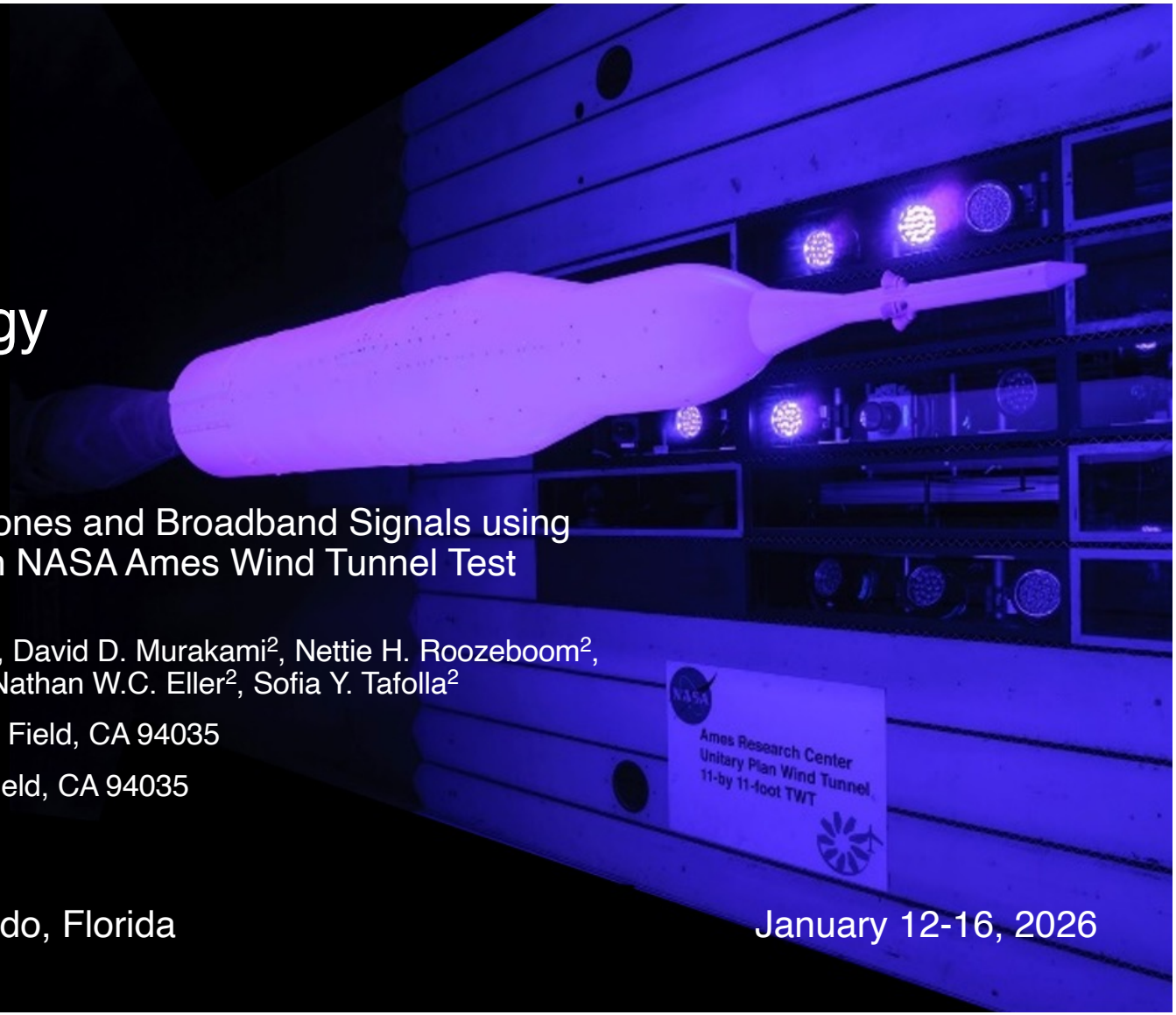
# uPSP Test Technology Capability Challenge




## Separation of Vortex Shedding Tones and Broadband Signals using SPOD of uPSP Measurements in NASA Ames Wind Tunnel Test

