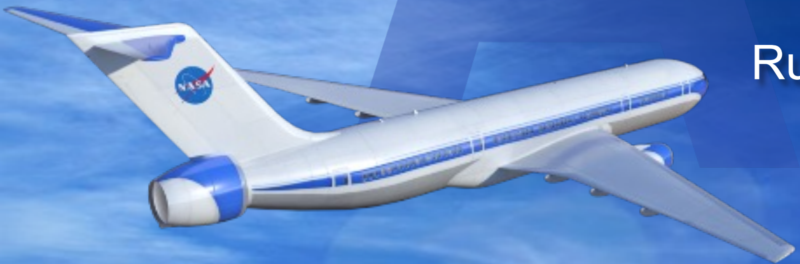
National Aeronautics and Space Administration

Aircraft Technology Pathways to Quieter and Sustainable Airports

Russell H. Thomas, Ian A. Clark, and Yueping Guo
NASA Langley Research Center



Noise Around Airports: A Global Perspective
Hosted by the International Institute of Noise Control Engineering
and the National Academy of Engineering

November 1-4, 2022

Outline

- Propulsion Airframe Aeroacoustics and Aircraft System Noise

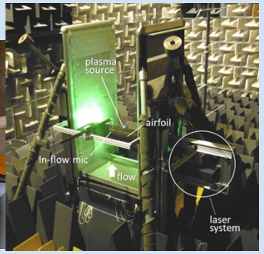
- Pathways for Source Noise Reduction Implementation
  - Challenges
  - Successful innovative examples

- NASA Advanced Concept Studies
  - Essentials to noise prediction progress
  - Example noise reduction roadmaps and findings
  - Prospects for electrification impact

- Summaries
  - Results and progress
  - Recommendations for increasing implementation of noise reduction

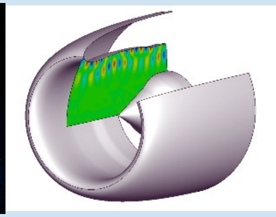
The NASA Advanced Air Transport Technology (AATT) Project is gratefully acknowledged for supporting the NASA research in this presentation

Propulsion Airframe Aeroacoustics and Aircraft System Noise Team



Collaboration with:

- System Analysis and Integration
- NASA Acoustics and other disciplines
- Industry
- Academia

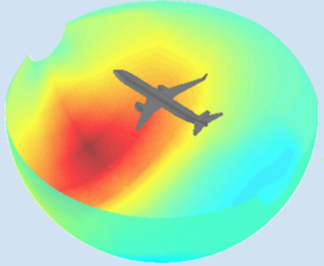
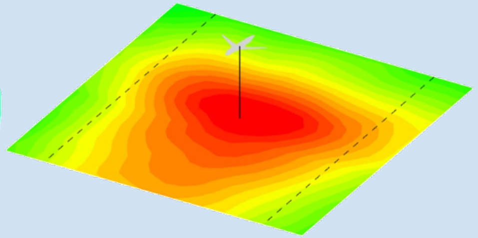
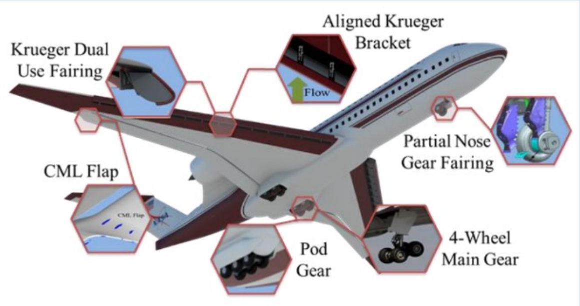



PAA & ASN Team

PAA = Aeroacoustic integration effects
ASN = Total aircraft system noise (e.g., certification noise)

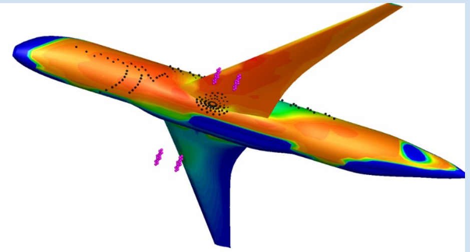
Products:

- ANOPP (Aircraft NOise Prediction Program)
- PAA and Aircraft Noise Prediction Methods
- Aircraft Concept Acoustic Assessments
- Noise Reduction Technology
- Technology Roadmaps to Guide Development

Aircraft acoustics research including:

- Simulations
- Wind tunnel research tests
- Full-scale flight research tests




Noise Reduction Implementation for More Sustainable Air Transport System Growth

- Introduction on Aircraft Products
  - Retrofit
  - Next Product
  - Past Successes

- Revolutionary Future Aircraft
  - Technology Levels
  - Noise Reduction Technology Roadmaps
  - Advanced Configurations and PAA Integration Effects

Productive linkages between the two

Introduction on the Next Aircraft Products

- 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 its way on an aircraft"

NASA/Boeing QTD2: PAA Chevron from Concept to Flight in Two Years 2003-2005

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

2011

B747-8 Product

Boeing LSAF Wind Tunnel Testing[2]

2004

2005

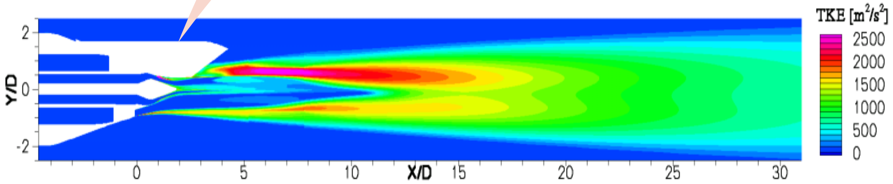
QTD2

Flight Test[3]

Quiet Technology Demonstrator 2 (QTD2)

2003 – 2004

Concept Exploration/CFD[1]

