Refined Predictions Compared with the Propulsion Airframe Aeroacoustics and Aircraft System Noise Flight Research Test Data

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Latest in a Related Group of Publications

1) Thomas, R.H., et al., "**Propulsion Airframe Aeroacoustics and Aircraft System Noise Flight Research Test: NASA Overview**," AIAA 2022-2993.
2) Czech, M.J., et al., "**Propulsion Airframe Aeroacoustics and Aircraft System Noise Flight Test on the ecoDemonstrator 2020 – Boeing 787 Testbed Aircraft**," AIAA 2022-2994.
3) Guo, Y. and Thomas, R.H., "**Assessment of Next Generation Airframe System Noise Prediction Methods with PAA & ASN Flight Test Data**," AIAA 2022-2995.
4) Clark, I.A., et al., "**Fan Acoustic Flight Effects on the PAA & ASN Flight Test**," AIAA 2022-2996.
5) Thomas, R.H. and Guo, Y., "**Systematic Validation of the PAAShA Shielding Prediction Method**," International Journal of Aeroacoustics, 2022, Vol. 21(5-7), pp. 558-584.
6) Guo, Y. and Thomas, R.H., "**Geometric Acoustics for Aircraft Noise Scattering**," AIAA 2022-3077.
7) Clark, I.A., et al., "**Turbofan Aft-Radiated Broadband Acoustic Flight Effects**," AIAA Paper 2024-3225.
8) Nesbitt, E., et al., "**Flight Effects on Turbofan Fan Tones**," AIAA Paper 2024-3222.
9) Guo, Y., "**Phased Microphone Array on Aircraft Fuselage**," AIAA Paper 2024-3010.
10) June, J.C., et al., "**Comparison of Inlet Broadband Acoustic Liner Predictions to Quiet Technology Demonstrator 3 Flight Data**," AIAA Paper 2024-3399.

Acknowledgments

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- Exceptional efforts of The Boeing Company and the Boeing ecoDemonstrator Program in executing the acoustic flight test

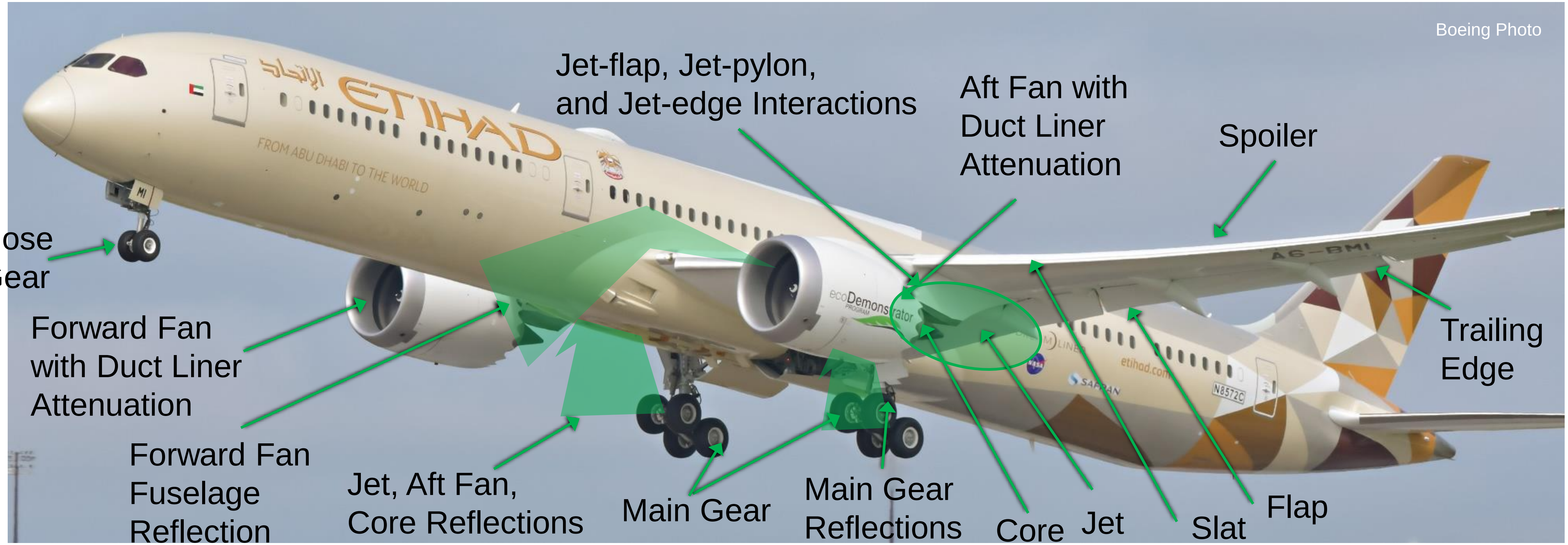
Outline

- Motivations
- Overview of the NASA/Boeing PAA & ASN 787 Flight Test
- ANOPP-Research Process and Method Improvements
- Aircraft-Level Comparisons
- Conclusions

Propulsion Airframe Aeroacoustics (PAA)
- Effects from integration of propulsion and airframe
- Both acoustic scattering and flow interaction types

Aircraft System Noise (ASN) is the total noise of the aircraft and is the combination of all noise sources and PAA integration effects

Motivations – from Current Aircraft



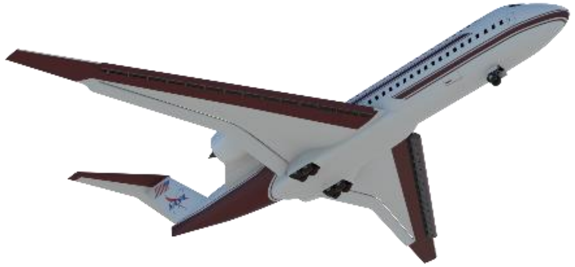
System noise must include all relevant sources and PAA effects, and accurate over:

