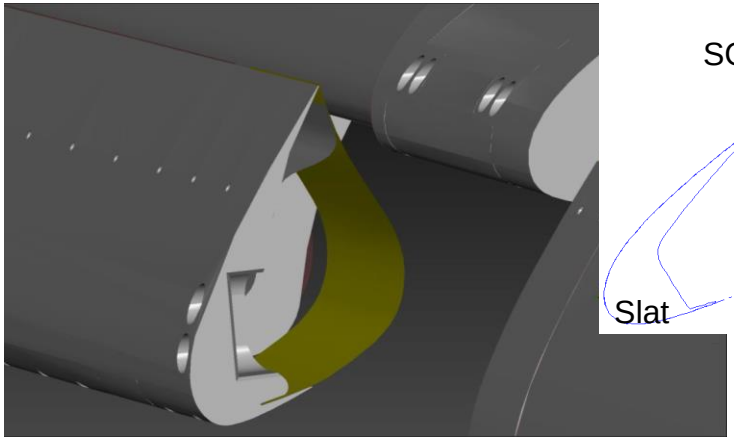
Liner in-between grooves

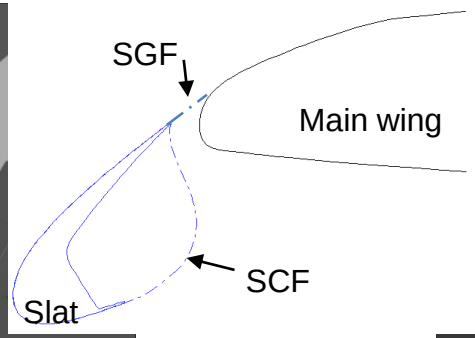
Over-the-Rotor (OTR) Treatment[2]

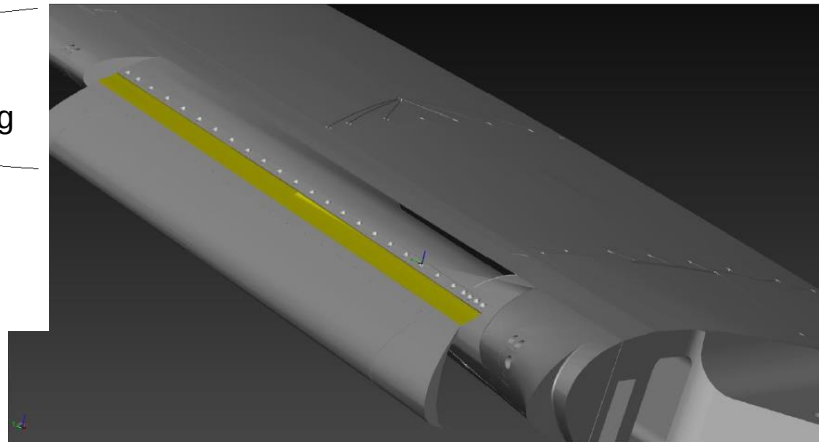
- Noise reduction of 2 to 4.5 dB for sub-components of fan noise[2]
- Aerodynamic performance loss estimated[2] between 0 and 0.5%

[1]Jones and Howerton, AIAA Paper 2016-2787
[2]Bozak, Jones, Sutliff, and Nark, "NASA's Over-the-Rotor Acoustic Casing Treatment Development," presentation at the NASA Acoustics Technical Working Group Meeting, October 23, 2019.
[3]Guo, et al. AIAA Paper 2018-3126