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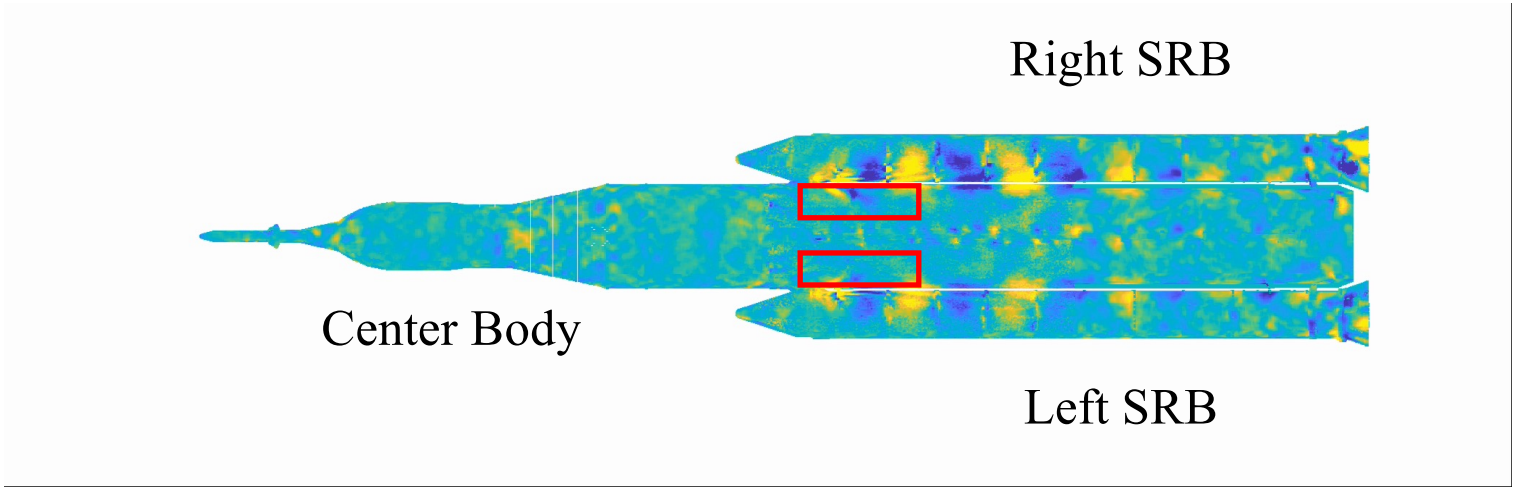
# Introduction

- Unsteady Pressure-Sensitive Paint (uPSP) measurements were collected in a Force & Moment Test of the Space Launch System (SLS) Block 1 crew vehicle at NASA Ames Research Center in April 2025.
- This paper discusses separation of vortex shedding tones and broadband signals using Spectral Proper Orthogonal Decomposition (SPOD) of the uPSP measurements.

