Acoustic Characterization of the NASA Langley 14- by 22-Foot Subsonic Tunnel Using Single-Microphone Analysis Techniques

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Overview

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- Facility Overview
- Test Overview
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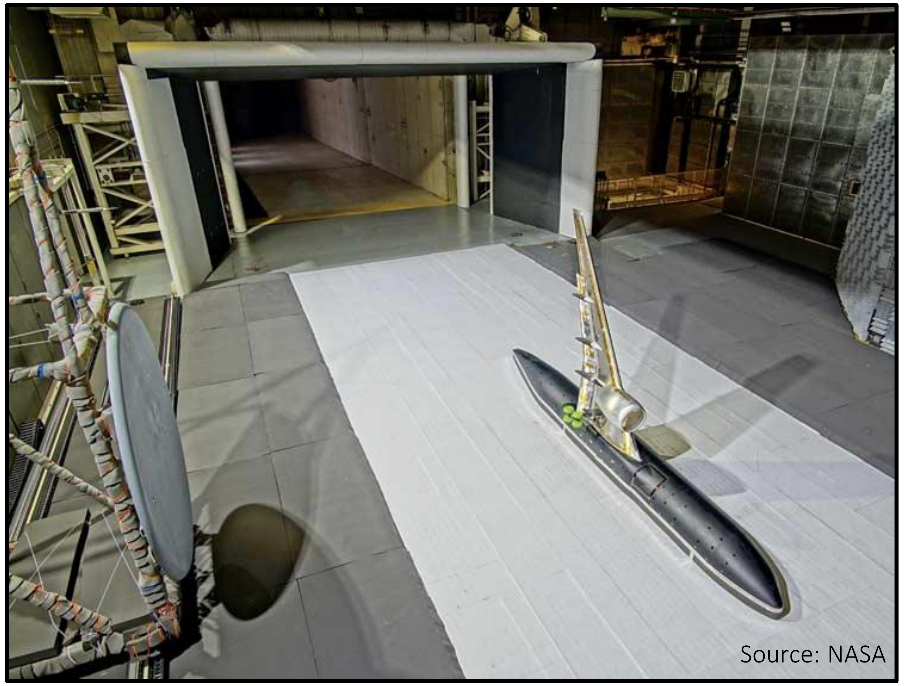
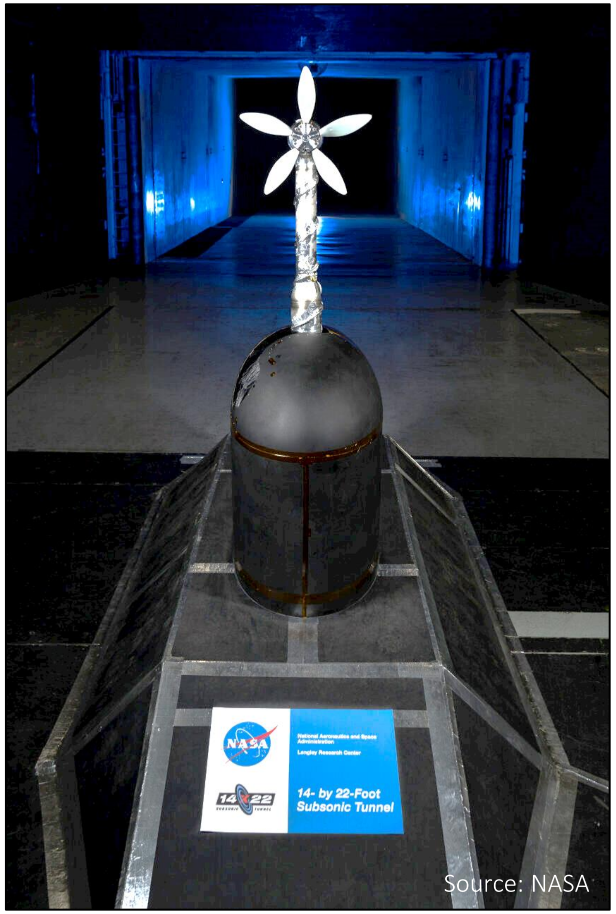
- Conclusions



Source: NASA



Source: NASA

Motivation

- Characterize tunnel for acoustic tests
  - Background noise
  - New acoustic floor treatments
- Interrogate acoustic characteristics at lower frequencies
  - Recent tests focused on airframe noise (higher frequencies)
  - Future tests will include rotorcraft and propeller/rotor noise (lower frequencies)
- Investigate methods for capturing signal in low signal-to-noise ratio (SNR) environments

Facility Overview

Tests conducted in the NASA Langley 14- by 22-Foot Subsonic Tunnel (14x22)

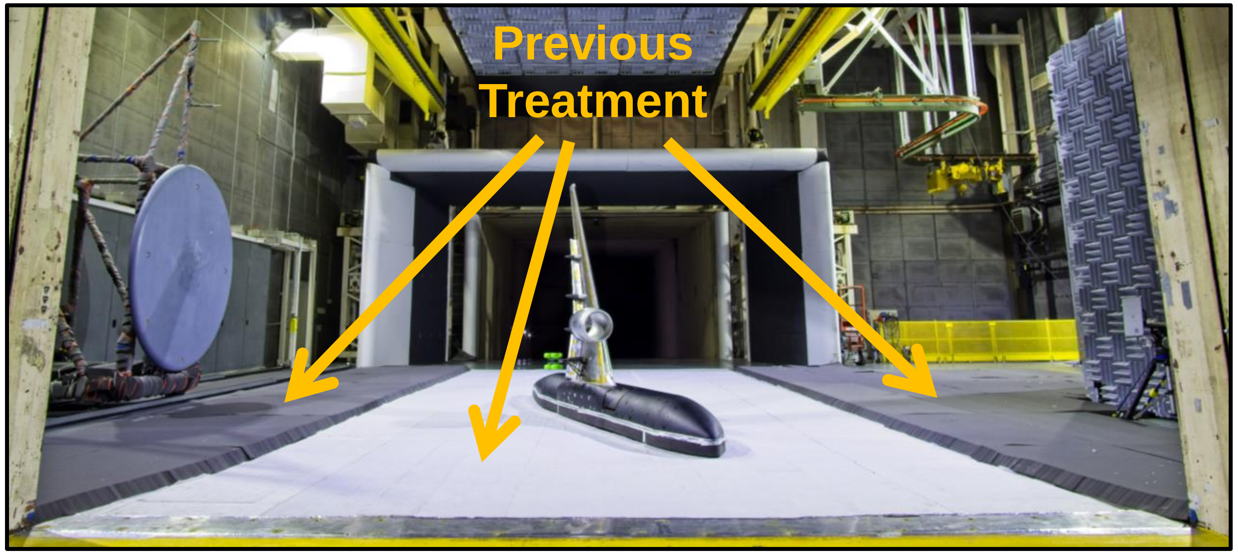
- Closed-circuit wind tunnel
- 14 ½ x 21 ¾ x 50 foot test section
- Operating speeds up to 348 ft/s
- Mach numbers from 0.02 to 0.26 (open-jet)
- Can operate in closed- or open-jet configuration
- Can be acoustically treated