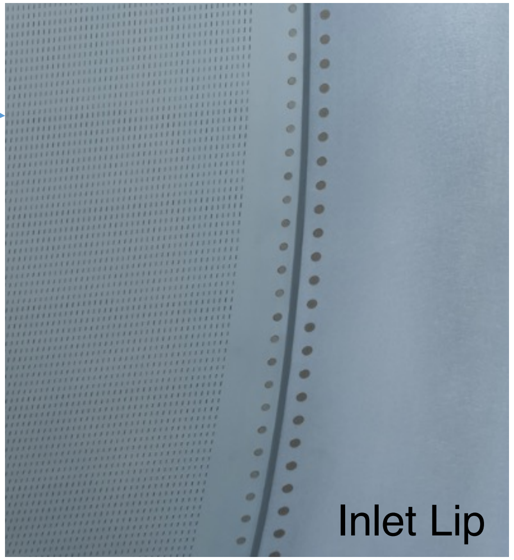


[1] AIAA 2005-3083, 2006-2436
[2] AIAA 2006-2438, 2006-2439
[3] AIAA 2006-2467,2006-2434, 2006-2435

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

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

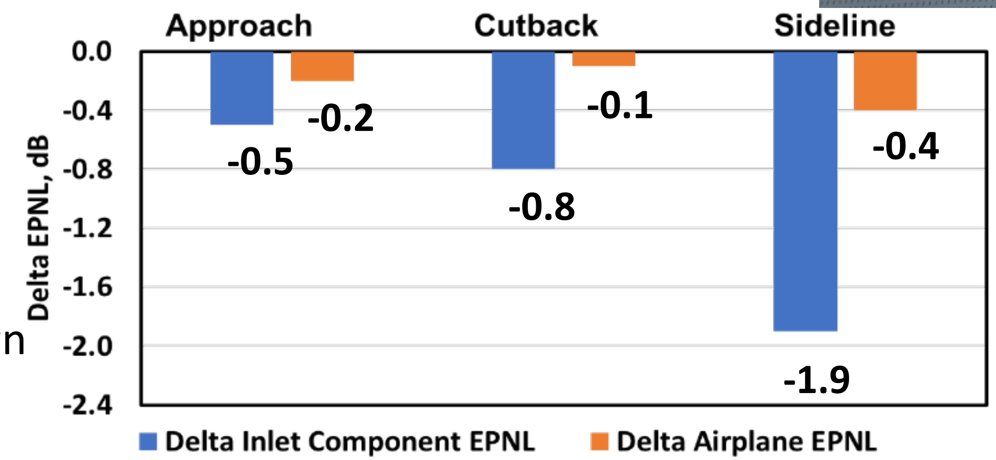
Slotted Facesheet Perforations



- 30% drag reduction, relative to conventional liner, Ref. AIAA 2019-2763
- Manufactured with existing tooling
- More drag reduction is possible

MDOF Liner Core

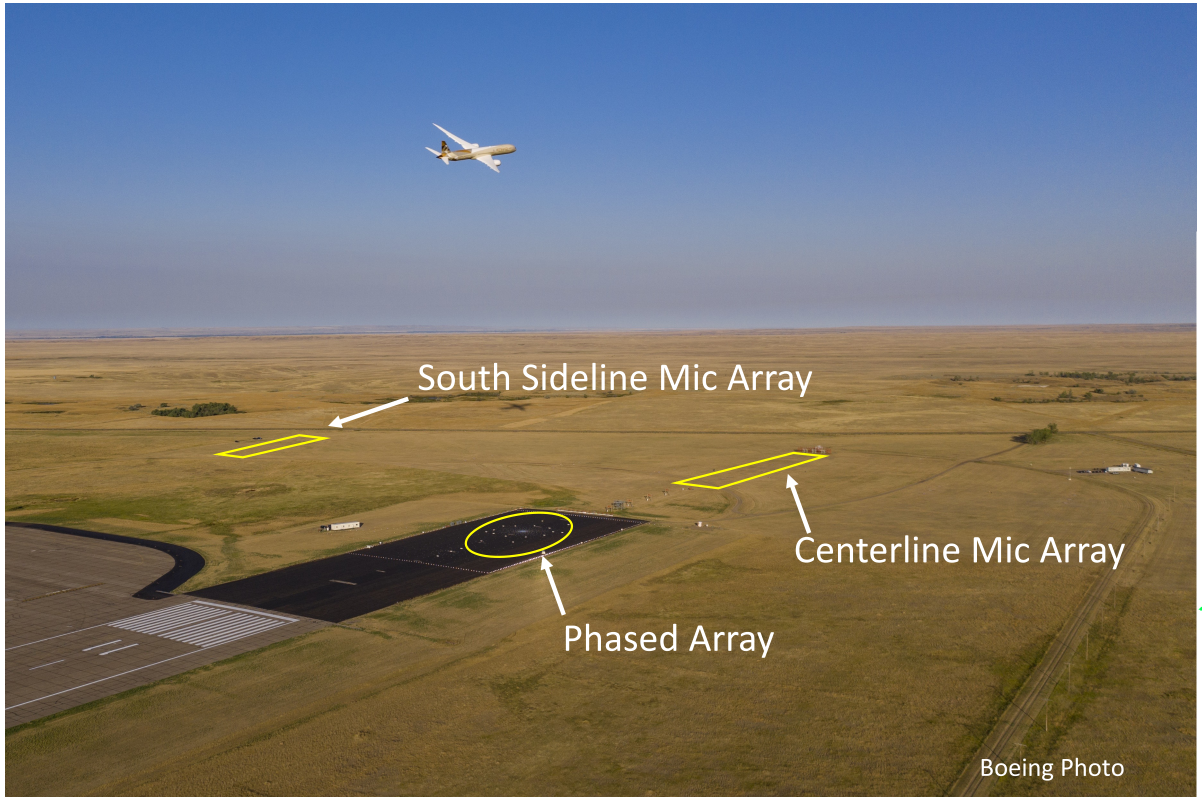
- 3.2 component and 0.7 aircraft cumulative EPNdB benefit
- High-level validation of liner design procedure

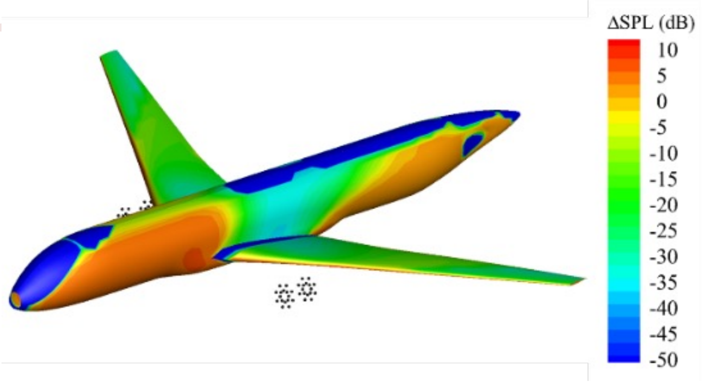


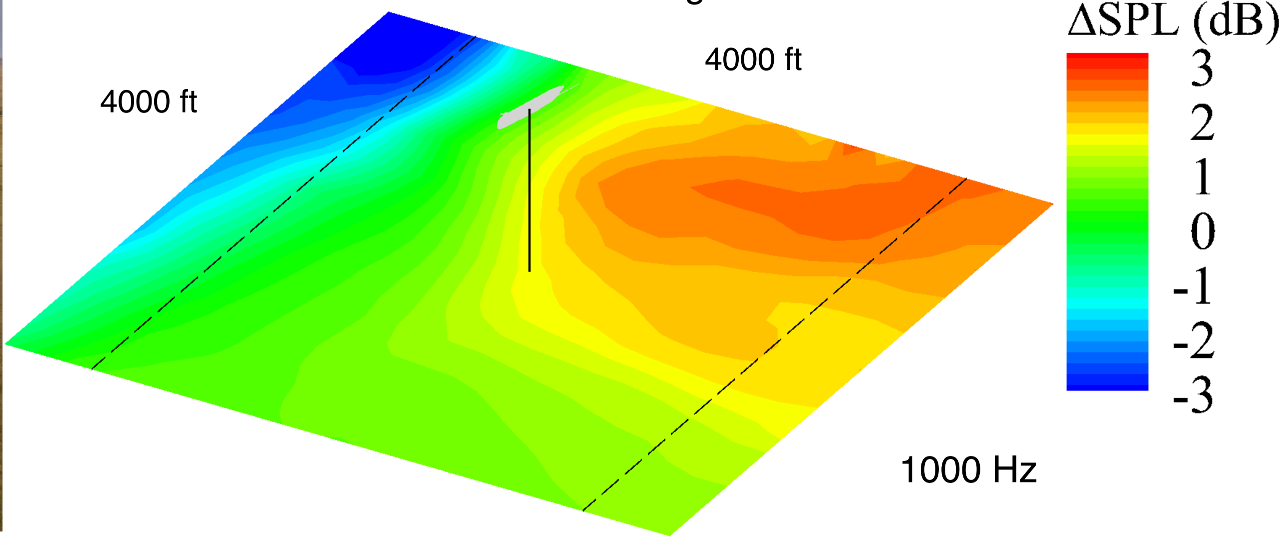
AATT Project and the Liner Physics Team demonstrated ability to leverage discipline expertise and facility investments to advance two innovative technologies

NASA/Boeing PAA & ASN Flight Test on the 2020 ecoDemonstrator Boeing 787-10

Thomas et al. AIAA 2022-2993
Czech et al. AIAA 2022-2994







Predicted scattered field for combined forward and aft fan broadband noise, both engines at high power.