- Range of operational conditions and maneuvers,
- 50 to 10000 Hz, and
- Polar (nose-to-tail) and azimuthal (wing tip-to-wing tip) angles

Motivations - from Current to Future Aircraft

Conventional Configuration

June et al., AIAA 2019-2428



Mid-fuselage Nacelle

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

Hybrid Wing Body

Thomas et al., AIAA 2017-3193

16 EPNdB Cumulative Quieter

- Equivalently modeled, future technology twin-aisle concepts
- Predicted noise reduction due to configuration change, largely from PAA scattering effects

- In general, many concepts under study with wide range of technologies to predict

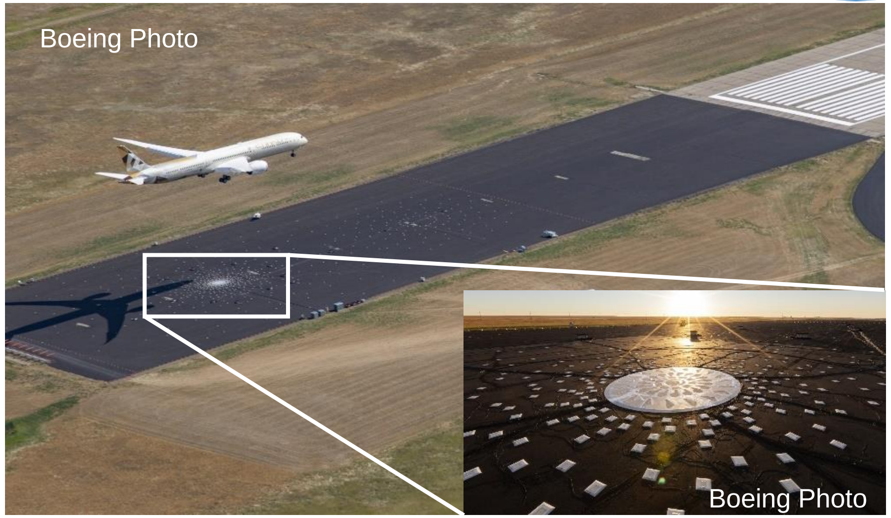
Aircraft system prediction methods, noise reduction approaches, and technologies must ultimately be verified and perform confidently for flight conditions

NASA/Boeing PAA & ASN 787 Flight Test

- Four major sections of the test matrix
  - engine powerline (and PAA) with hardwall aft duct
  - engine powerline (and PAA) with aft duct liner
  - airframe noise
  - special PAA operations: banking, offset, spoiler

- Highly integrated plan, each test condition and system with multiple objectives
  - 960-microphone phased array
  - 214 on-aircraft microphones in four distinct arrays
  - 31 far field microphones

- Data collection exceeded success criteria:
  - 20 flight hours
  - six flight days
  - 50 unique test conditions
  - 88 fully successful passes