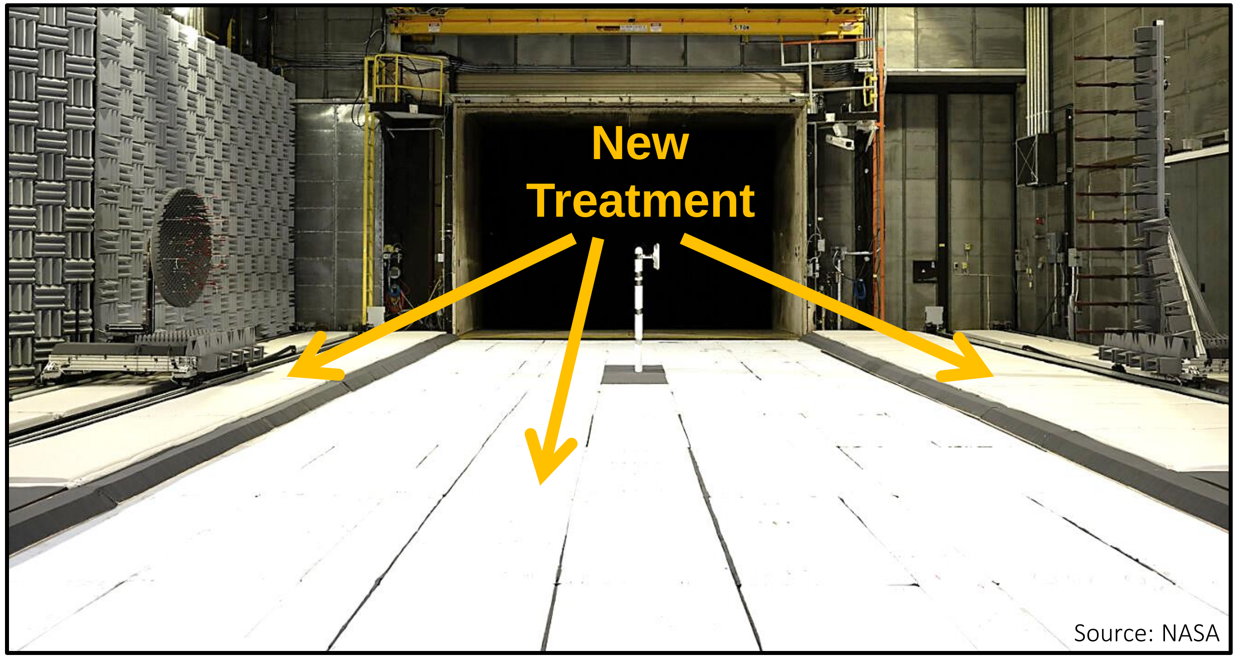
Source: NASA

Facility Overview

- Tunnel open-jet configuration is really quasi-open-jet
- New out-of-flow treatment
  - Previous treatment was foam panels glued to the floor
  - New treatment used cloth-wrapped fiberglass in bolted-down frames
  - Reusable and thicker material than old treatment
- New in-flow floor treatment
  - Still “baskets” filled with foam
  - Previous baskets tops: metal perforate sheets covered with adhesive-backed felt
  - New basket tops: no perforate sheets and nonadhesive felt stretched over top
- Comparison of new vs previous treatment in upcoming publication (Zawodny et al. 2024)

Source: NASA





Source: NASA

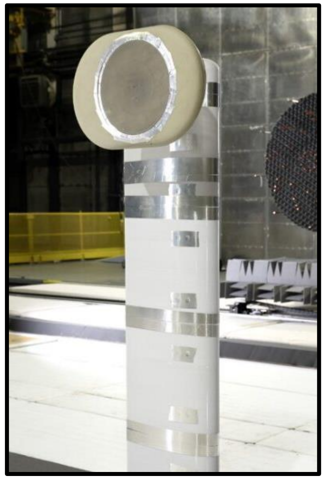
Test Overview

- Two microphone arrays on traverses outside the flow
  - Linear tower array with 11 mics
  - Phased array with 55 mics (companion paper, Houston et al.)
- Two test set-ups
  - Static testing: reflectivity
  - Flow-on testing: background flow noise
- Two static noise sources
- Two fairing-mounted in-flow sources

