# Investigation of Aerodynamic Flow Structures in Mach 5 Inlet Buzz Bi-Stability

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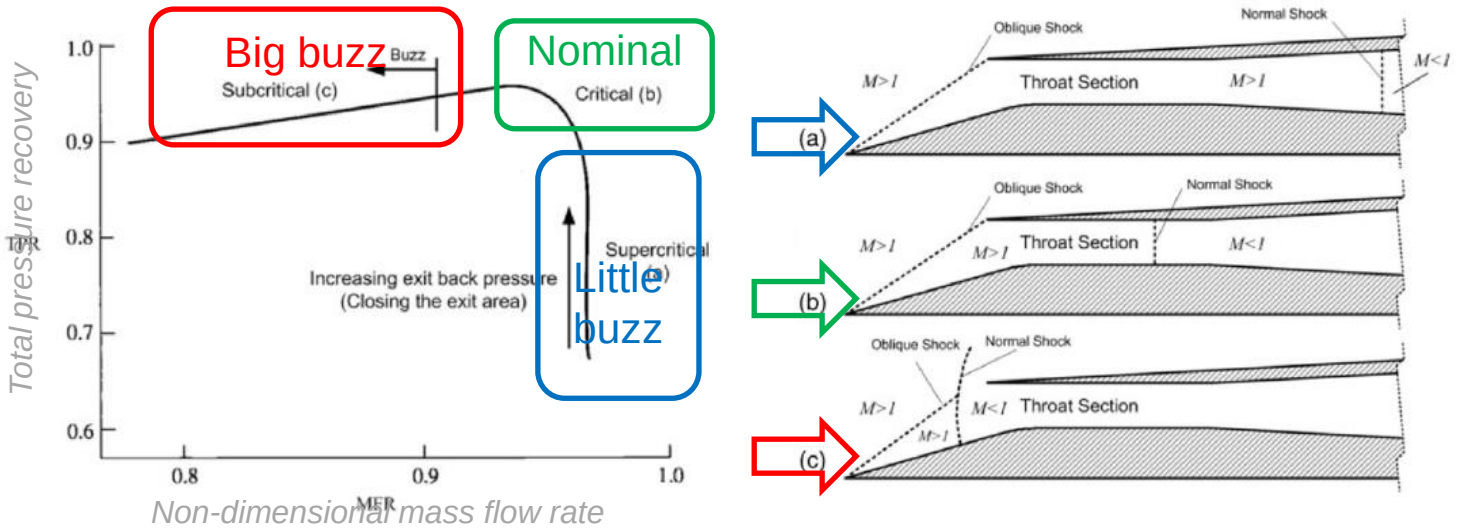
- Study Overview
- Experimental Setup
- Results and Discussion
- Conclusion

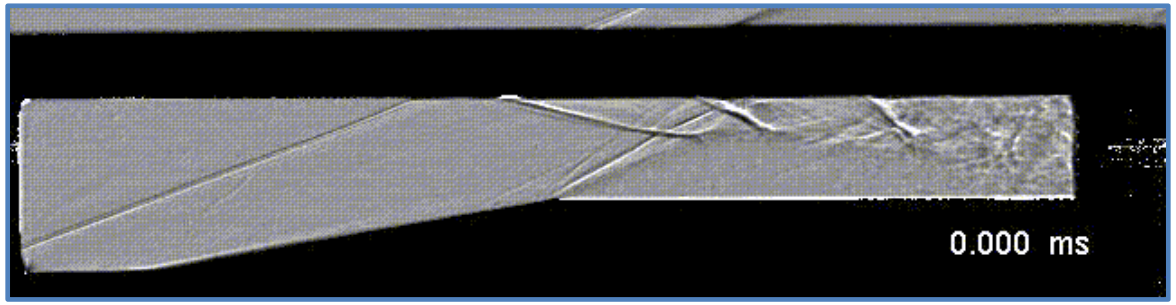

# Motivation

- Shock waves are crucial.
- Buzz classical categorization:
  - Little buzz (low-amp., high $f$)
  - Big buzz (high-amp., low $f$)