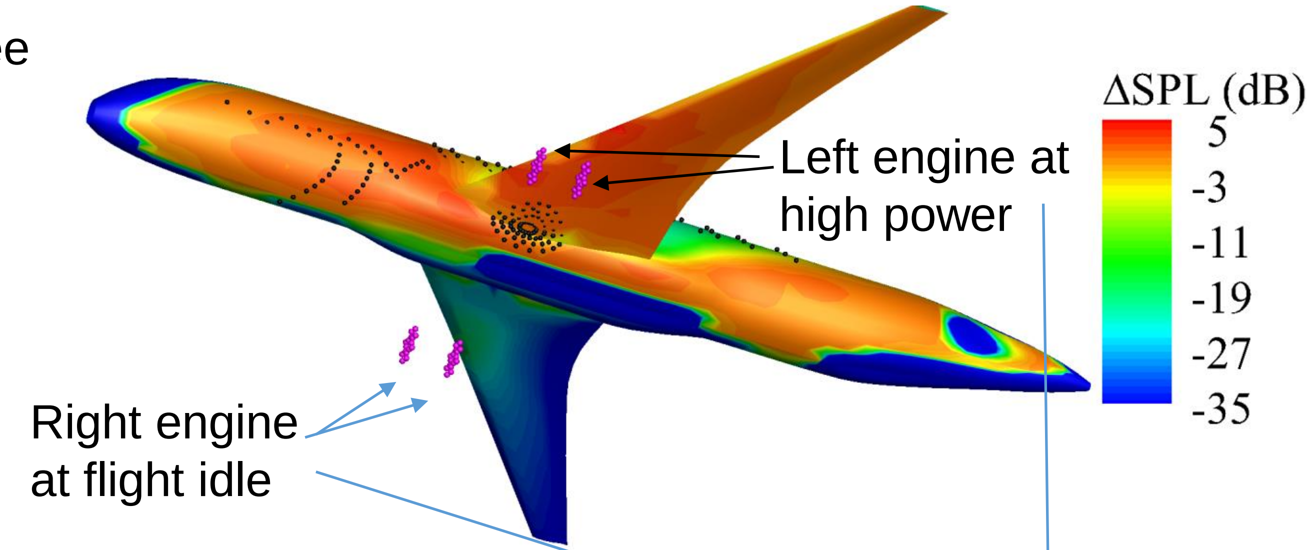
Ground phased array

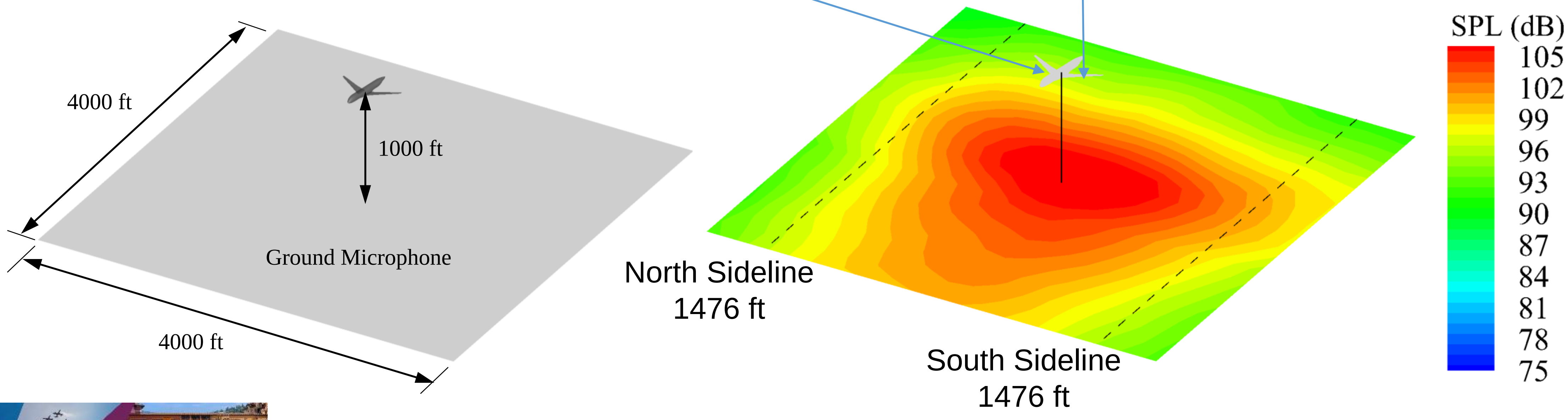
On-aircraft arrays

Example Key Technical Approach – PAA Effects on the Aircraft and in the Far Field

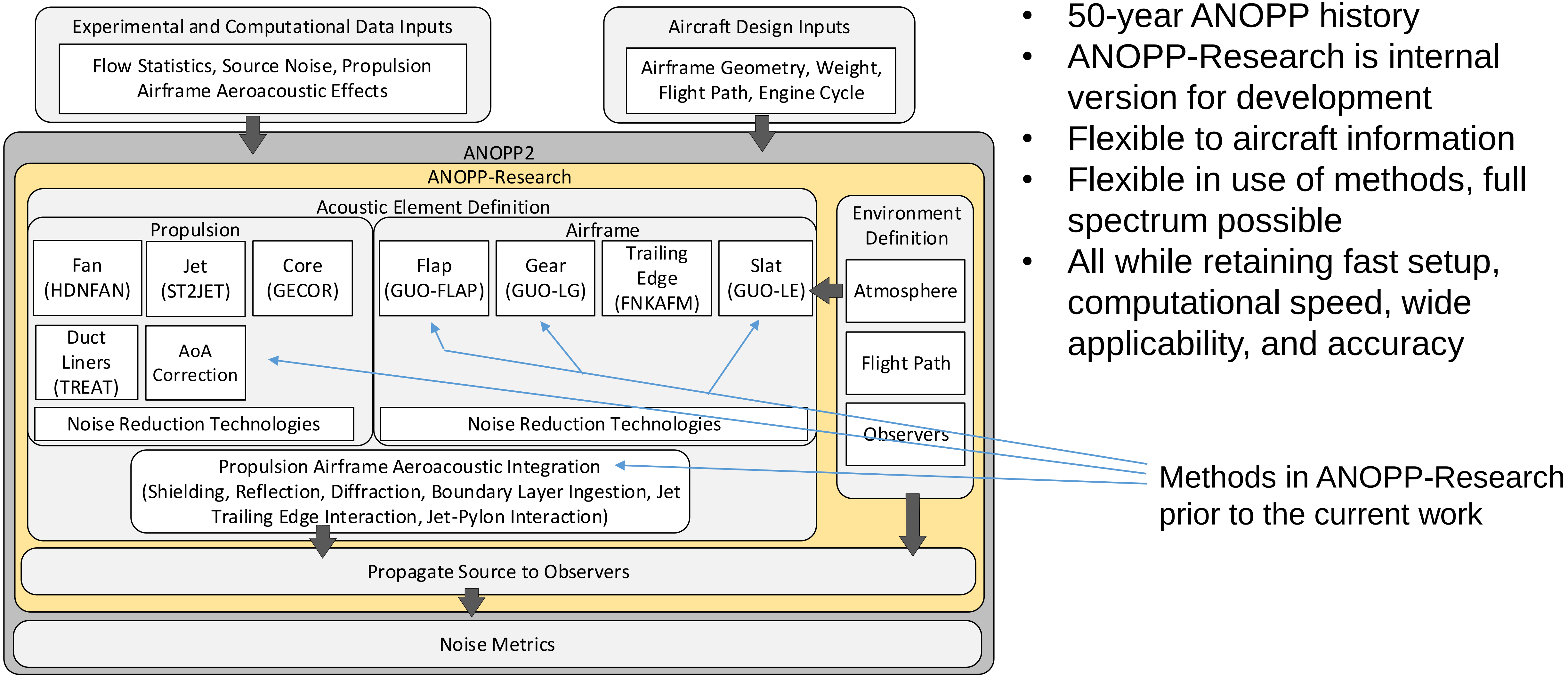
New prediction method, see Guo and Thomas AIAA 2022-3077:

Propulsion **A**irframe **A**eroacoustic **Sc**attering, PAASc





ANOPP-Research Overview



- 50-year ANOPP history
- ANOPP-Research is internal version for development
- Flexible to aircraft information
- Flexible in use of methods, full spectrum possible
- All while retaining fast setup, computational speed, wide applicability, and accuracy