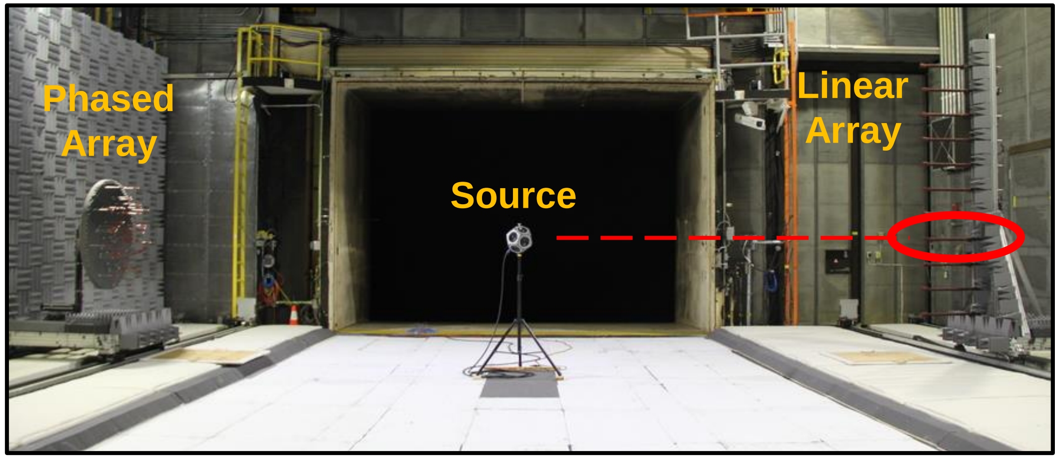
Static Directional

Static Omnidirectional

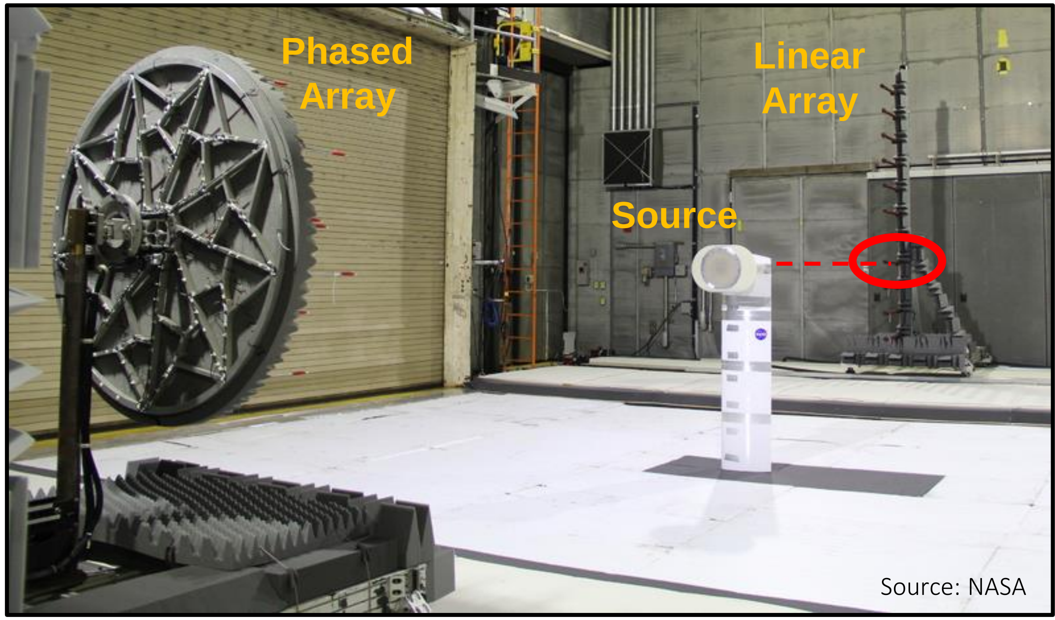
In-Flow



Static Testing

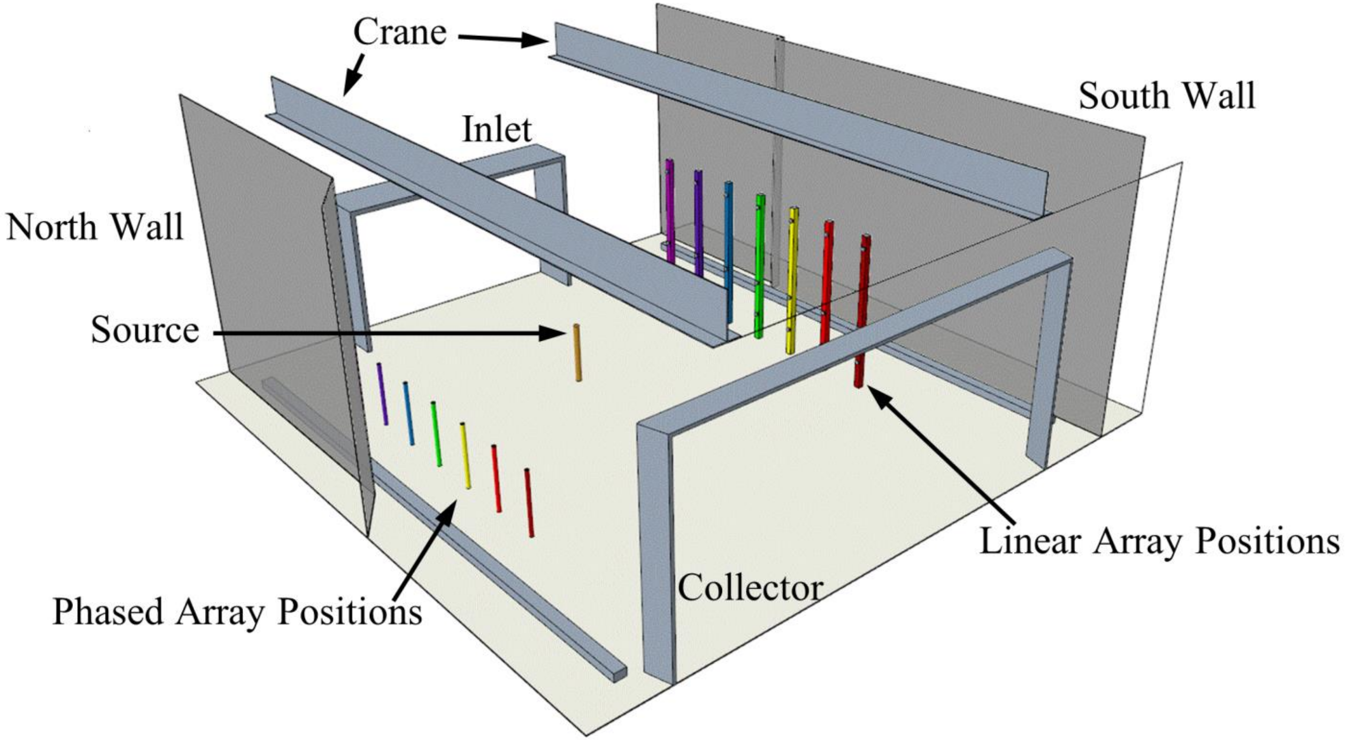


Flow-On Testing



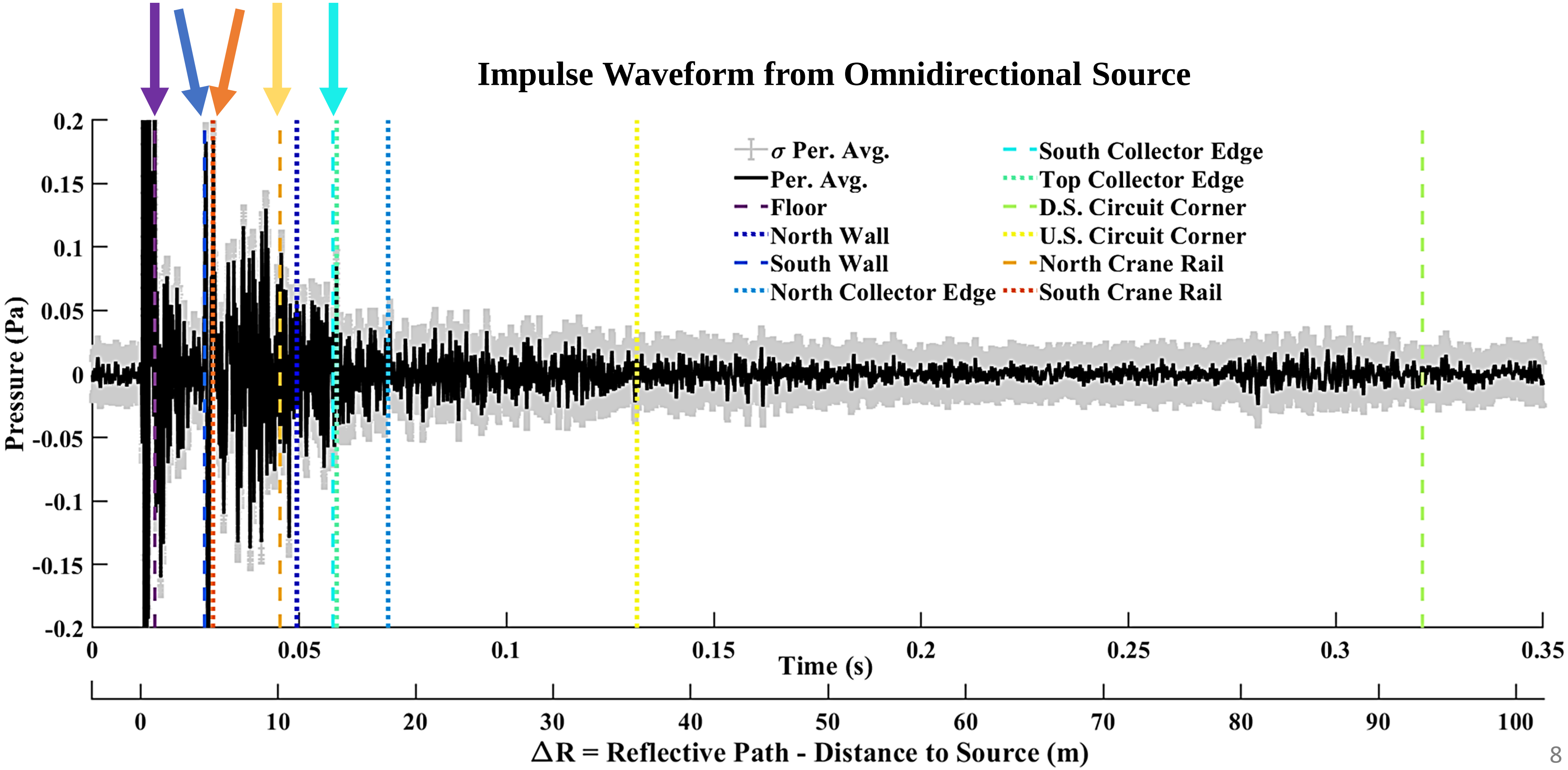
Reflection Identification

- Rudimentary computer model of open-jet test section created
  - Based on nominal measurements