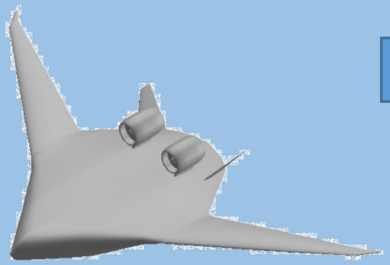
Benchmark Validation of ANOPP-Research PAASc Demonstrated with Flight Data

Exploring Possible Applications

Evolution of an Aircraft Concept and Noise Assessment

Systems Analysis and Integration within NASA AATT Project

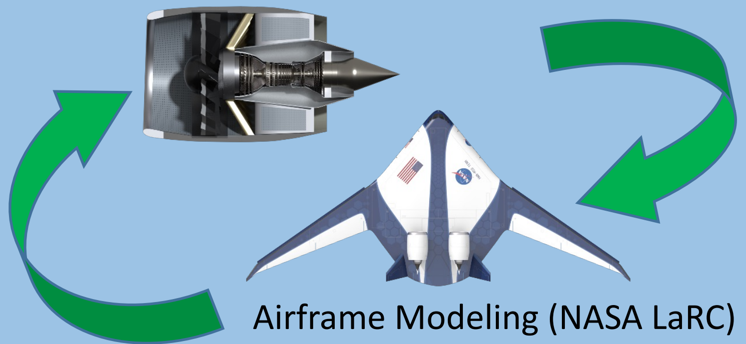
Configuration Layout from:
- NASA
- Industry
- Academia



Refine

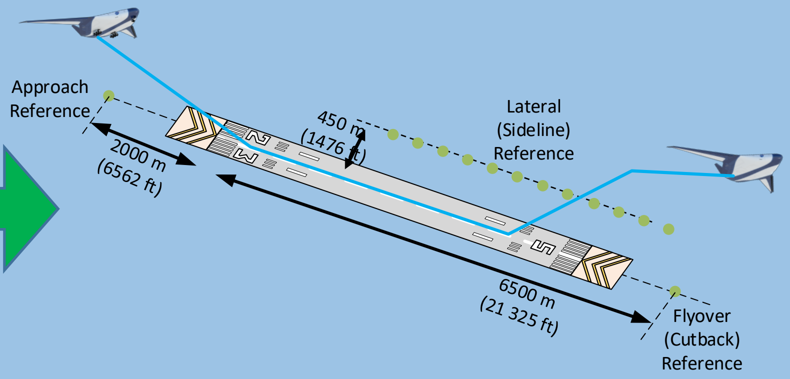
Technology Assumptions

Propulsion System Modeling (NASA GRC)



Airframe Modeling (NASA LaRC)

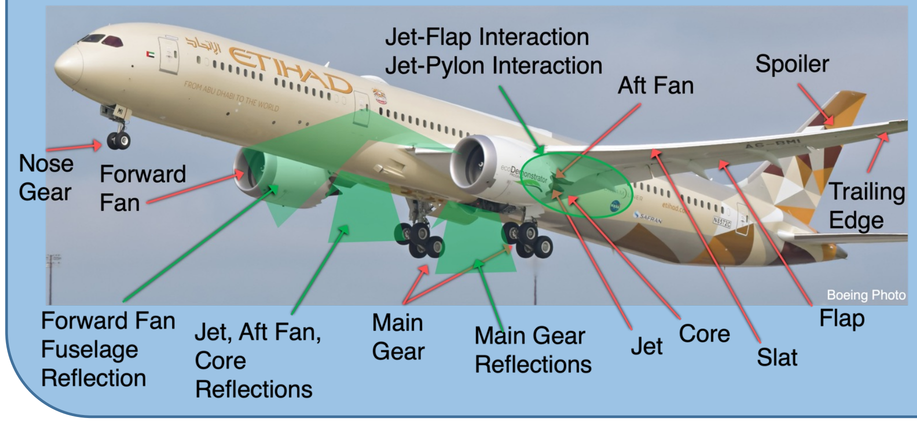
Mission Analysis (e.g., noise certification)



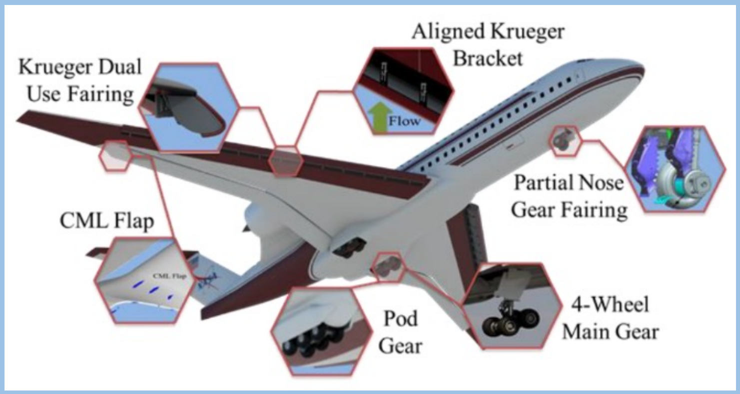
Detailed Flight Characteristics (NASA LaRC)

Inform

Aircraft System Noise Prediction (with ANOPP)

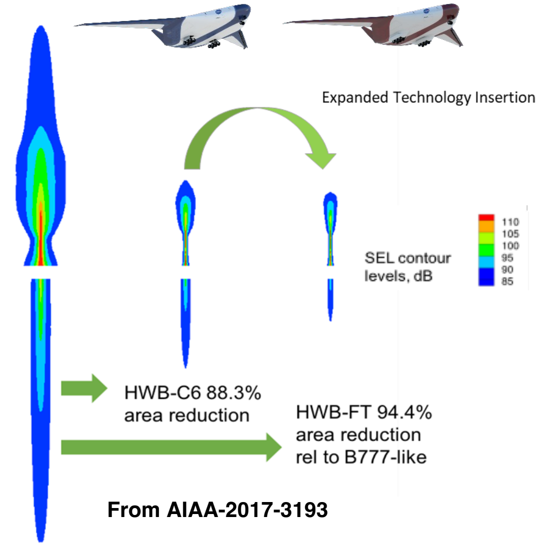


Technology Package



Results

Acoustic Assessment



From AIAA-2017-3193

3rd Generation Airframe Noise Prediction Compared to NASA/Boeing PAA & ASN 787 Flight Test Data