NASA AATT Noise Reduction Technologies





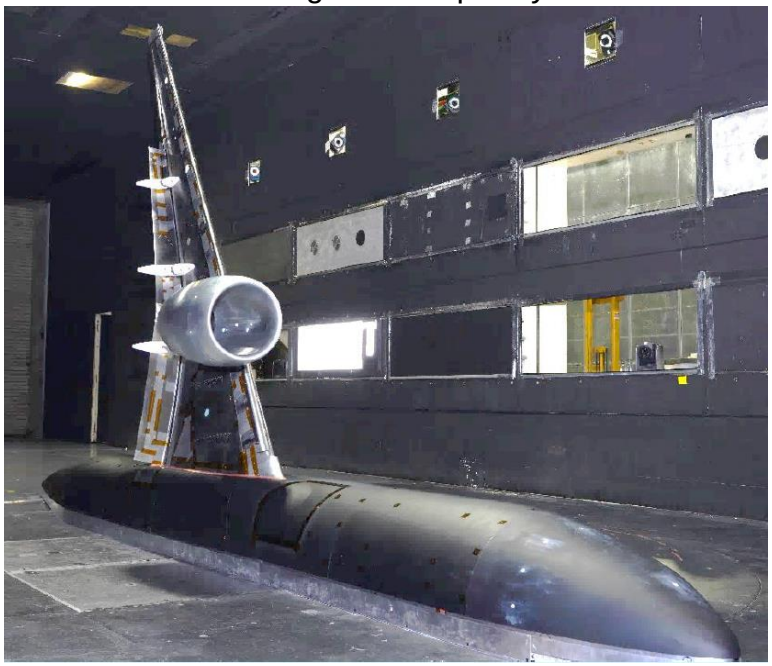


Slat Cove Filler[1]

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]

[1]Lockard, D. "Slat Noise Reduction Devices for the High-Lift Common Research Model and Aeroacoustic Test Plans," NASA Acoustics Technical Working Group Meeting, October 23, 2019.

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

Boeing Image

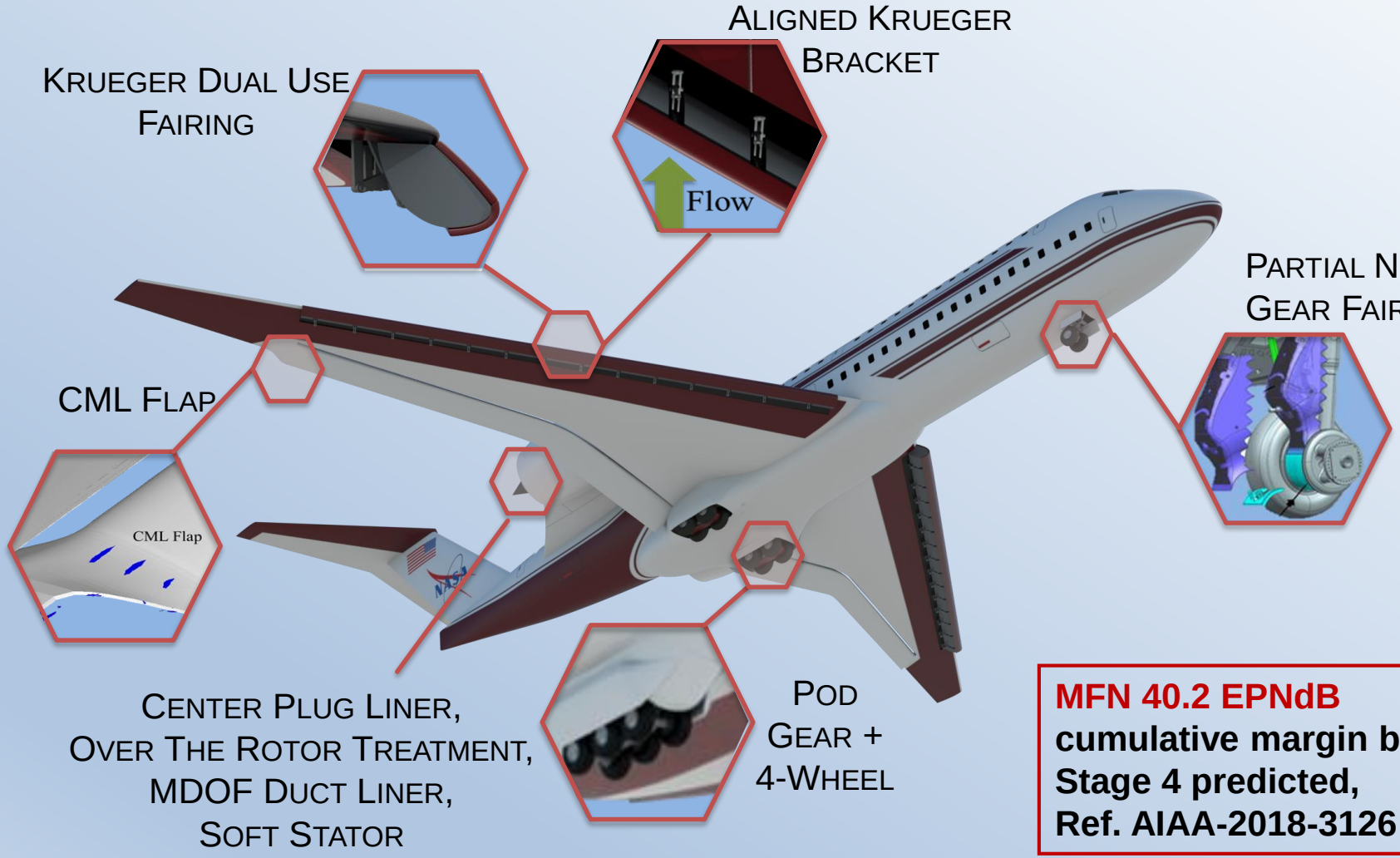
Measure PAA effects:

- 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

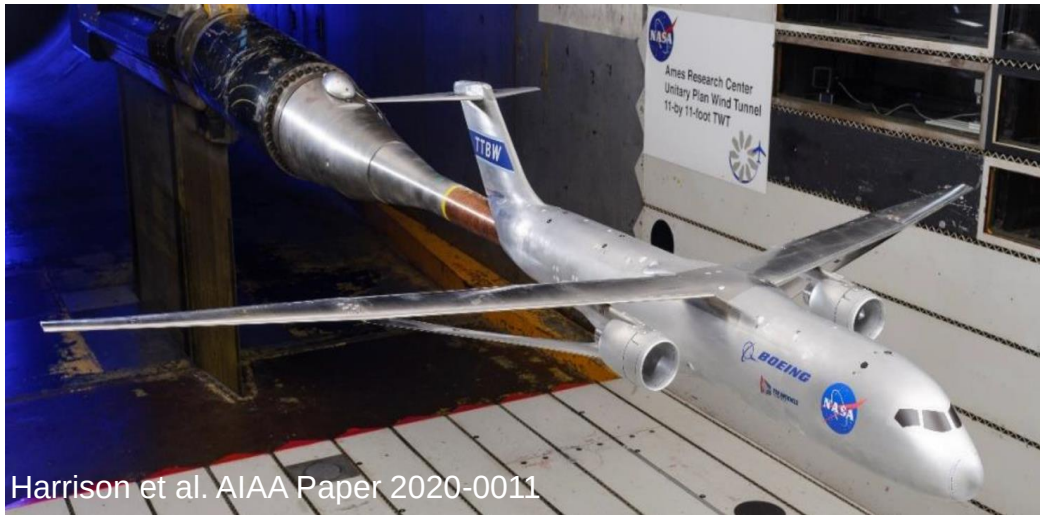
Revolutionary - Mid-Fuselage Nacelle (MFN) with Far Term Technology Roadmap