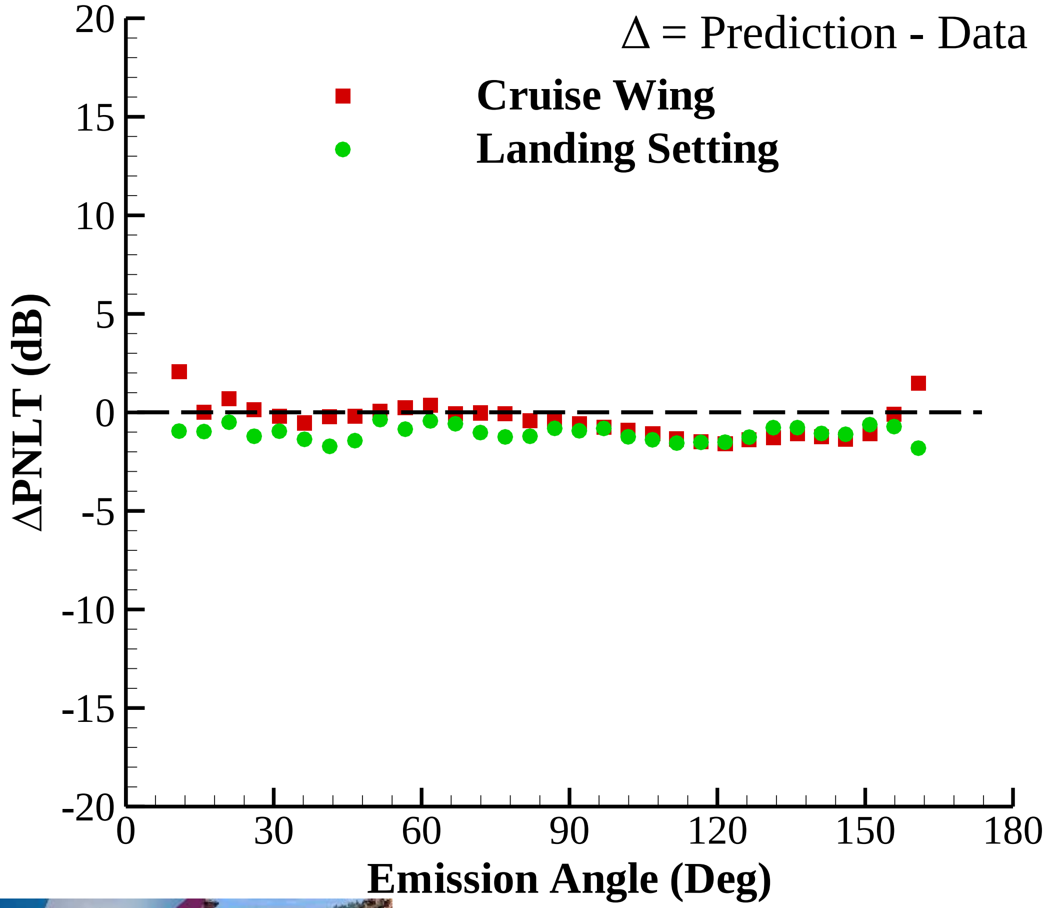
3rd Generation Airframe Noise Prediction Compared to PAA & ASN 787 Flight Test Data from 2022

Guo and Thomas, AIAA 2022-2995

Landing Gear

Error in EPNL

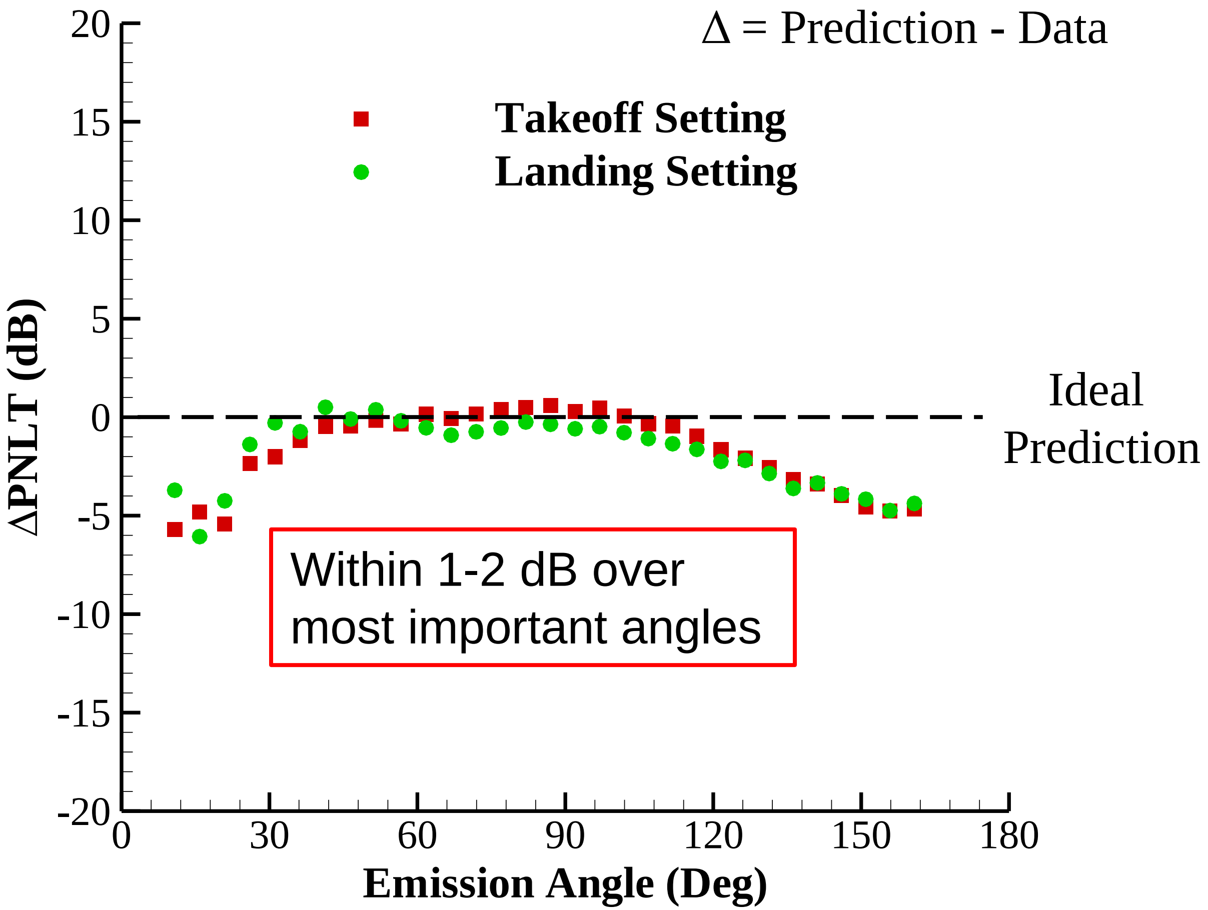
- Cruise wing: ΔEPNL = -0.5 dB
- Landing setting: ΔEPNL = -1.0 dB