  - Only captured major structures
- Model used to predict propagation paths
  - Basic equal-angle reflections
  - Only captured most direct paths



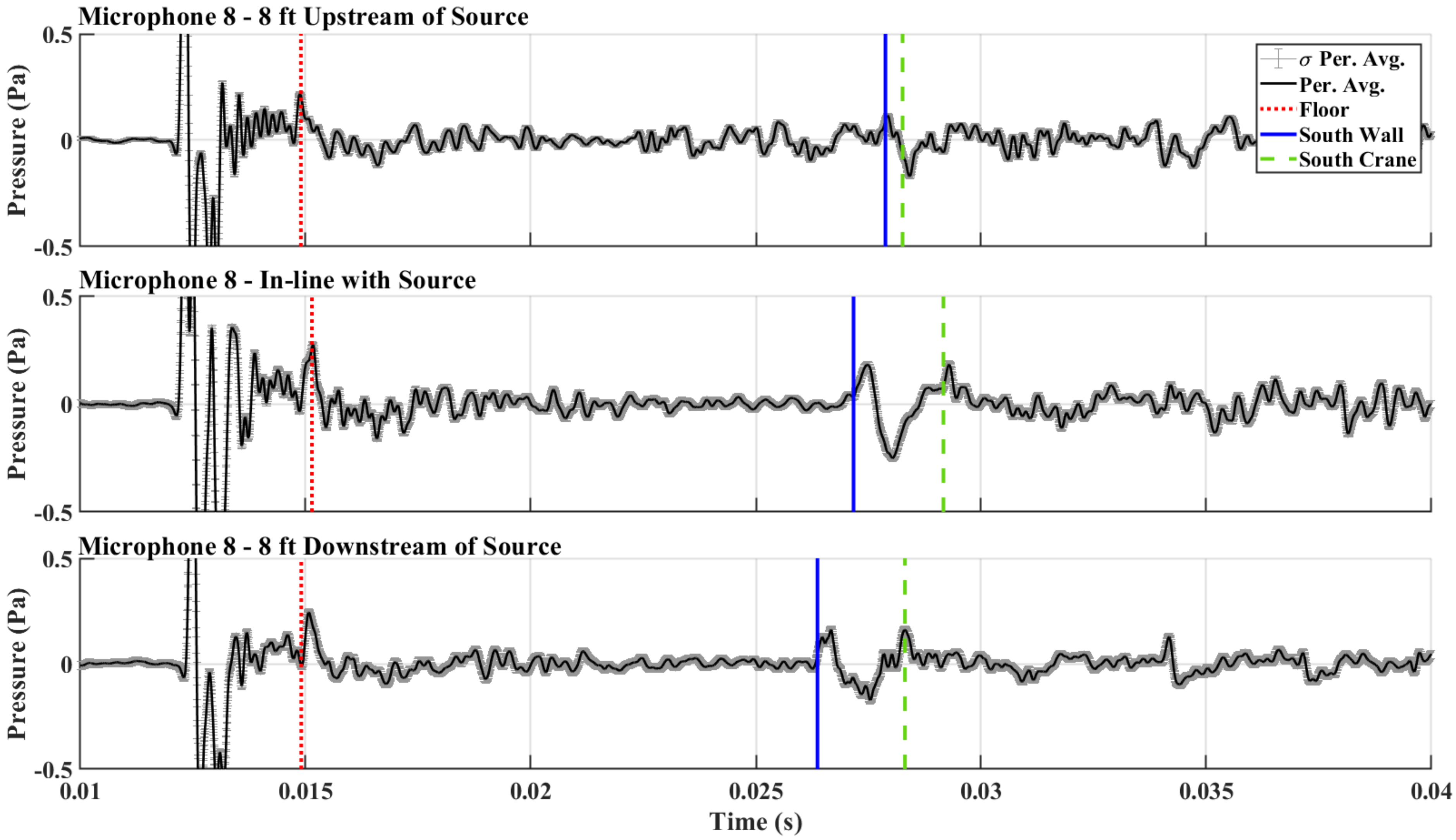
Reflection Identification

- Simple model was able to capture major reflections:
  - Floor
  - South wall (behind array)
  - Crane rails
  - Collector edges