Guo and Thomas, AIAA 2022-2995

Landing Gear

Error in EPNL

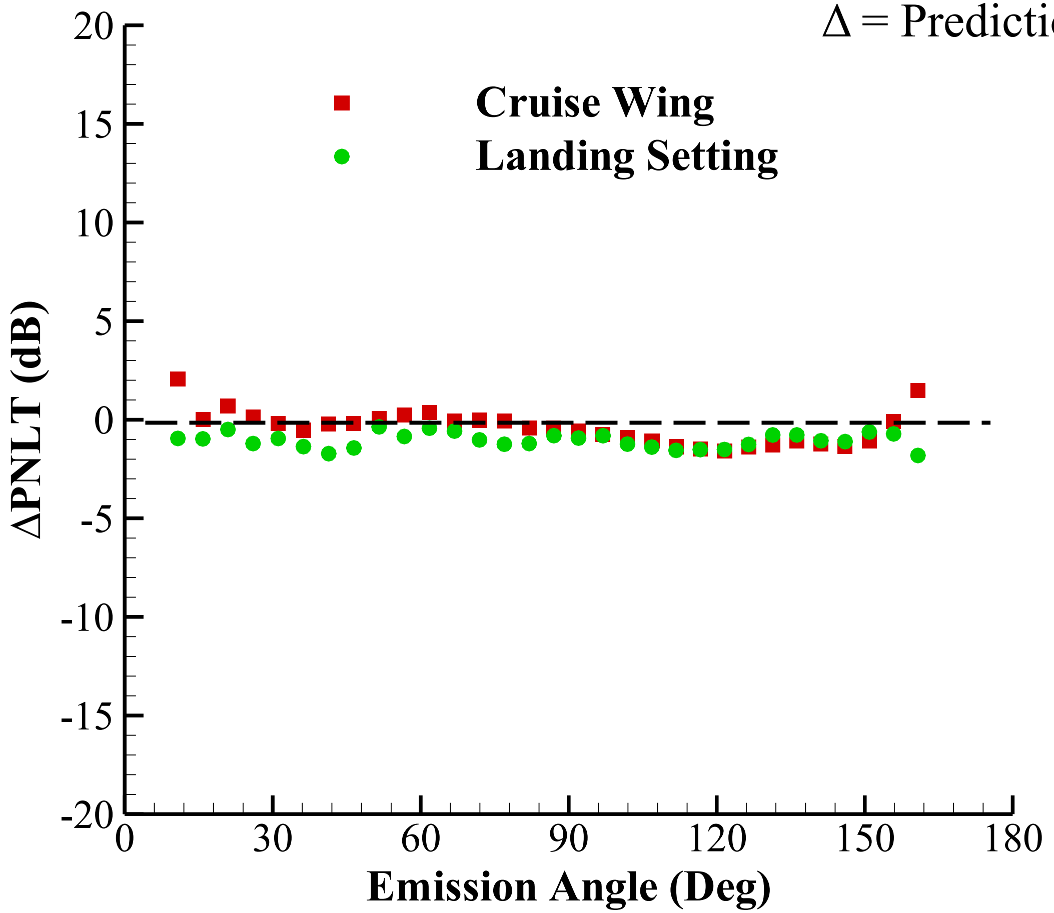
- Cruise wing: ΔEPNL = -0.5 dB
- Landing setting: ΔEPNL = -1.0 dB