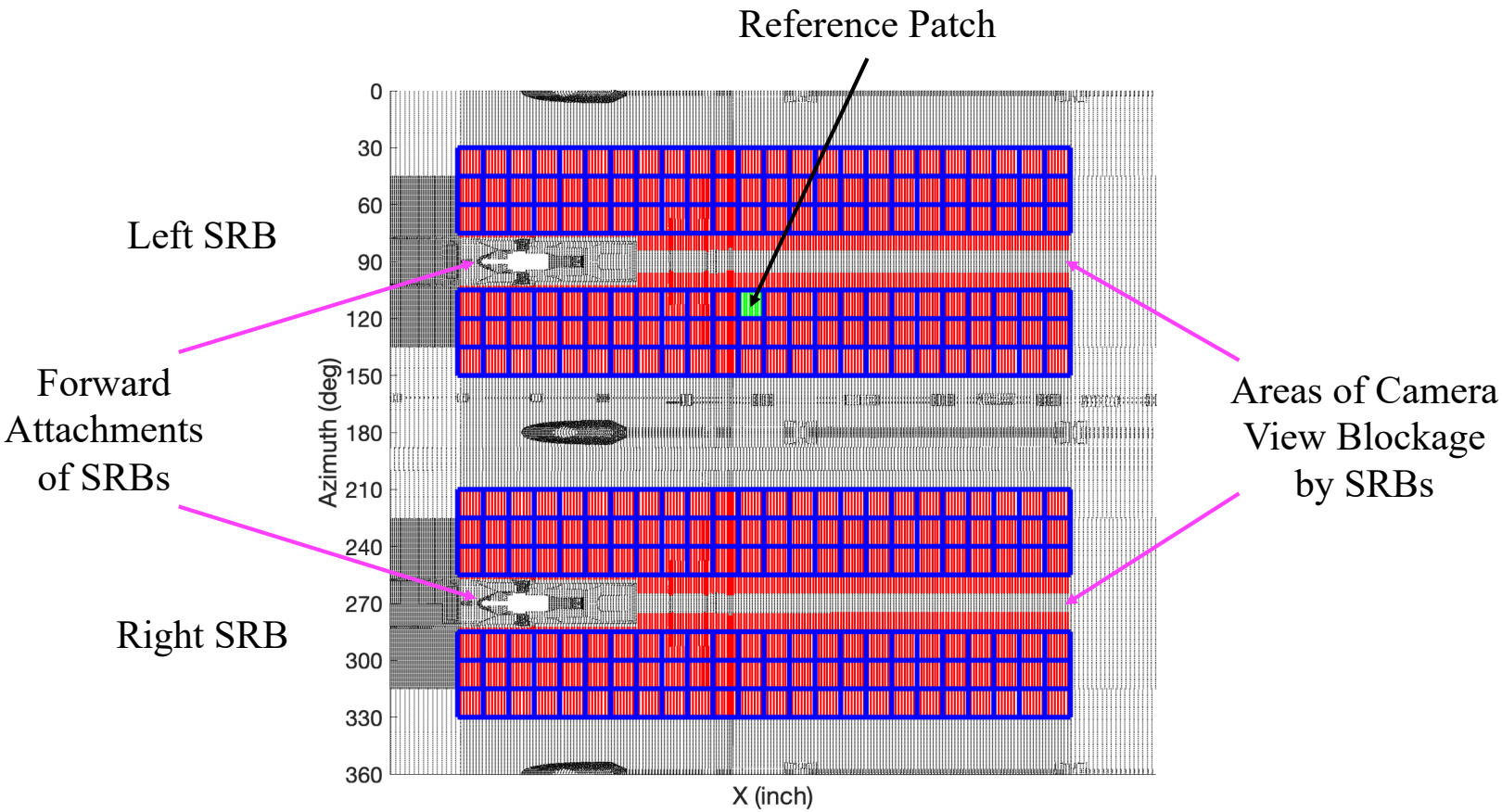
Scale Model of the SLS Block 1 Crew Vehicle
in the Force & Moment Test in April 2025

# Vortex Shedding Tones

- Vortex shedding tones, generated by the forward attachments of the Solid Rocket Boosters (SRBs), were consistently observed in the uPSP measurements.