Slat

Error in EPNL

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

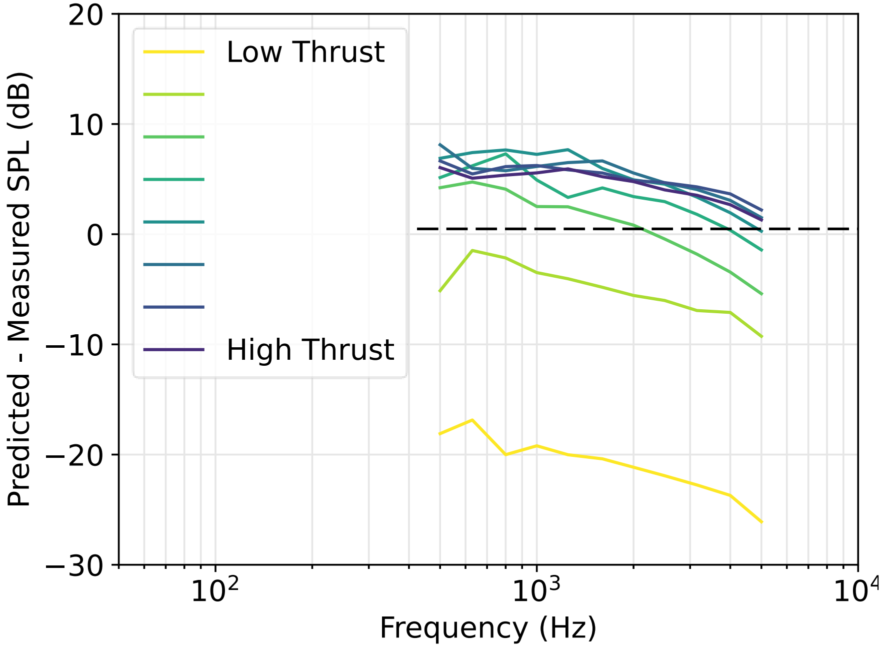


Improved Predictions to ANOPP-Research AFTER 2022

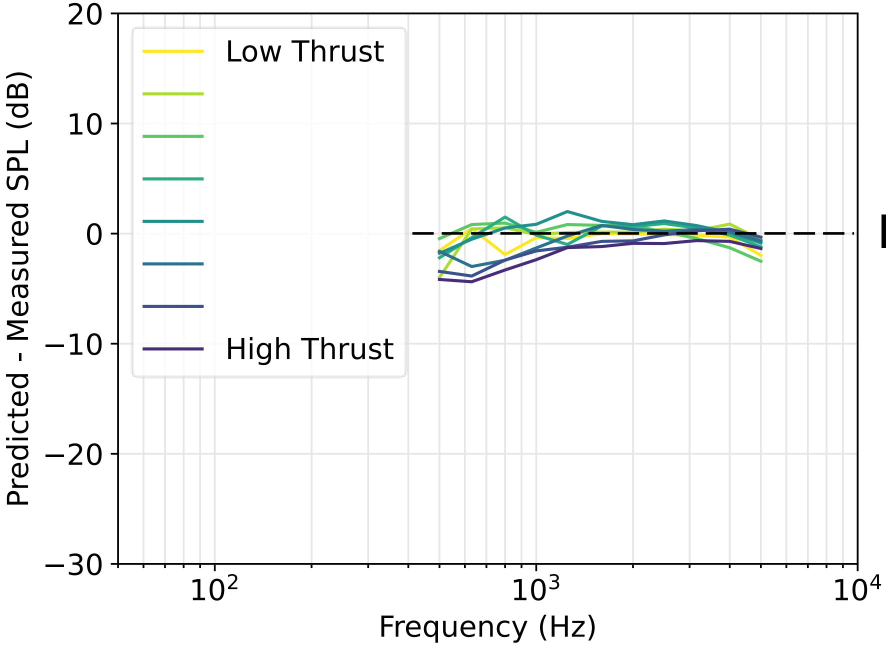
Improved Prediction Methods
- Jet source with jet-flap interaction noise
- Scattering of fan broadband noise by the physics-based PAASc method
- Proposed fan source method for aft broadband (below) and both aft- and inlet-radiated fan tones