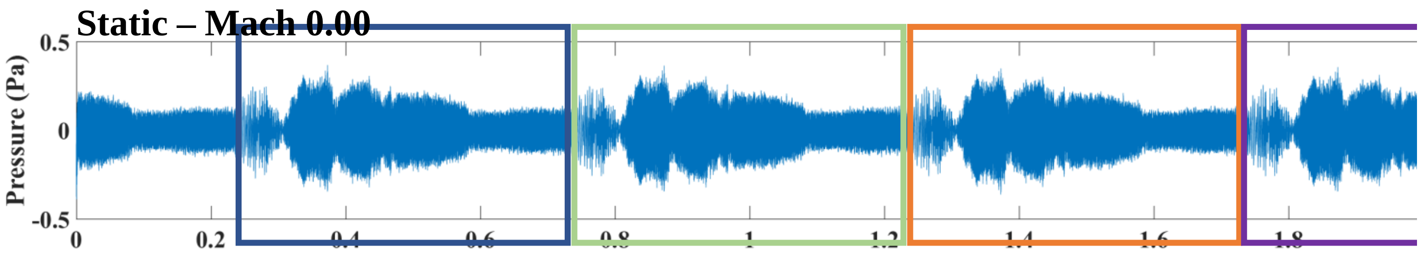
Reflection Identification

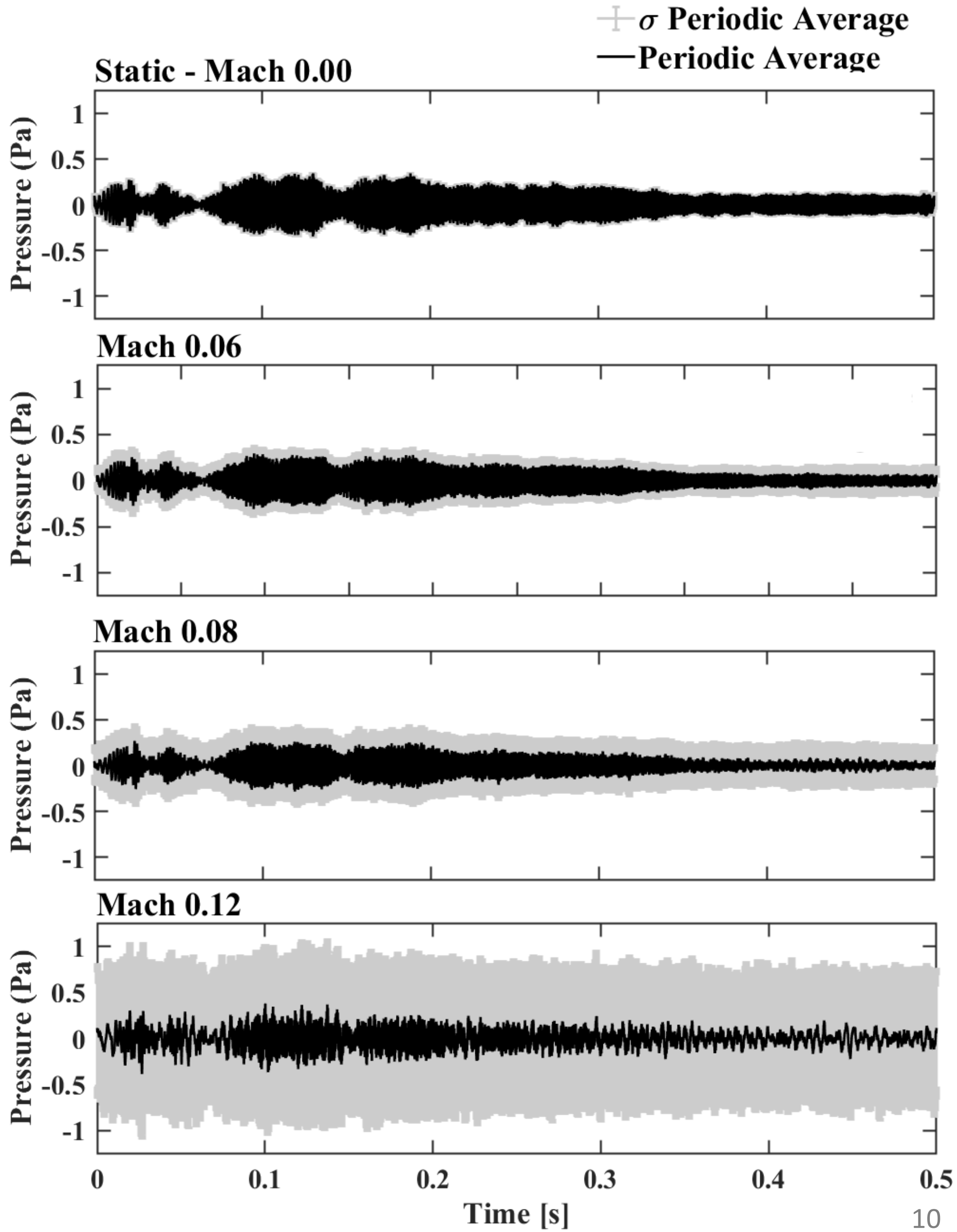
- Simple model also captured motion of array
- Floor and south crane were symmetric for symmetric motion about source
- Also captured change in depth of south wall (behind array) at upstream location



Periodic Averaging

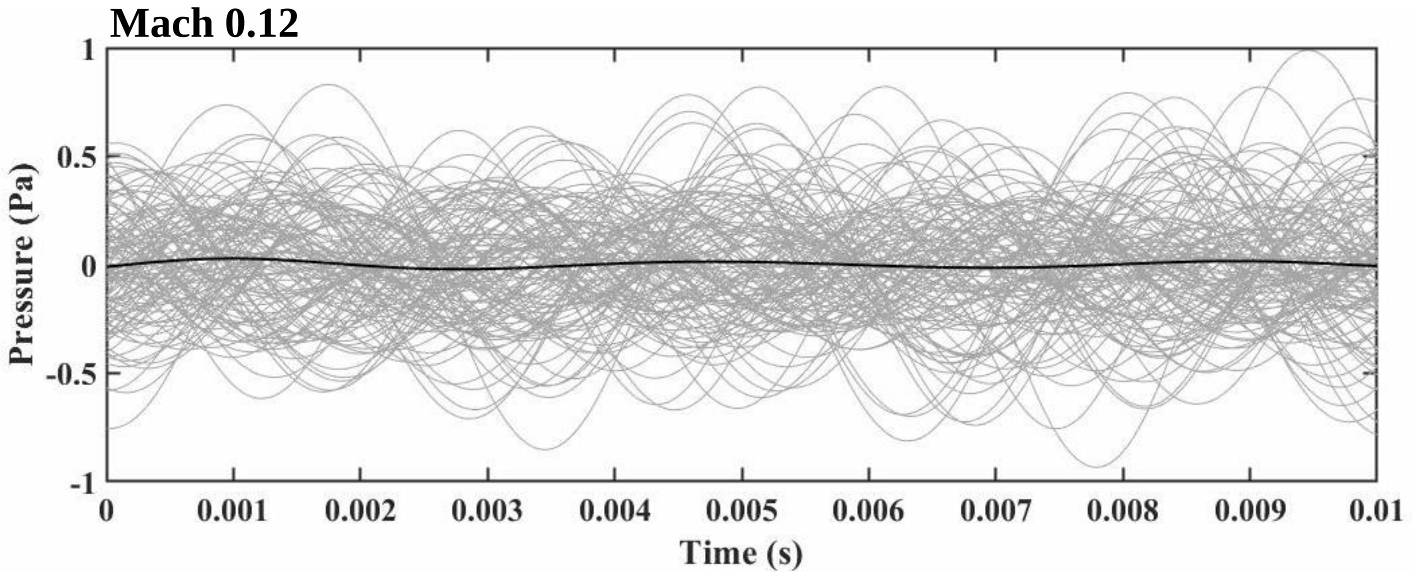
- Method for processing periodic signals
  - Ensemble average based on signal period
  - Can remove stochastic noise
- Method applied to data collected with in-flow source using signal with ½-second period
- General shape of signal captured by periodic averaging
- Method struggles at higher Mach numbers