# Selected Grid Nodes and Patches

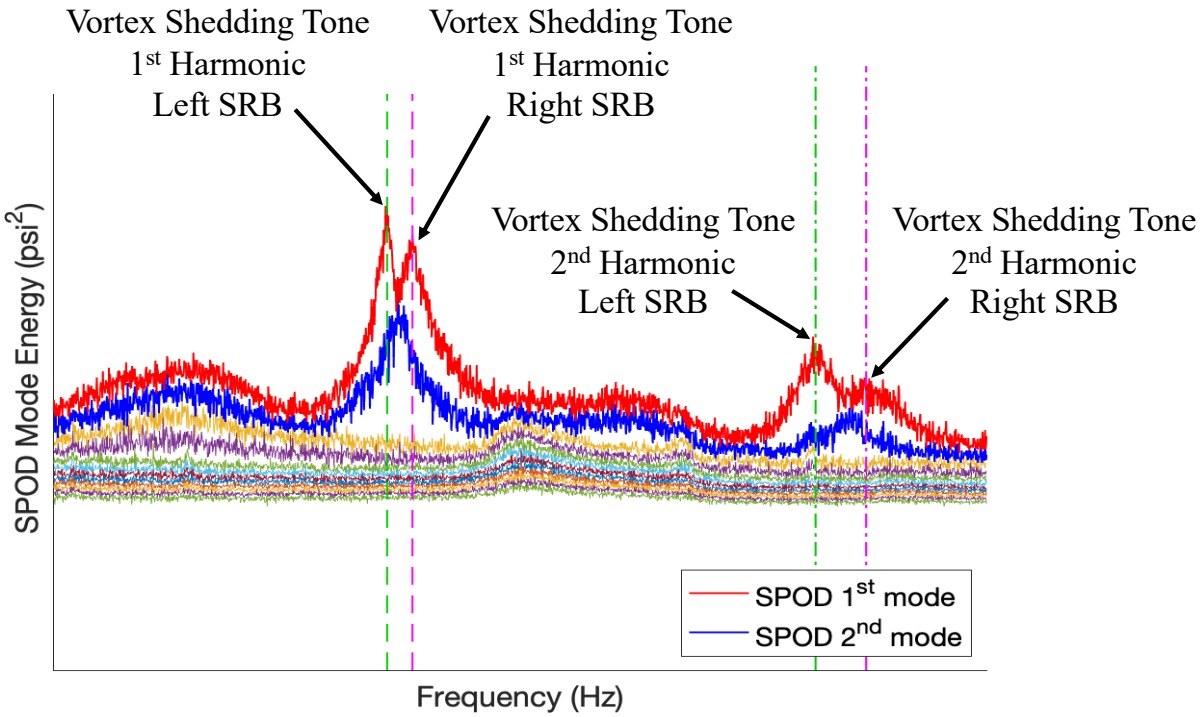


# SPOD and Inverse SPOD Algorithms

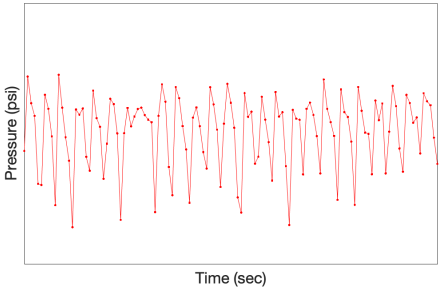
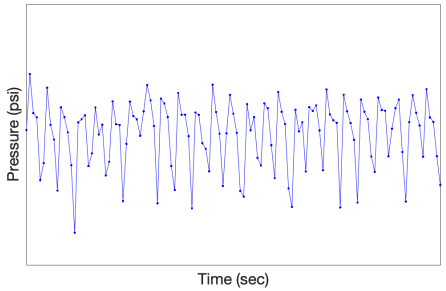
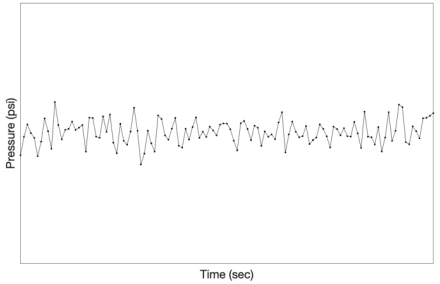
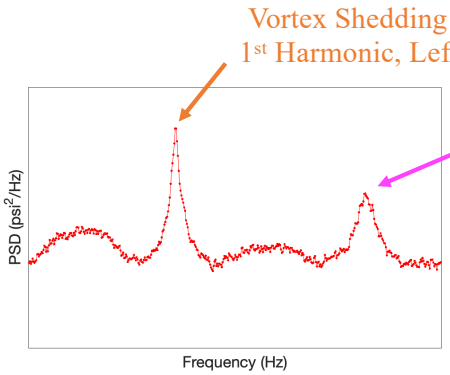
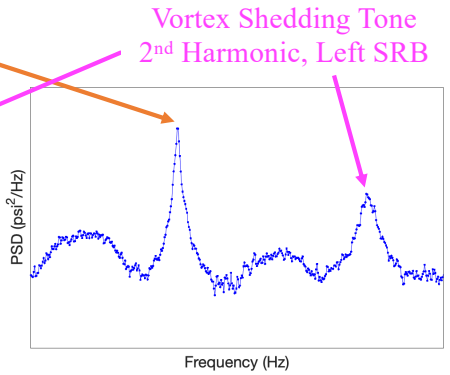
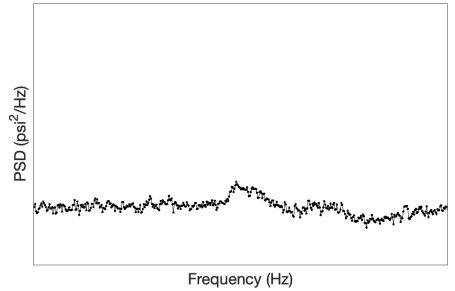
- SPOD of uPSP measurements
  - Full timeseries of uPSP measurements are partitioned into a set of smaller blocks, and each block is converted from the time domain to the frequency domain with the Discrete Fourier Transform (DFT);
  - At each frequency, the Cross Spectral Density (CSD) matrix is estimated with Welch's method, and the SPOD modes are determined as the eigenvectors of the estimated CSD matrix.
- Inverse SPOD
  - Dominant SPOD modes are converted from the frequency domain to the time domain.