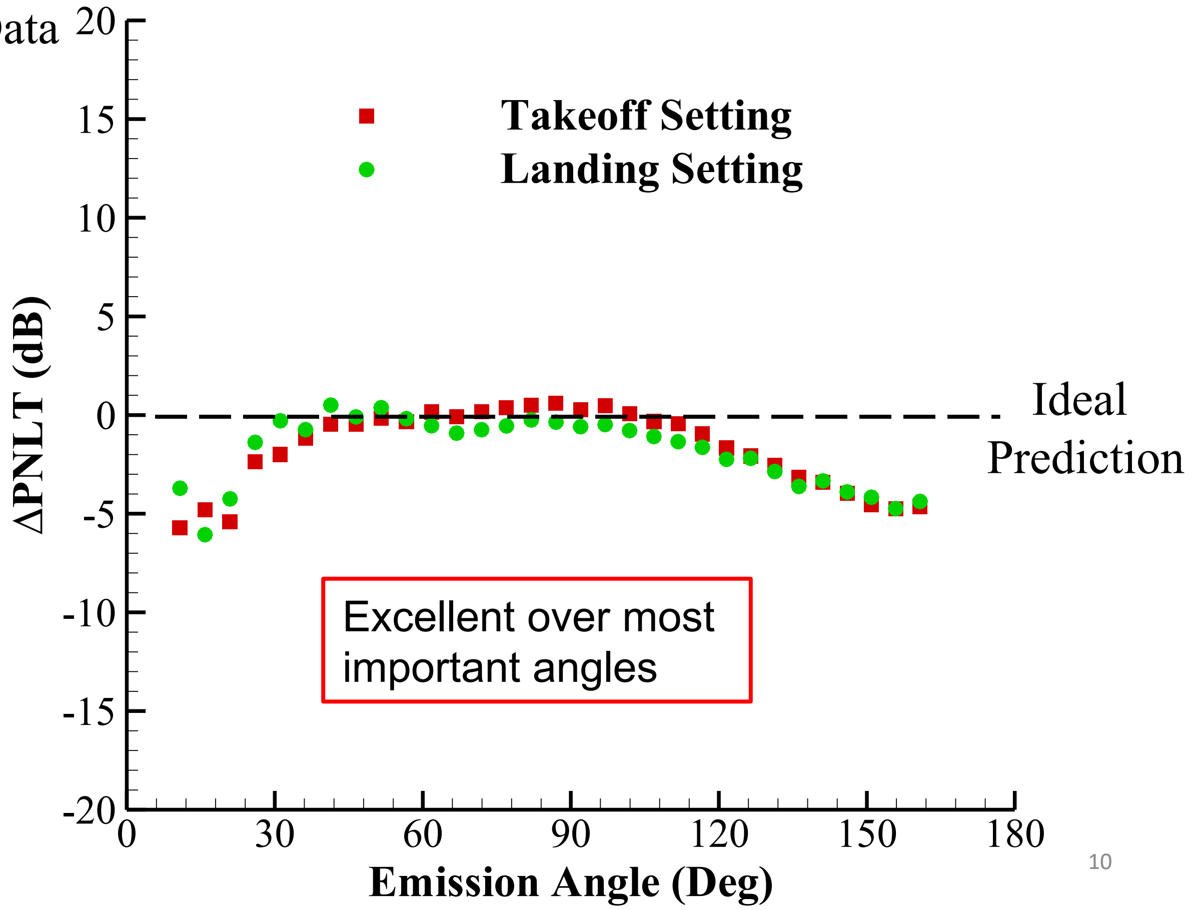
Slat

Error in EPNL

- Takeoff setting: ΔEPNL= -0.3 dB
- Landing setting: ΔEPNL = -0.8 dB

Δ = Prediction - Data

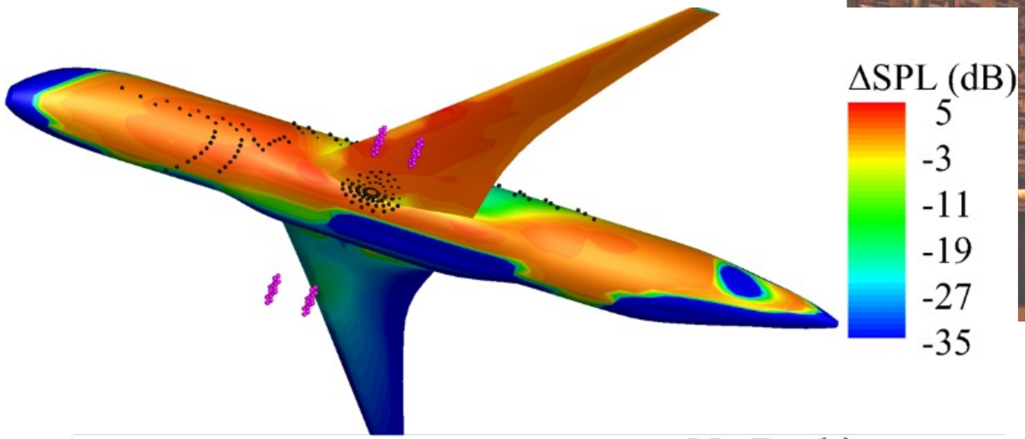


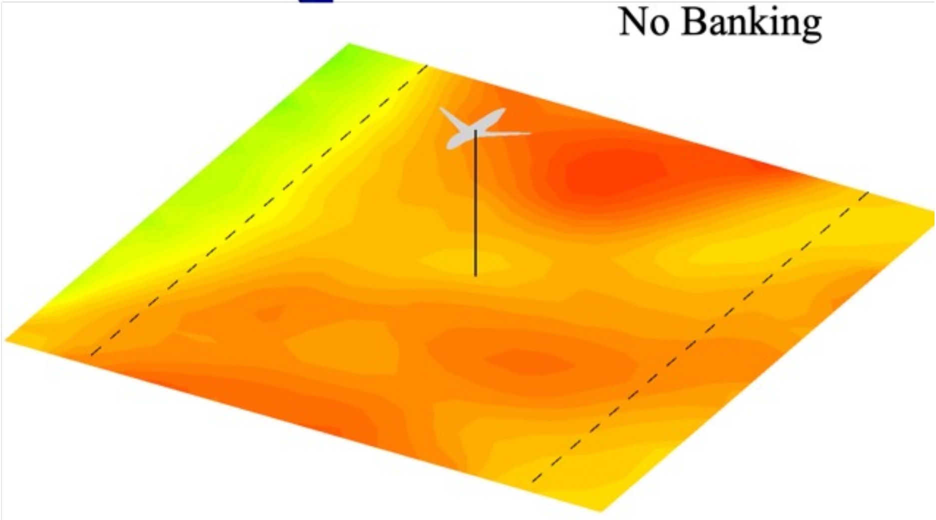


Two Methods for Prediction of PAA Scattering Effects

PAASc Prediction

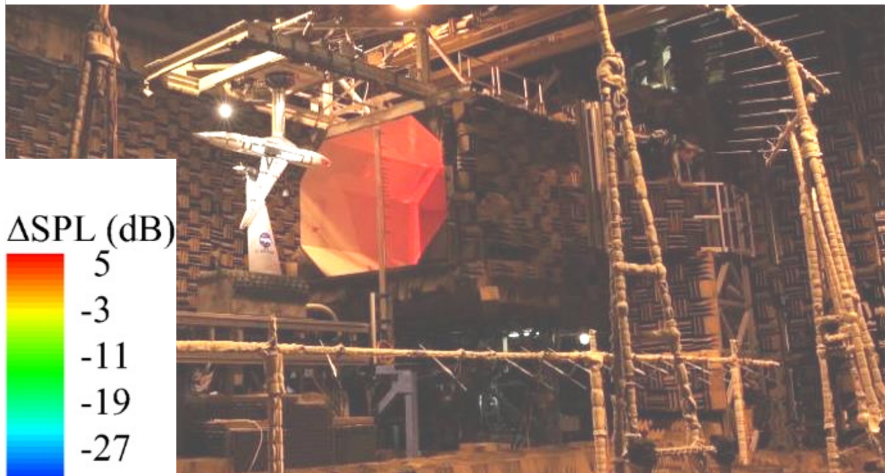
Guo and Thomas, AIAA 2022-3077





Prediction from LSAF PAA Data

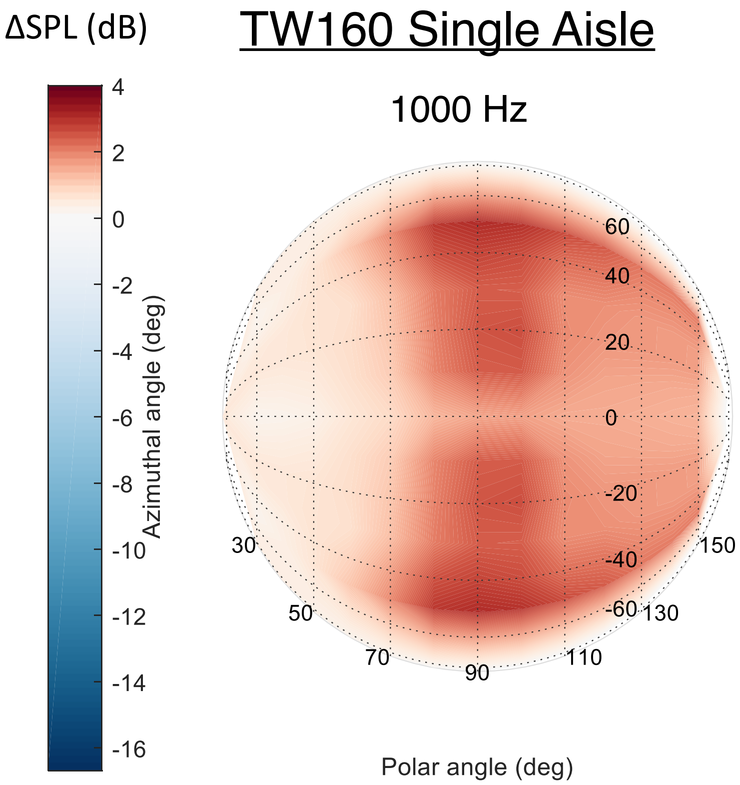
Czech and Thomas, AIAA 2013-2185



Boeing Low Speed Aeroacoustics Facility (LSAF)