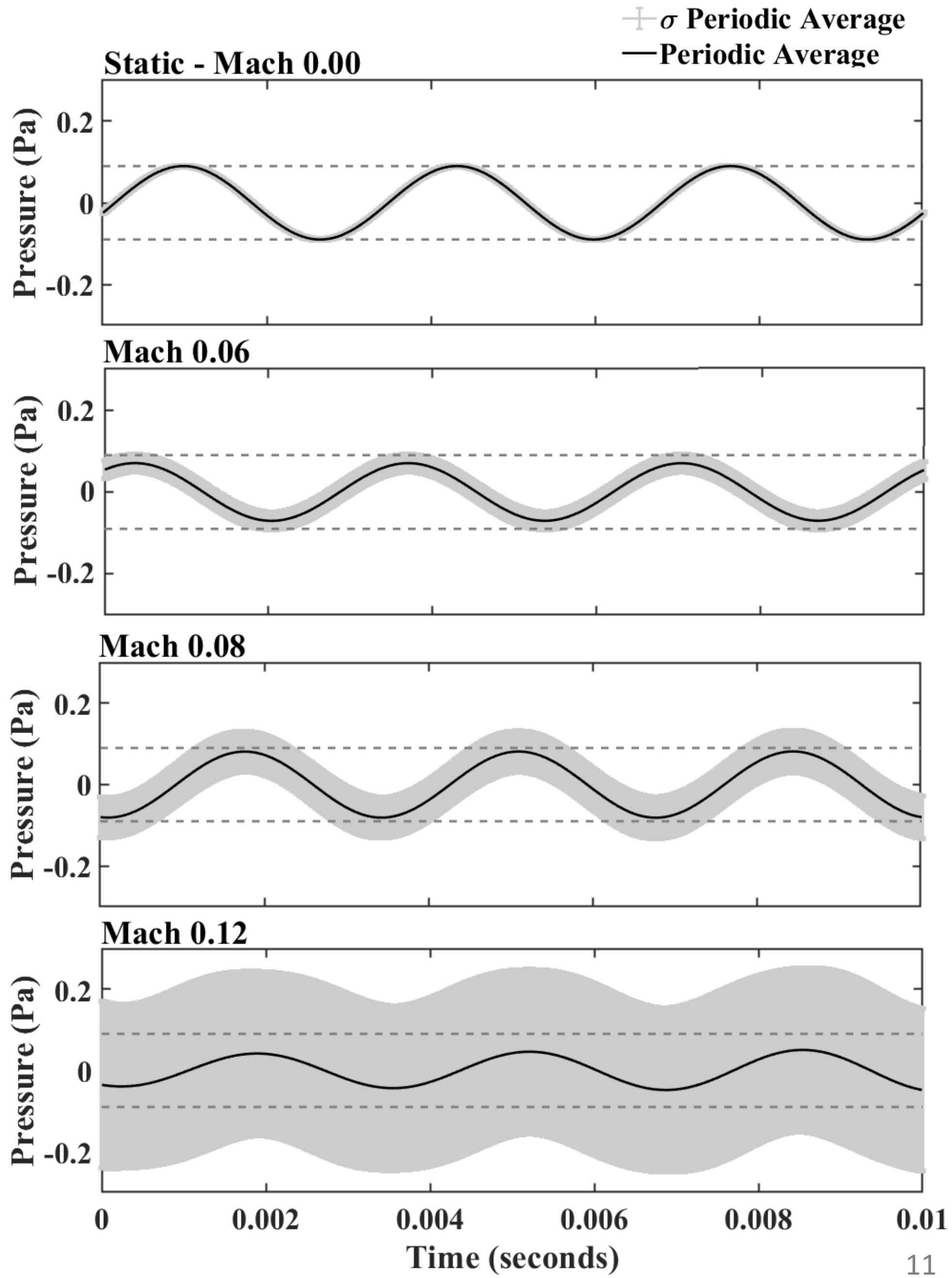




Periodic Averaging

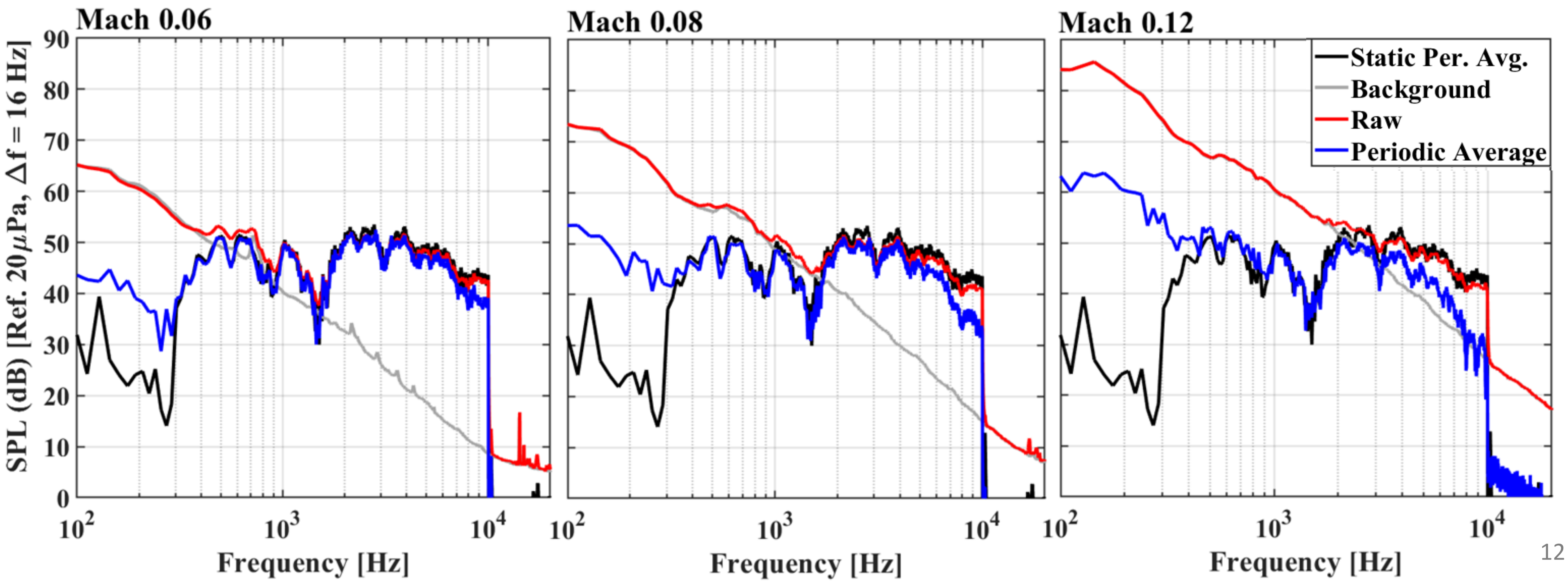
- Method applied to pure tone signal
- Tonal signal demonstrates effects of freestream flow on amplitude and phase of measured signal
- Likely caused by the facility turbulent shear layer