# Energy of SPOD Modes at Mach 1.2

Energy of SPOD modes of uPSP measurements on selected grid nodes at Mach 1.2



# Separation of Vortex Shedding Tones and Broadband Signals (1)

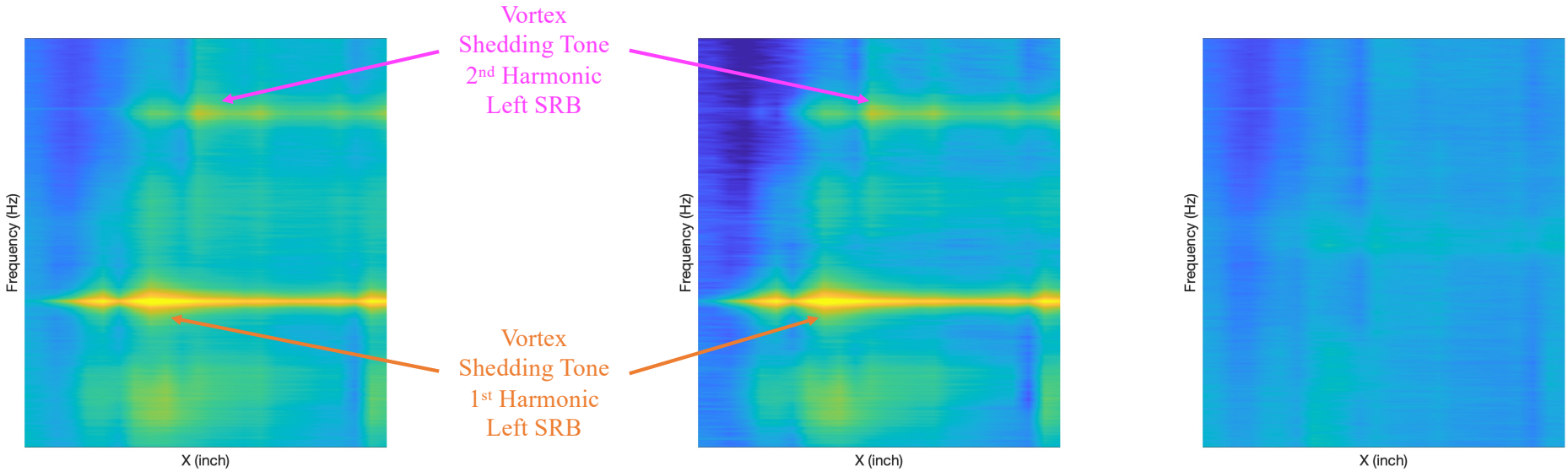
| | Original uPSP Measurements | Vortex Shedding Tones | Broadband Signals |
|---|---|---|---|
| Timeseries of Average Pressures |   |   |   |
| Power Spectral Densities (PSDs) |   |   |   |