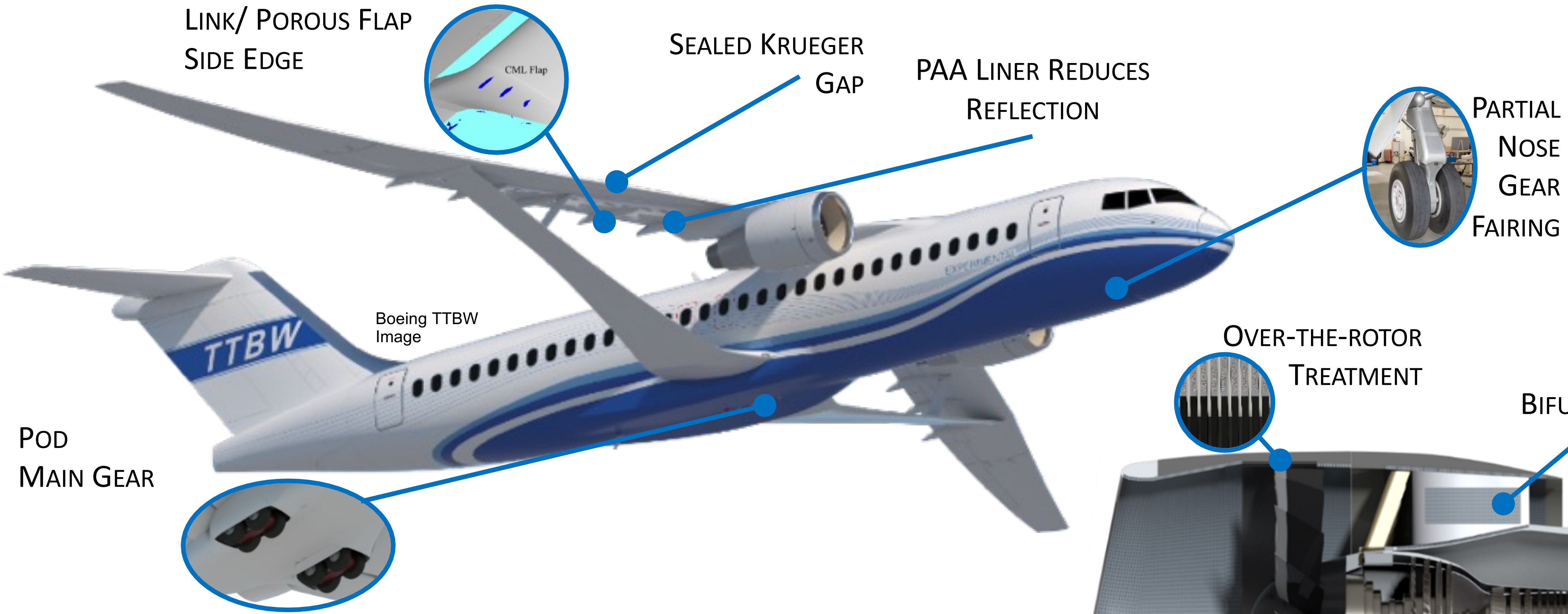
Modify engine-under-wing reflection data from LSAF data for geometry

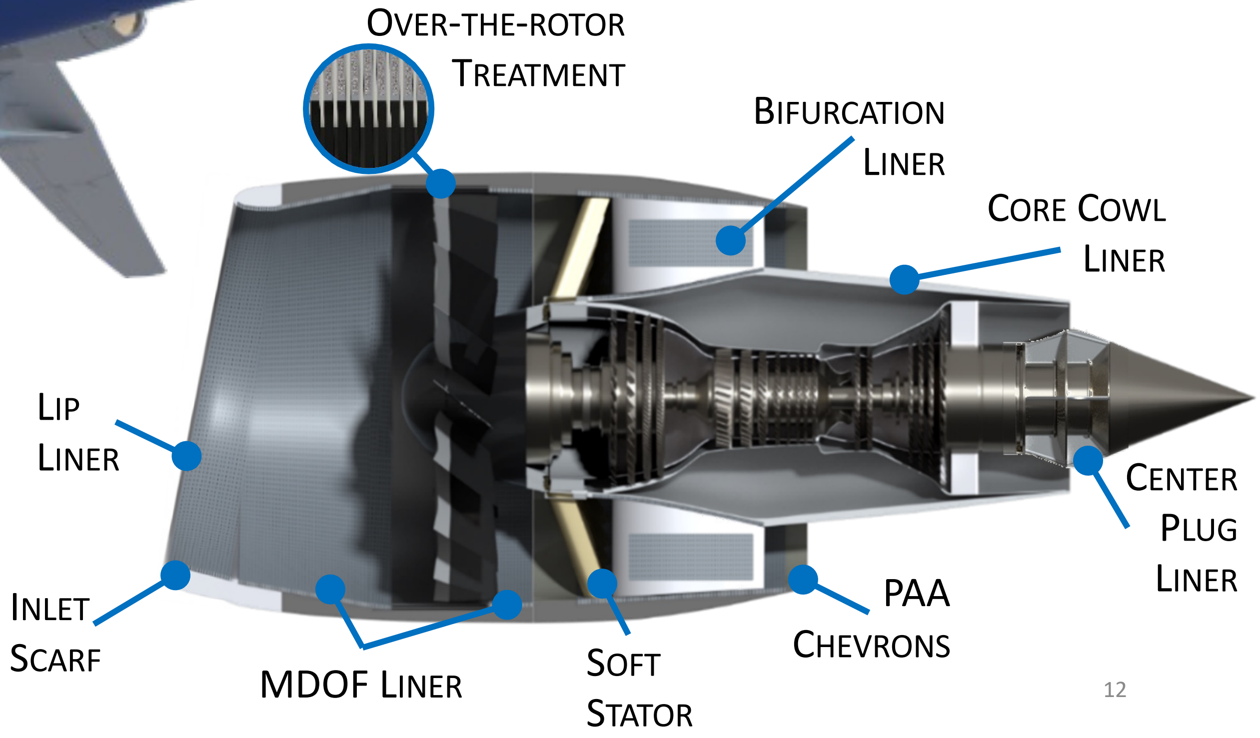
Clark, Thomas, and Guo, AIAA 2019-2427



Transonic Truss Braced Wing (TTBW) Roadmap Technologies

June, Thomas, and Guo, AIAA 2022-3049





Configuration	Roadmap Noise Reduction [EPNdB]	Resulting Cumulative Margin to Stage 5 [EPNdB]
TTBW	7.8	25.8
N3 Conventional	7.2	20.5