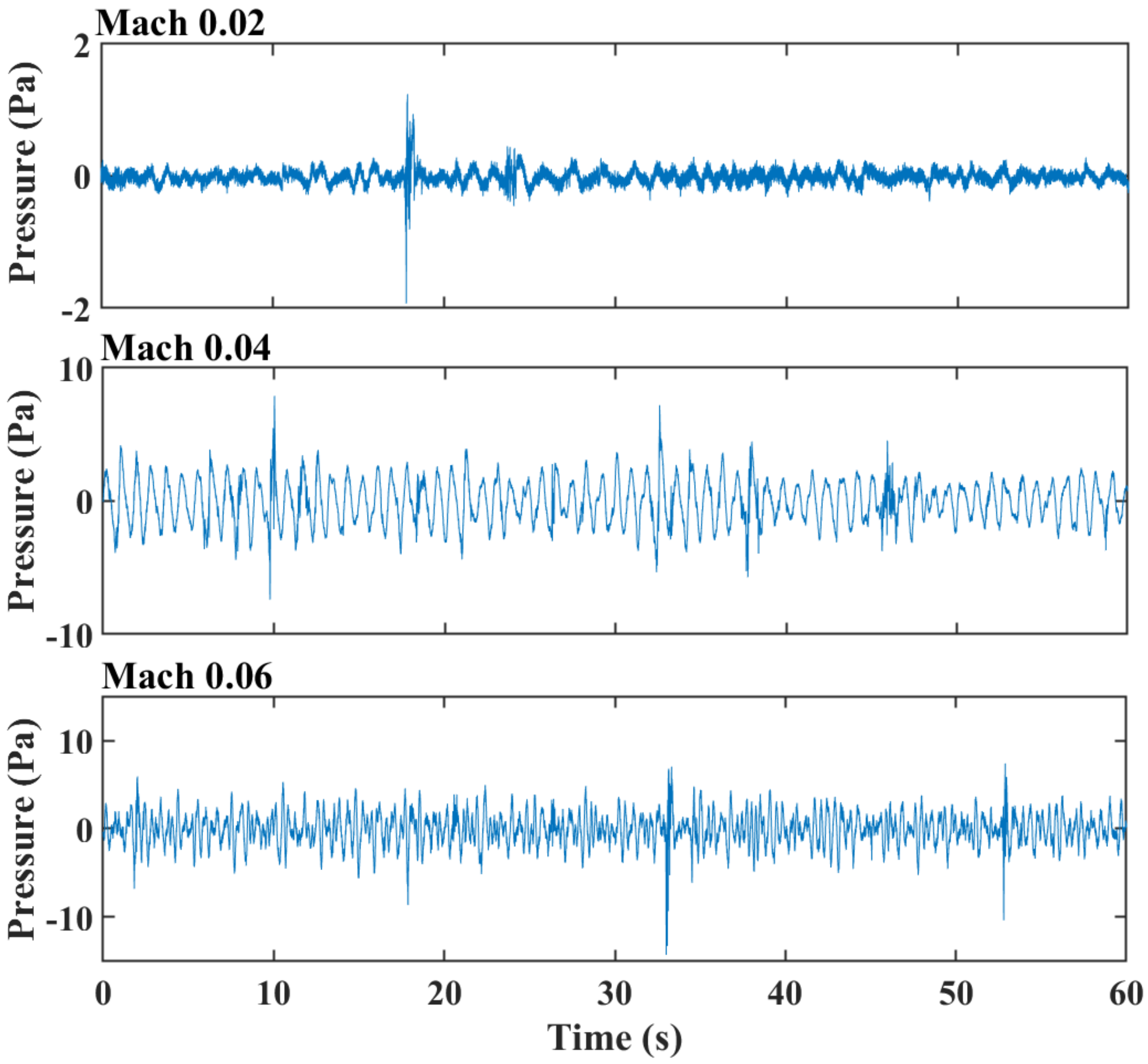
Periodic Averaging

- Method successfully removes background noise from spectra even for SNR < 0 dB
- Microphone capturing higher-frequency content in “raw” data
- Turbulent shear layer effects attenuate higher-frequency content in periodic averaging