# Separation of Vortex Shedding Tones and Broadband Signals (2)

Original uPSP Measurements

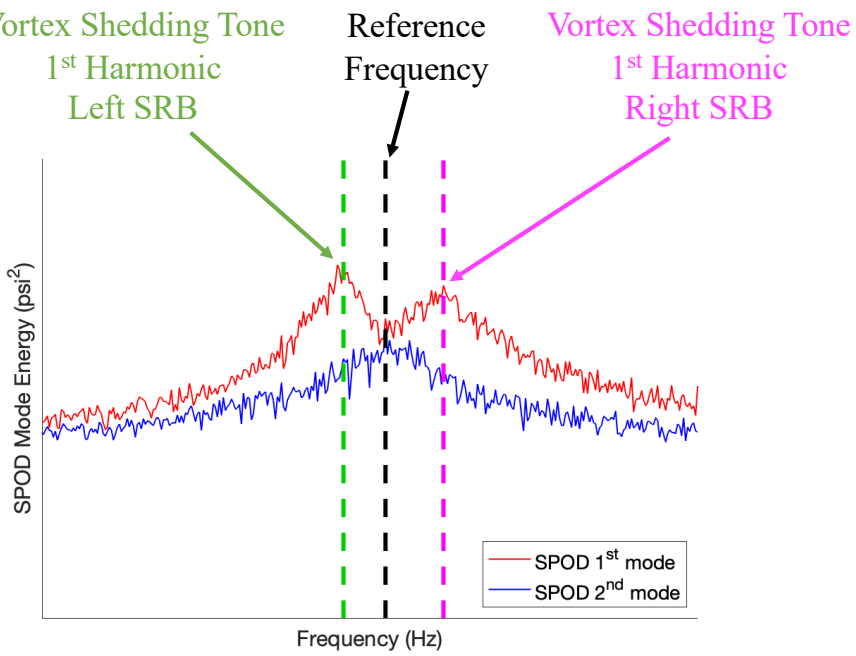
Vortex Shedding Tones

Broadband Signals

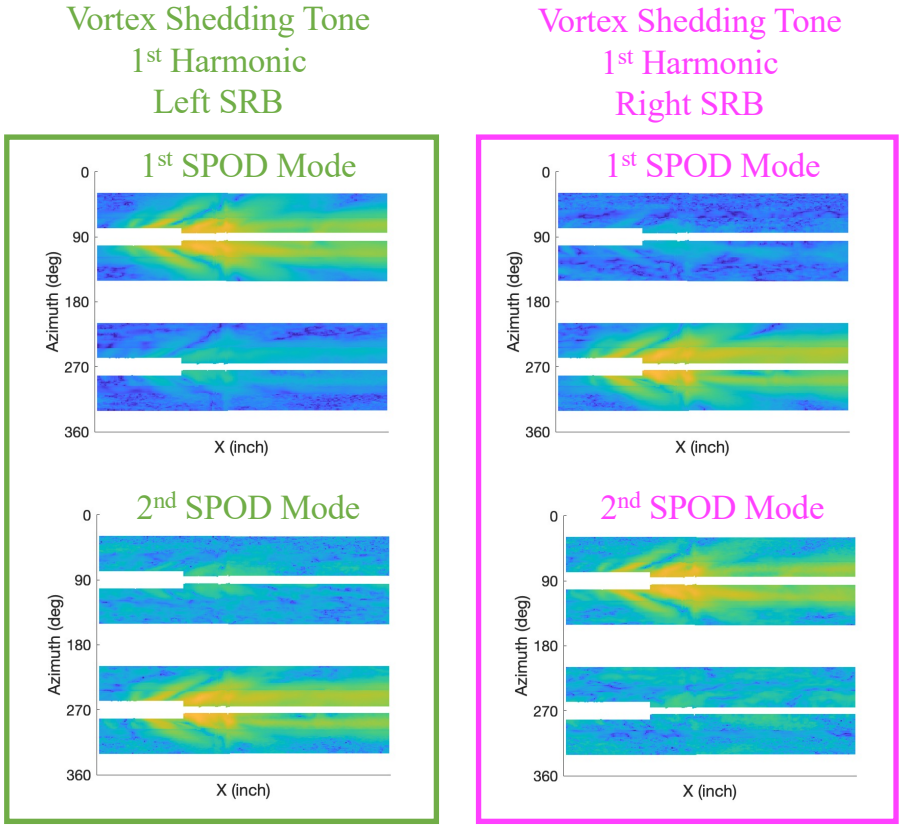


# Visualization of SPOD Modes of Vortex Shedding Tones in Frequency Domain

## Energy (psi$^2$) of SPOD Modes

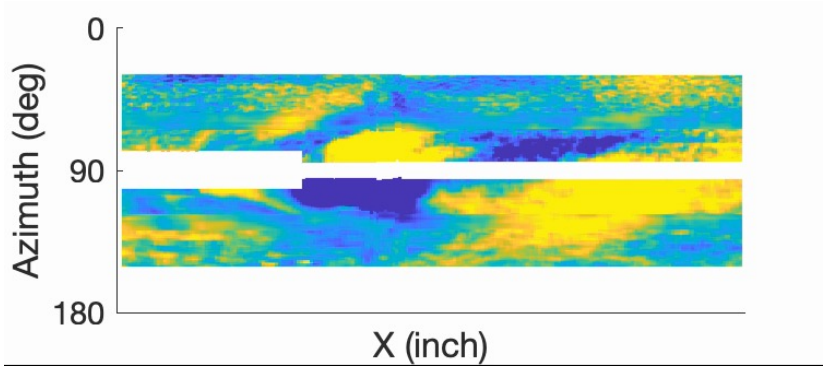



## Magnitude (psi) of SPOD Modes

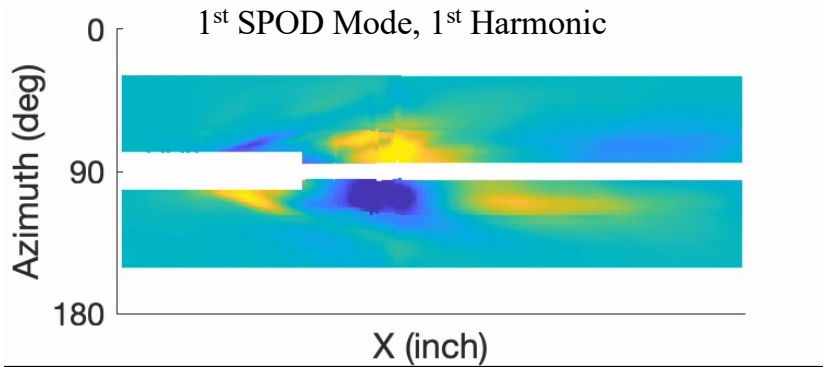


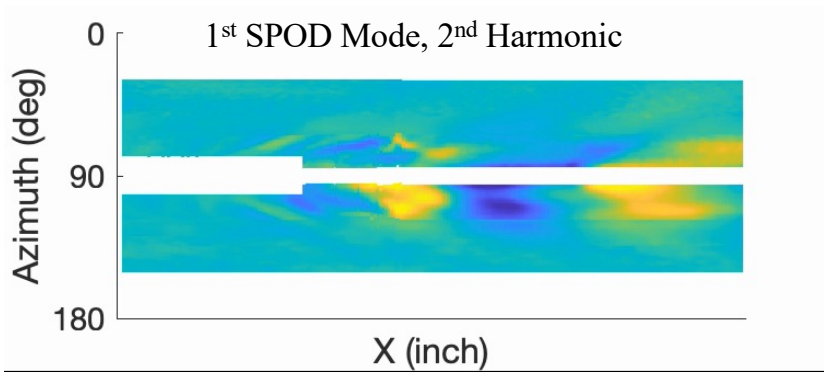
# Visualization of SPOD Modes of Vortex Shedding Tones in Time Domain

Raw uPSP Measurements




1st SPOD Modes of Vortex Shedding Tones of Left SRB



# Conclusions

- The outputs of SPOD of uPSP measurements of an SLS Force & Moment Test are discussed.
- It is demonstrated the vortex shedding tones can be effectively separated from the broadband signals in the time domain using the Inverse SPOD of the dominant SPOD modes of uPSP measurements.
  - Different aerodynamic and aeroacoustic phenomena may be analyzed separately.
- The characteristics of the vortex shedding tones are presented through visualization of the SPOD modes.
  - The measurements of uPSP have much higher spatial resolution compared to those of the conventional pressure transducers.

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