N2 Single Aisle TW160 Technology Roadmap

Impacts of each technology varies by aircraft due to source ranking order

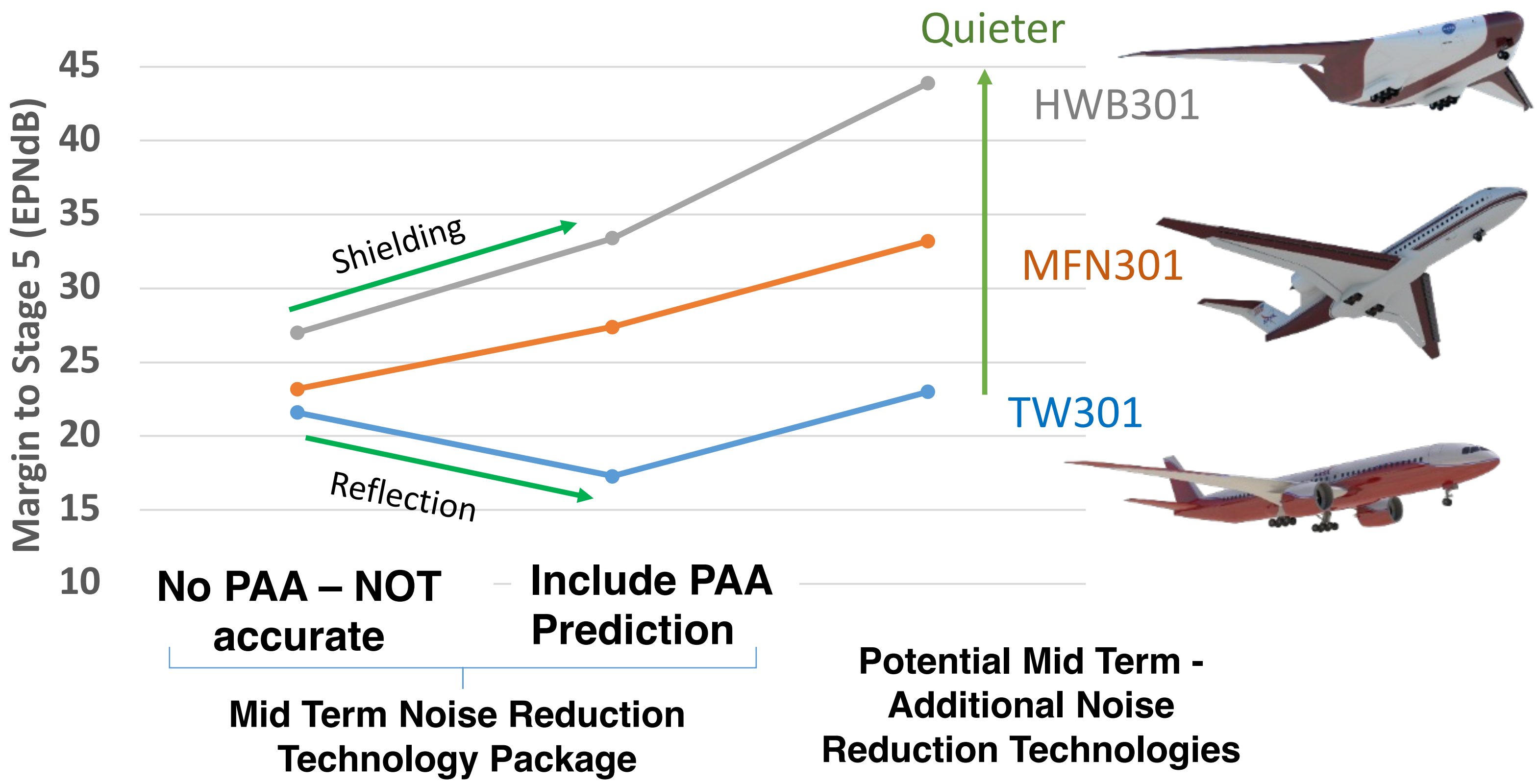
Clark, Thomas, and Guo, AIAA 2019-2427

Technology	Target Source	Effect (EPNdB)
Over-the-Rotor Liner	Fan	-1.5
Scarf Inlet	Fan PAA	-1.3
Krueger Dual-Use Fairing	Leading Edge	-1.0
Bifurcation Liner	Fan	-0.8
Center Plug Liner	Core	-0.8
Lip Liner	Fan	-0.5
PAA Liner	Fan/Core	-0.3
Continuous Mold Line Flap	Flap	-0.1
Nose Gear Fairing	Nose Gear	-0.1
Sealed Krueger Gap	Leading Edge	0.0

- 27.4 EPNdB below Stage 5
- Several technologies are needed to contribute to total aircraft noise reduction

Impact of a Low-Noise Configuration

Multiyear study on a set of equivalently modeled advanced concepts to determine the noise reduction value of configuration change.



Thomas et al. AIAA 2017-3193

Guo et al. *J of Aircraft* Vol. 56, No. 5, 2019

June et al. AIAA 2019-2428

- Total PAA effect is the largest share of the 16.1 EPNdB difference.
- Add innovative technologies including improving PAA effectiveness. Increases difference to 20.9 EPNdB cumulative.

Electrification – Potential Noise Impacts

Near Term: Commuter and regional aircraft

NASA X-57 Maxwell (demonstrator)

Some recent first flights:

- Harbour Air electrified DHC-2 Beaver
- Eviation Alice

Some concepts in development:

- Heart Aerospace ES-30 (30-pax, target EIS 2028)
- Ampaire Eco Otter (modified DHC-6 Twin Otter)

Option A

Infusion into larger transports

Option B

Conventional, Electrified Propulsion

No direct noise impact – combustor is insignificant noise source

Expanded Design Space **enabled by** Electrified Propulsion

NASA Hybrid Wing Body concept: 43.9 EPNdB cumulative margin below Stage 5 (conventional fuel), Ref. AIAA-2017-3193

NASA STARC-ABL and SUSAN concepts:

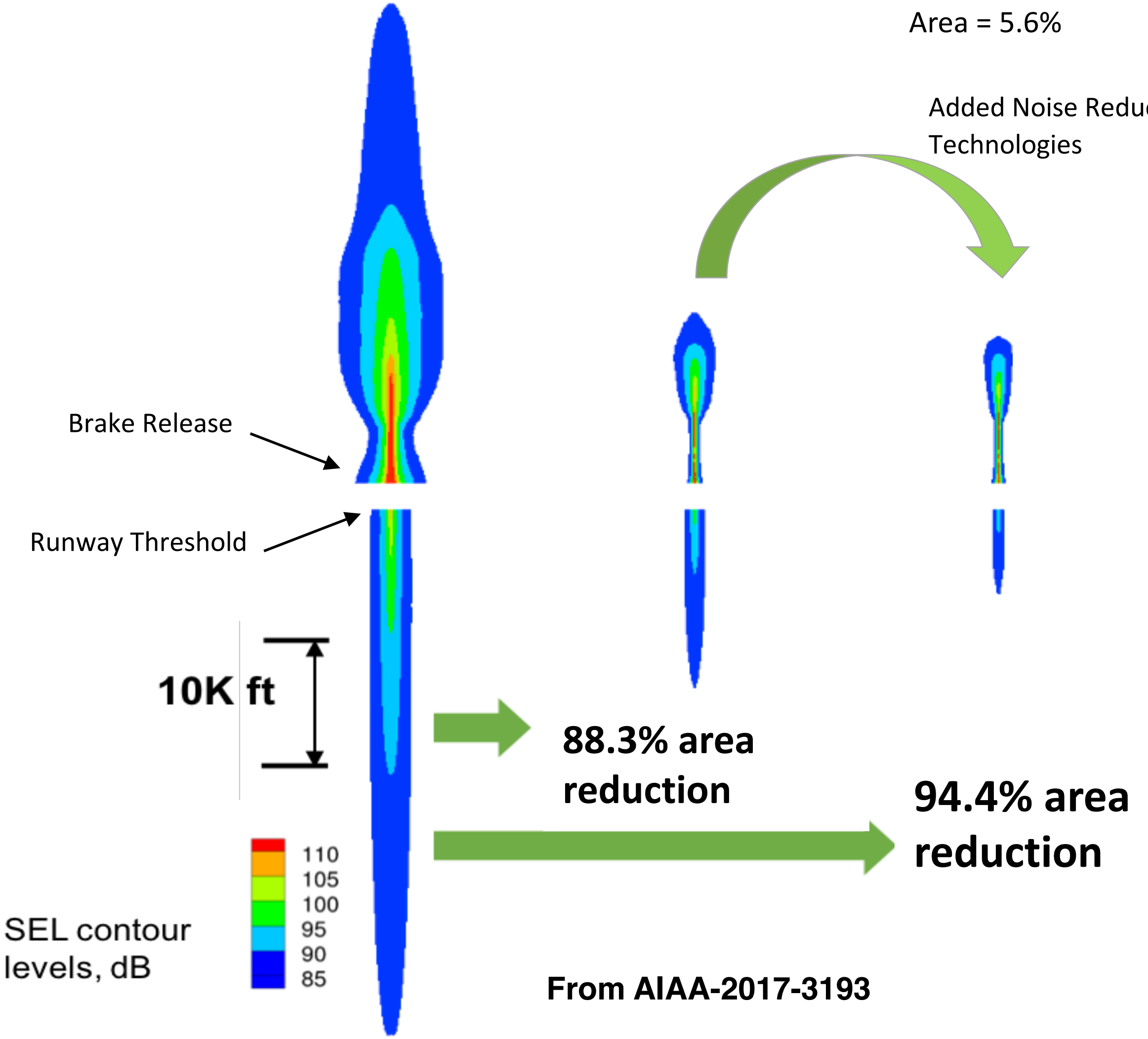
- Redistribution of propulsors offers increased efficiency and enables unconventional configurations.
- Potential exists for low noise, but additional research and analysis are needed.