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



Harrison et al. AIAA Paper 2020-0011

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

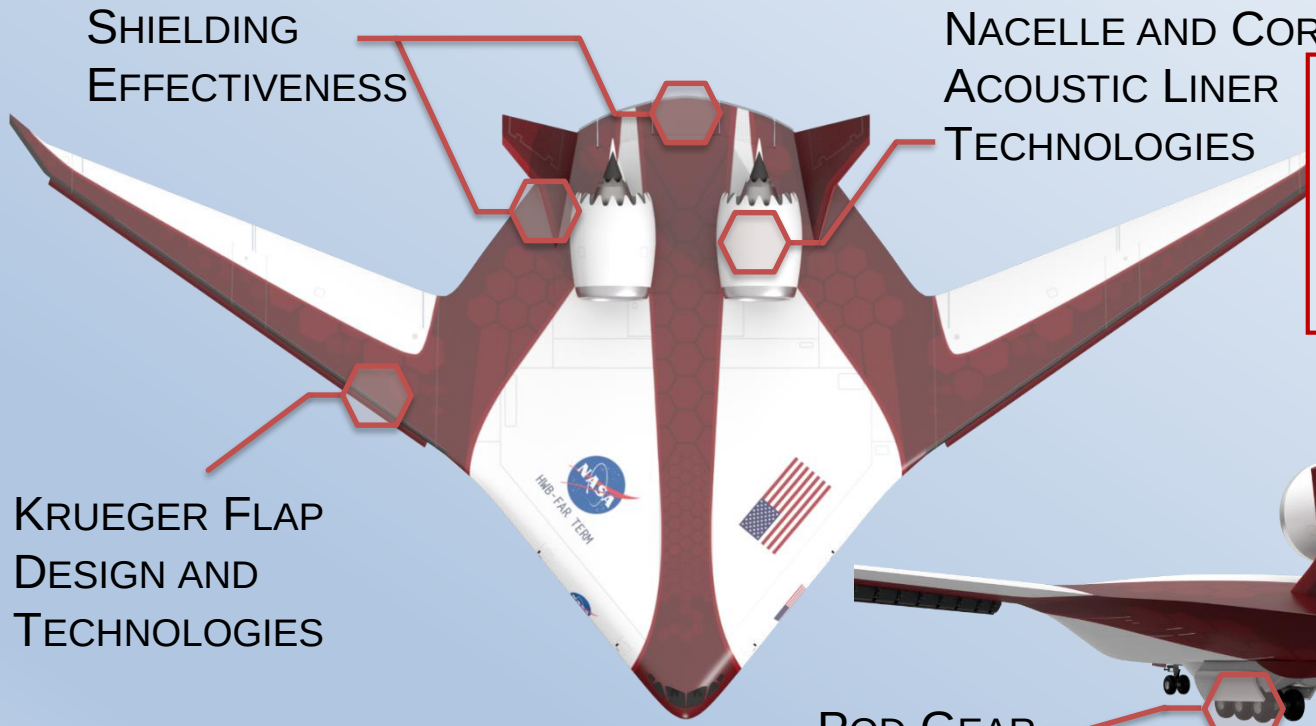
- Electric-propulsion aircraft are in their infancy, with focus on taxi, commuter, and regional aircraft.
- Reduced noise is a commonly cited benefit of electric propulsion, few quantitative studies exist.
- For large commercial aircraft, combustor/core noise is a relatively small contributor.
- Electric propulsion does not directly affect the dominant sources.

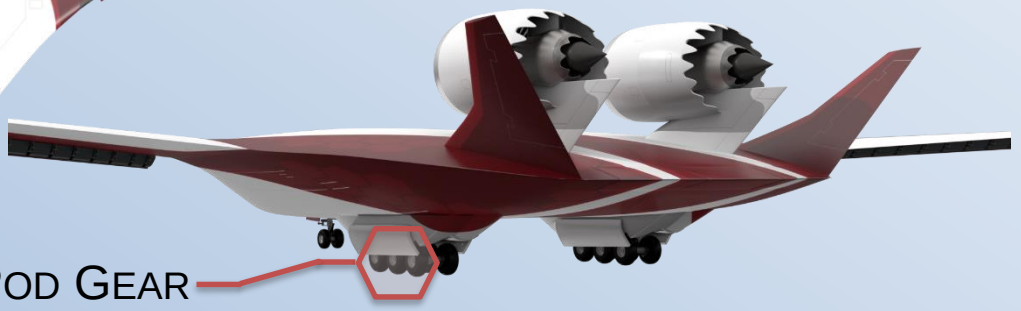
Airbus E-Fan X

United Technologies Advanced Projects
Project 804

Transformational - HWB Concept with Far Term Technology Roadmap

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





HWB 50.9 EPNdB cumulative margin below Stage 4, Ref. AIAA-2017-3193 With gas turbine engines

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

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:
  - Justifies the setting of lower regulatory noise levels
  - More likely to be proactively implemented by industry
  - More possibilities for retrofitting
- Emphasize:
  - Healthy discovery portfolio
  - Focused development:
    - ❑ Feasibility
    - ❑ Neutral to favorable weight, fuel burn, and other impacts
    - ❑ Less complexity
  - 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


NASA

Certification Noise Conditions for Transport Aircraft