Aft Fan Broadband for Flyover

Krejsa Prediction (used in 2022)



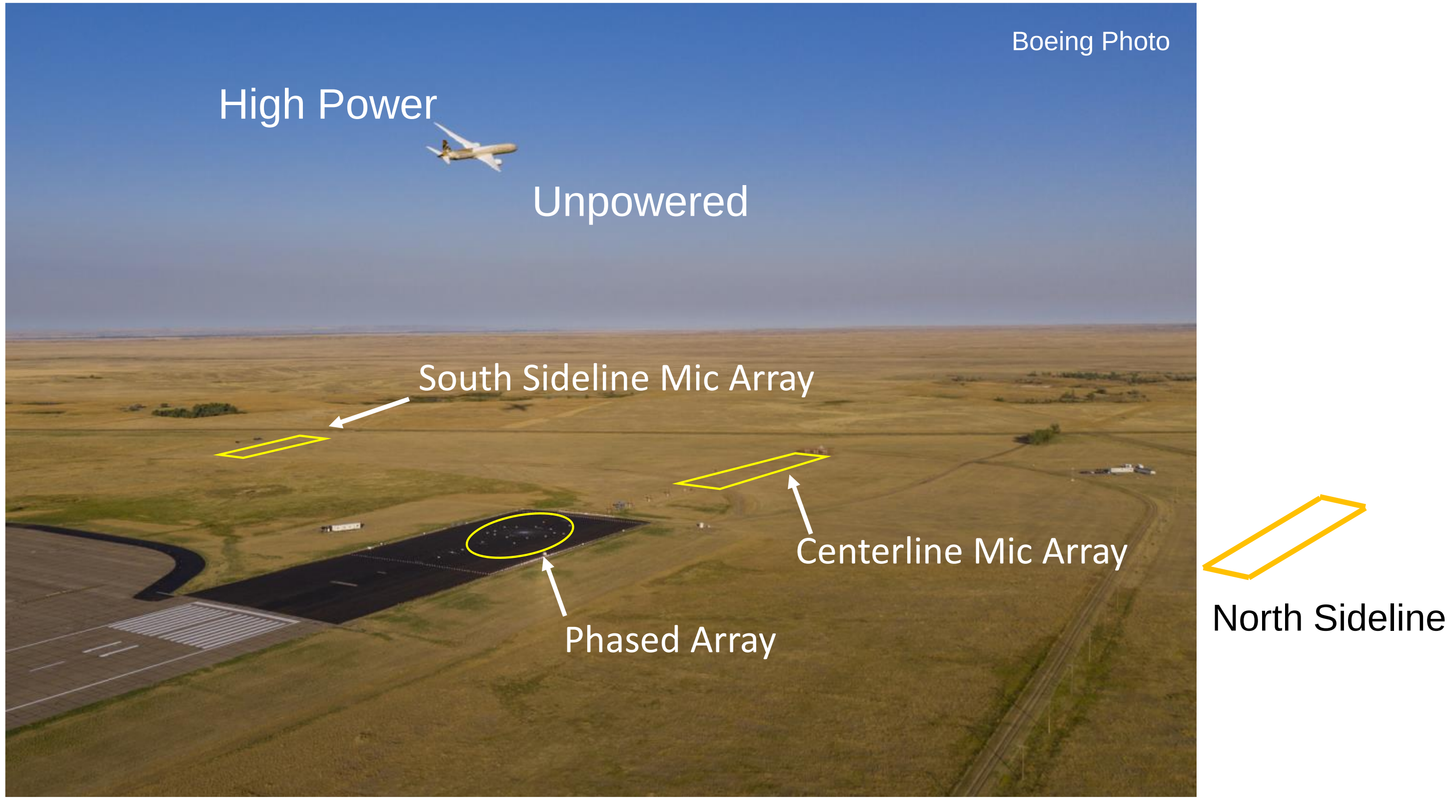
Proposed Prediction (2024)