Grand Opportunity to Realize a Step Change in Aircraft Noise

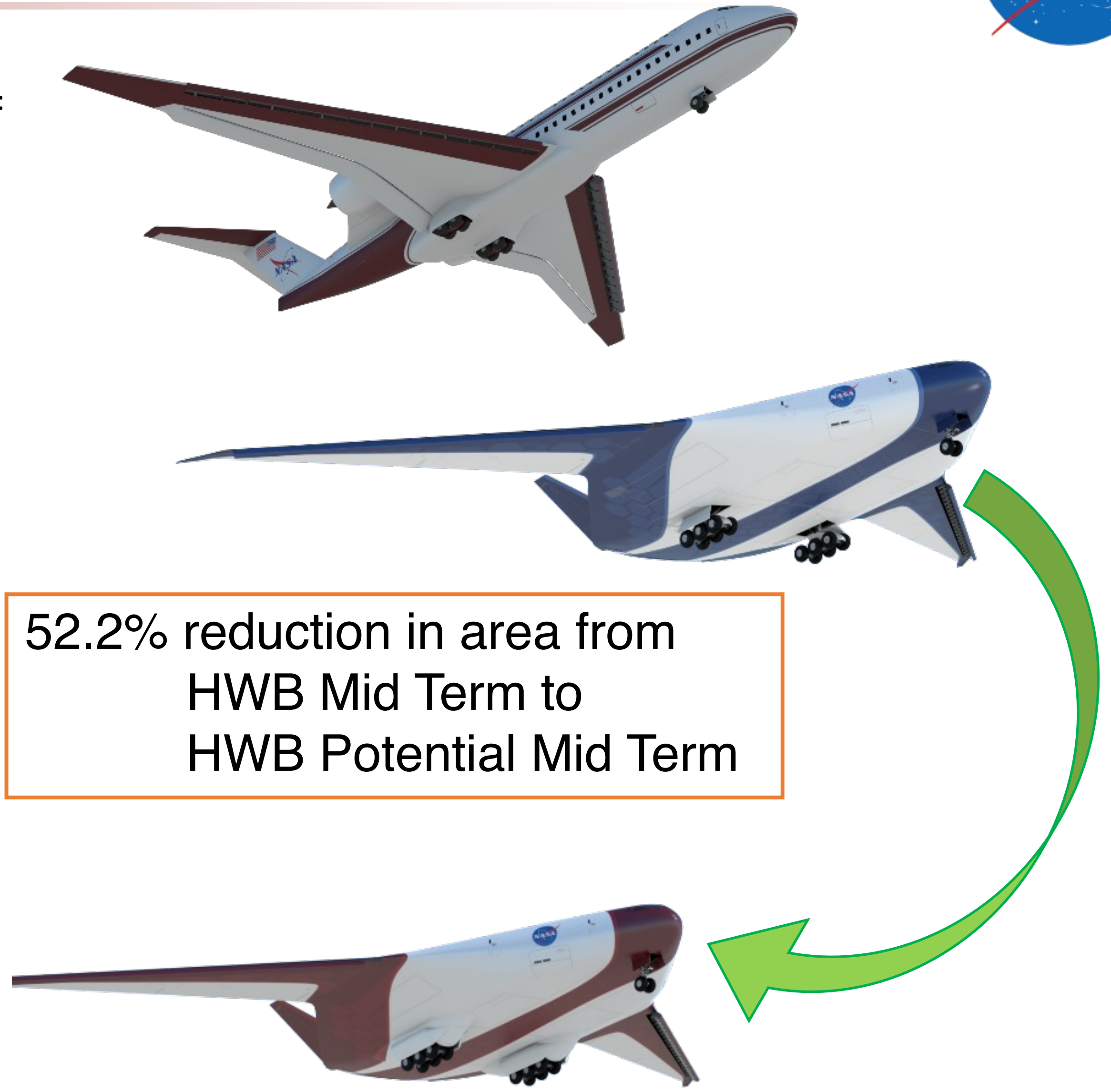
B777-like:
Approx. Stage 5
Area = 100%

HWB Mid Term (or MFN):
St5 – 34.7 EPNdB
Area = 11.7%

HWB Potential Mid Term:
St5 – 43.9 EPNdB
Area = 5.6%



From AIAA-2017-3193



52.2% reduction in area from
HWB Mid Term to
HWB Potential Mid Term

Summary – Results and Progress

- Assessment and technology roadmap findings:
  - Many advanced concepts and technologies considered
  - Future noise reduction potential:
    - About 7 dB from noise reduction technology roadmaps
    - About 7 dB from more advanced aircraft technology levels
    - Up to 11 dB from favorable configuration change
    - Significant risk and cost to development
  - Transformative technology could expand the design space and could enable configuration change
  - Can stimulate new technology with more near-term application supporting sustainable growth

- Significant improvements are being made in NASA's system noise capability, continuing to increase realism of noise prediction:
  - NASA/Boeing PAA & ASN 787 flight test research analysis
  - New physics-based methods for PAA and airframe noise
  - New liner attenuation and fan source noise methods in development

Summary – To Implement More Noise Reduction Technology

- Must increase the available portfolio of feasible noise reduction technology:
  - Supports the setting of lower regulatory noise levels
  - More likely to be proactively implemented by industry
- Emphasize:
  - Robust discovery portfolio
  - Focused development:
    - ❑ Feasibility
    - ❑ Neutral to favorable weight, fuel burn, and other impacts
    - ❑ Less complexity
  - Flight/engine research:
    - ❑ Accelerates maturation (system integration and manufacturing proof-of-concept)
    - ❑ A key tool to explore and develop unique information and innovative approaches (e.g., 2020 NASA/Boeing PAA & ASN flight research on the 787 ecoDemonstrator)
    - ❑ Drives creativity

Optimistic on potential for innovative development of both technologies and operational approaches:

- ❑ Unique information and experience with innovative approaches
- ❑ Key new prediction methods in place
- ❑ Need well-structured collaborations between NASA and industry

NASA