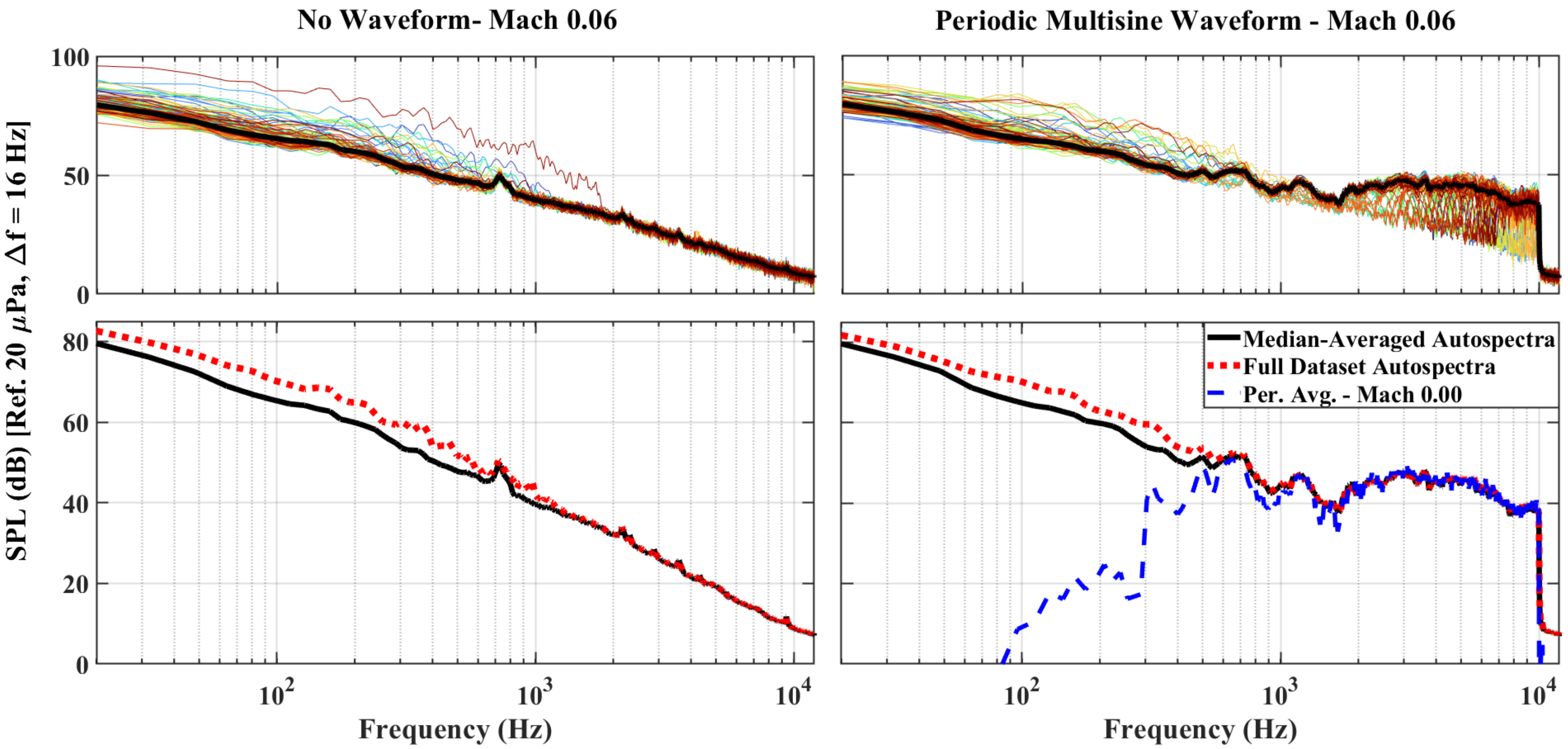
Test Section Pressure Wave

- Observed a hydrodynamic pressure pulse through the test section
  - Known phenomenon in closed-circuit/open-jet tunnels (Hu et al. 2022, Wickern et al. 2000)
  - Exacerbated in quasi-open-jets (Jin et al. 2022)
  - “Low”-frequency (occurrence, not content)
  - Severity of pulse is a function of Mach number, strongest around Mach 0.04-0.06
- Previous studies in 14x22 on this pulse:
  - Focused on freestream turbulence
  - Proposed solutions generated noise (Sellers et al. 1985, Manuel et al. 1992)



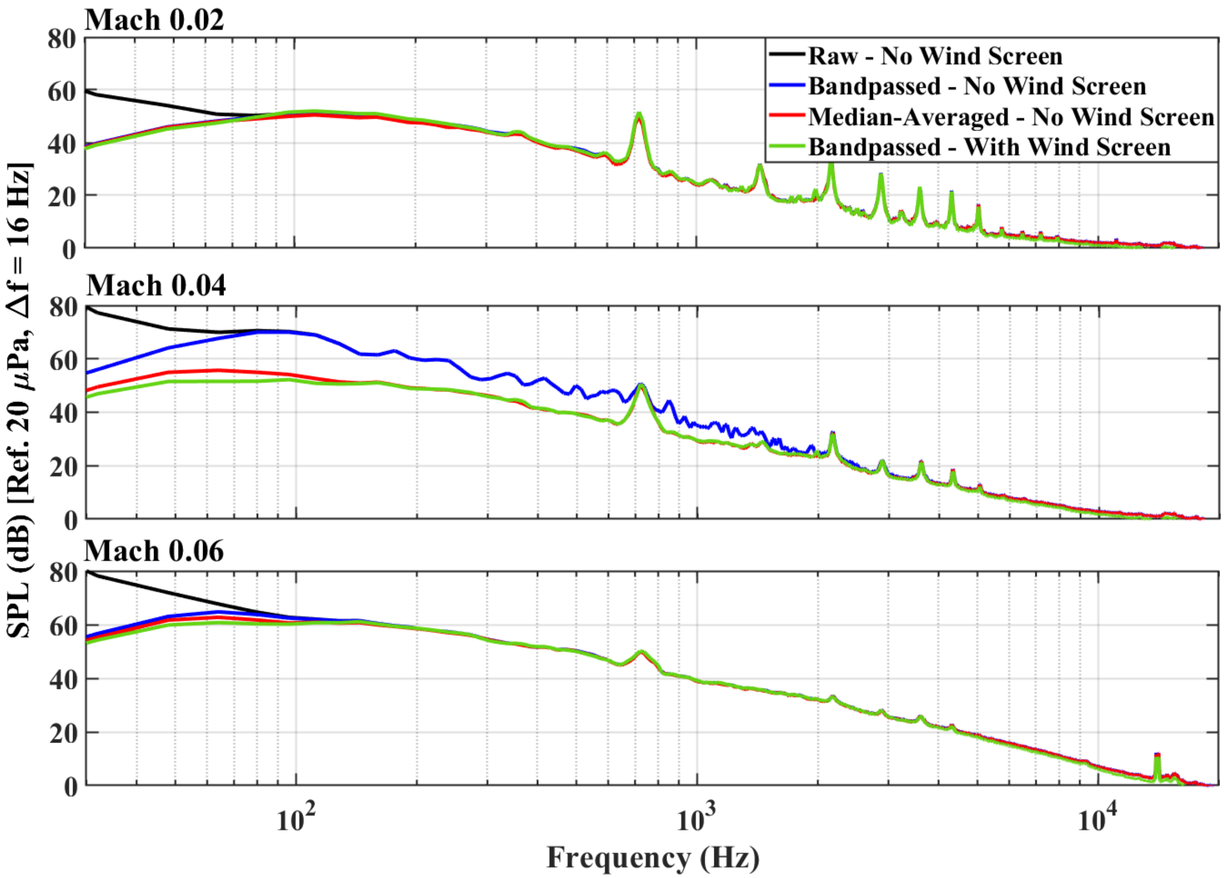
Test Section Pressure Wave

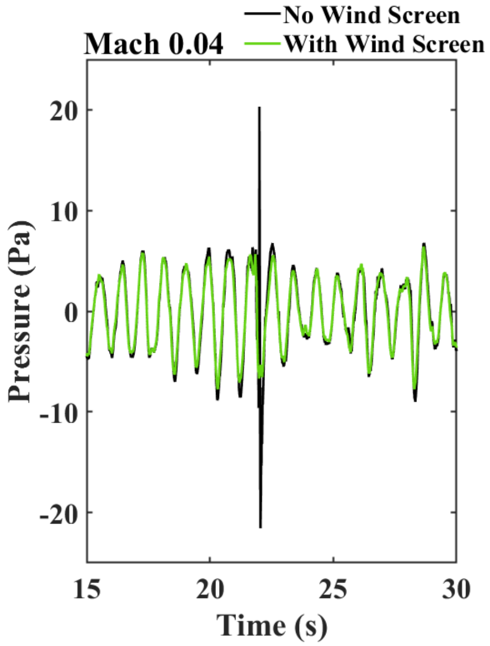
- Proposed simple processing solution: Median Averaging
  - Break data into time segments and calculate autospectrum of each segment
  - Find median spectral amplitude at at each frequency bin
- Pulse captured in small number of spectra
- Acoustic signals still captured



Test Section Pressure Wave

- Pulse observed in phased array data but not linear array data. Why?
- Linear array outfitted with windscreens
  - In-house design
  - Mesh stretched over a thin frame
- Removed windscreen from one mic and compared data
- Also implemented median averaging to uncovered microphone





Conclusions

- Major reflective surfaces identified in the 14x22 test section
  - Floor and walls
  - Will inform potential future upgrades of acoustic treatment
- Investigated periodic averaging as a method for capturing data with low signal-to-noise ratios
  - Captured acoustic signals at lower frequencies where background noise could be upwards of 20 dB greater
  - Method has limitations at higher frequencies once measuring though a shear layer
- Test set-up (windscreens) and data processing methods for rejecting the hydrodynamic pressure pulse in the test section

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Questions

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  - LSAWT and 14x22 test engineers and technicians
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Noise Source Characteristics