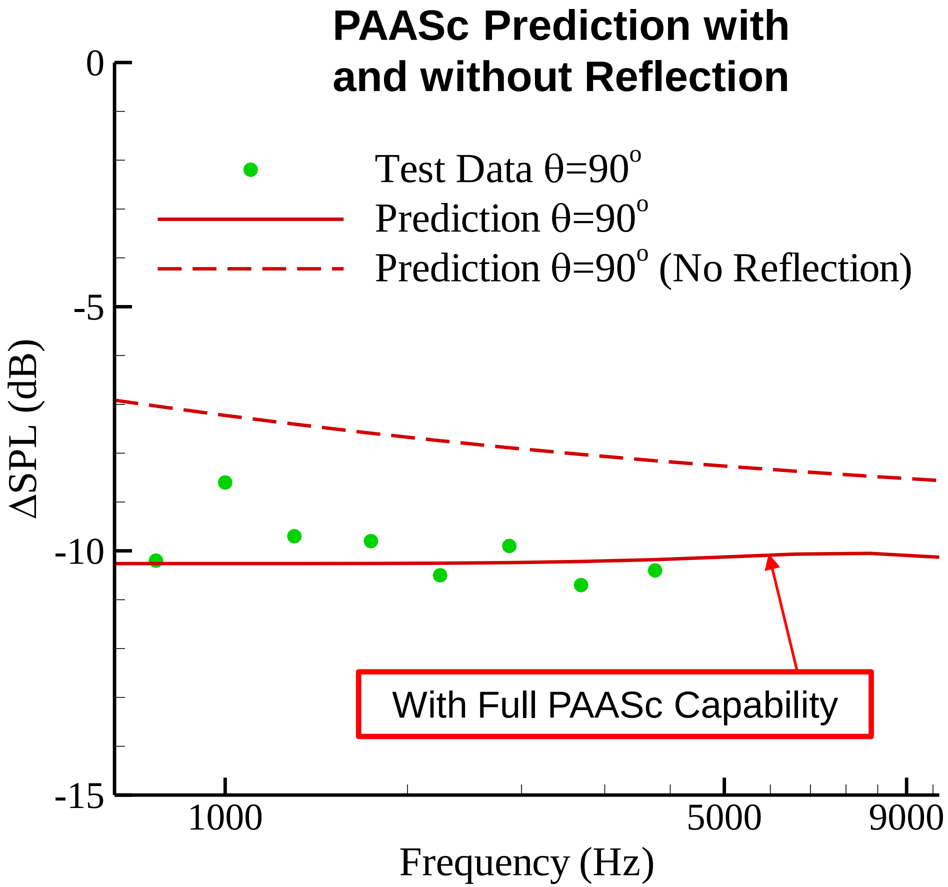
Ideal Prediction

PAASc Prediction Compared with PAA & ASN 787 Flight Data

- Banking angle 34 degrees
- Altitude 800 feet
- Mach 0.3



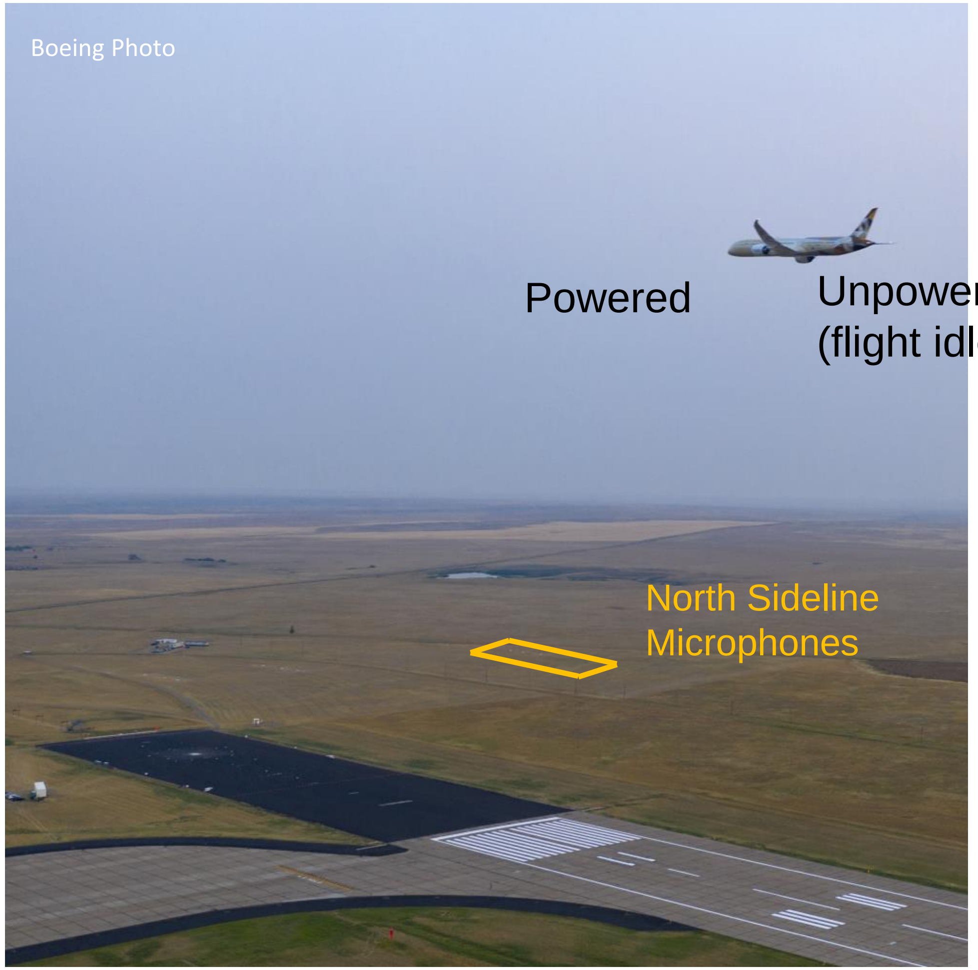
ΔSPL = North Sideline – South Sideline

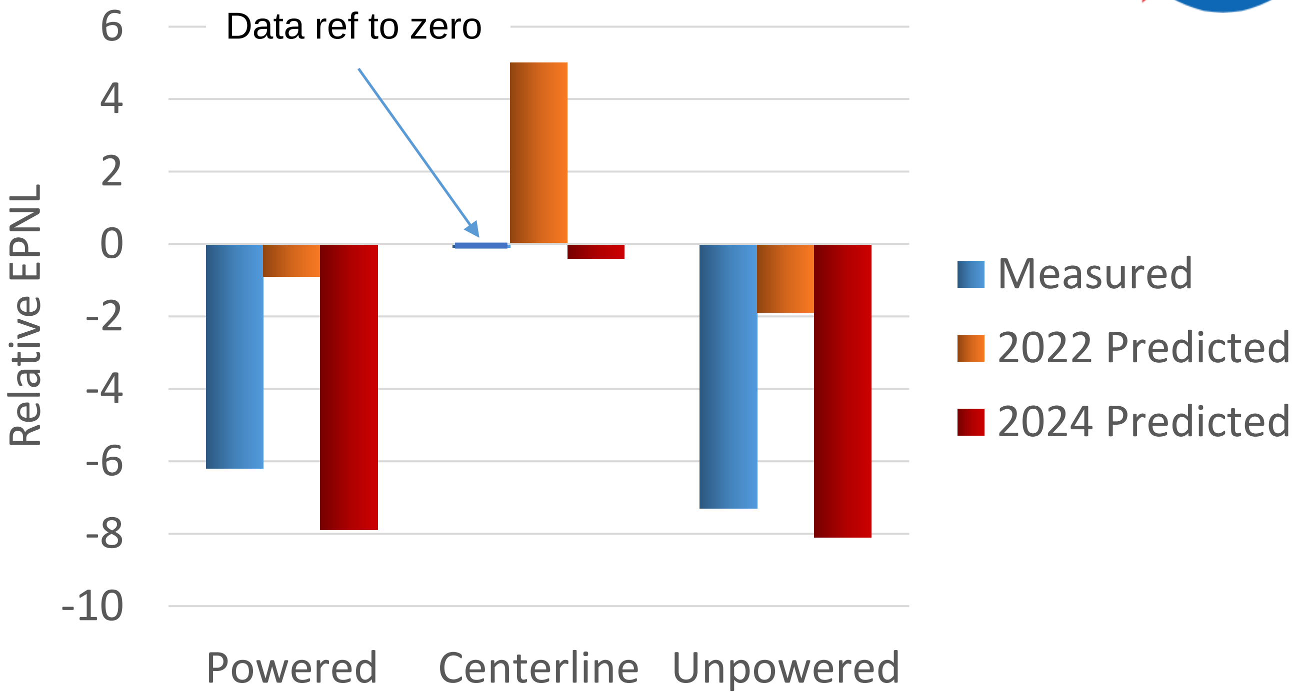


Extending Benchmark Validation of PAASc with Flight Data

Aircraft-Level EPNdB Comparisons

Straight Flyover on Centerline



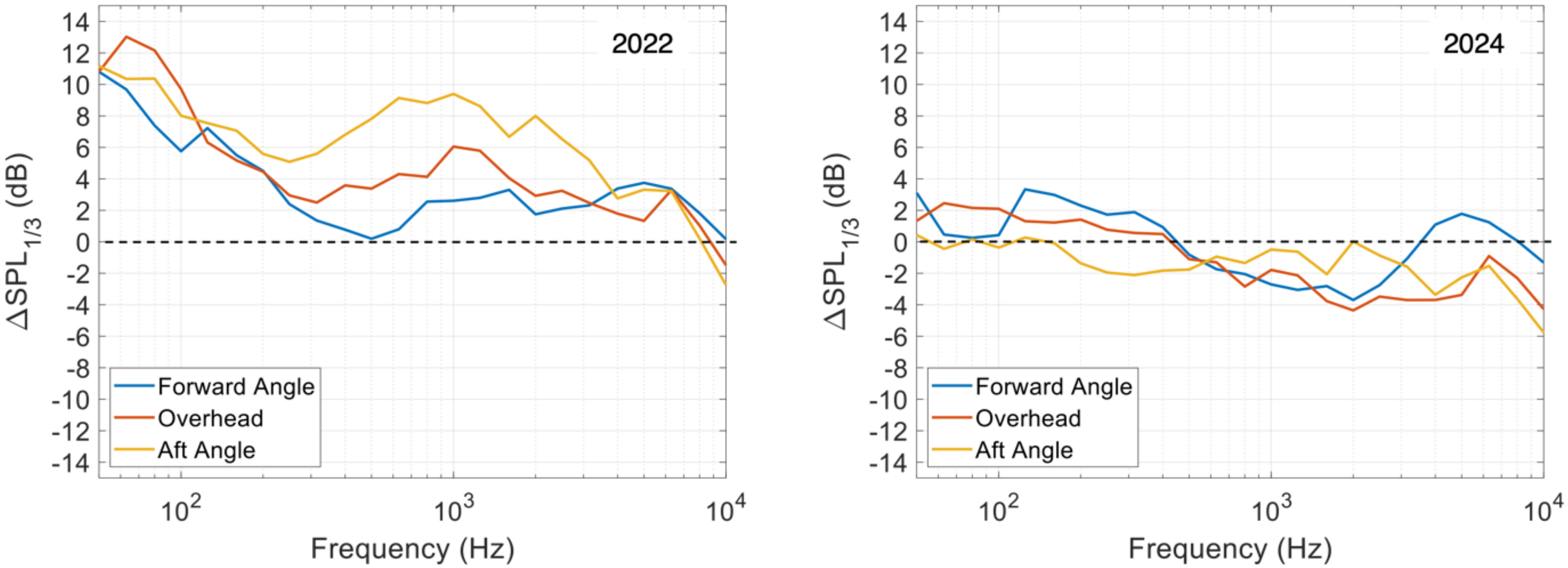


- Measured data are another demonstration and quantification of PAA effects in flight, PAASc predicts correctly

- Current predictions within 2 EPNdB of measured data (within 5.4 EPNdB in 2022)

Aircraft-Level Spectral Comparisons

High Power, Flyover



ANOPP-Research
Overprediction

Underprediction

- 15-dB difference range in 2022 reduced to 8 dB
- Strong bias to overpredict has been improved to a slight bias to underpredict
- Very significant improvement in accuracy over entire spectral range

Conclusions

- PAA & ASN 787 is a NASA dataset of enduring value
- New ANOPP-Research prediction methods are in progress
  - Guo Airframe methods
  - proposed fan aft broadband, forward and aft tones
  - jet source noise with jet-flap interaction
  - PAASc for shielding, reflection, and diffraction
- Comparisons with flight data show greatly improved accuracy
  - ability to predict PAA scattering effects for flyover and banking flight
  - spectral differences typically ±4 dB, over power range
  - on an EPNdB level, predictions now within 2 EPNdB underneath the aircraft and at sidelines even with an intentional asymmetry from one engine at idle

- Future studies in progress using major parts of the dataset not included to date
- Above new methods will be completed, more methods are in progress

NASA