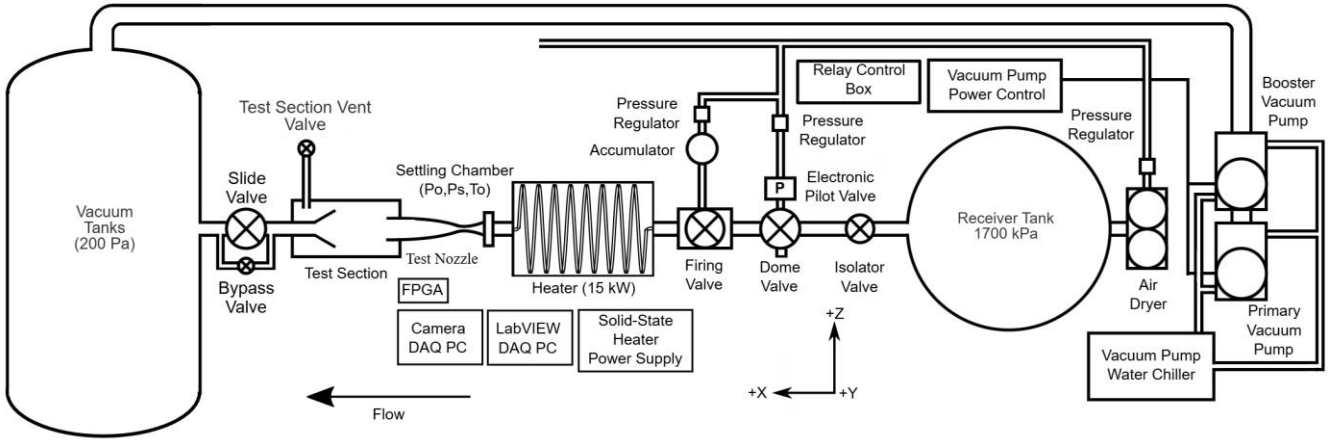



*Credit: Soltani et al. (2015) J.Aero.Eng., 229*(8).

- <u>Why this study?</u>:
  - Unconventional buzz dynamics remain unexplored at Mach 5
  - No prior high-speed imaging (66 kHz) of such buzz dynamics
  - Bi-stability in inlet buzz has not been reported before



# Facility and Test Model

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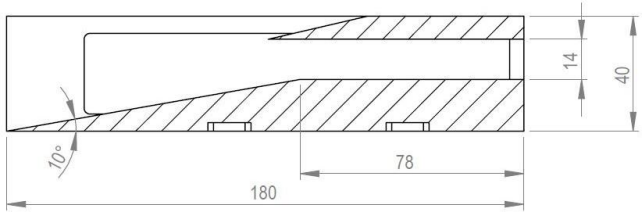
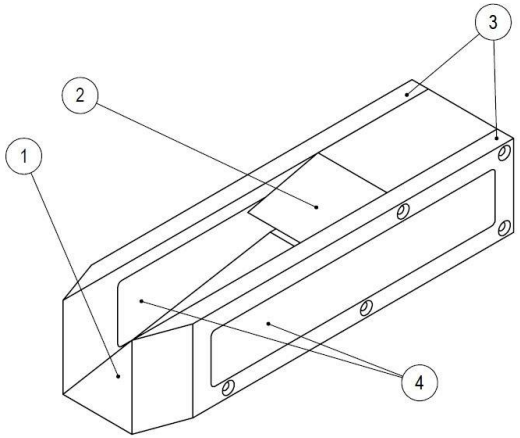
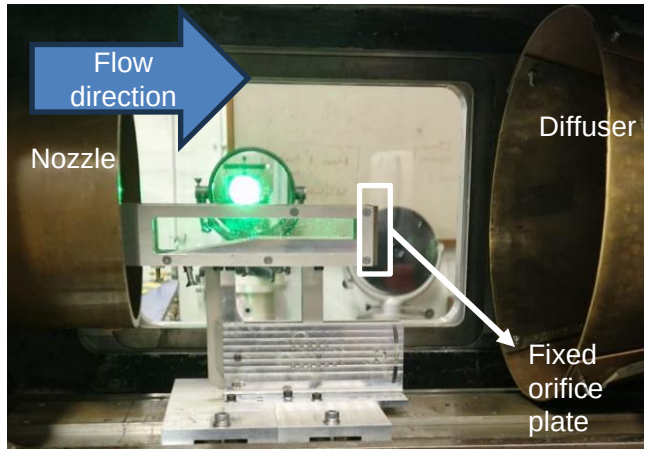
| Test conditions | |
|---|---|
| $M_\infty$ | 5.0 |
| $T_0$ | 350 K |
| $P_{0\infty}$ | 820 kPa |
| $v_\infty$ | 777 m/s |
| $Re_l$ | 1.48 x 10e7 (1/m) |

1) Ramp
2) Cowl
3) Sidewall metal frames
4) Sidewall acrylic windows



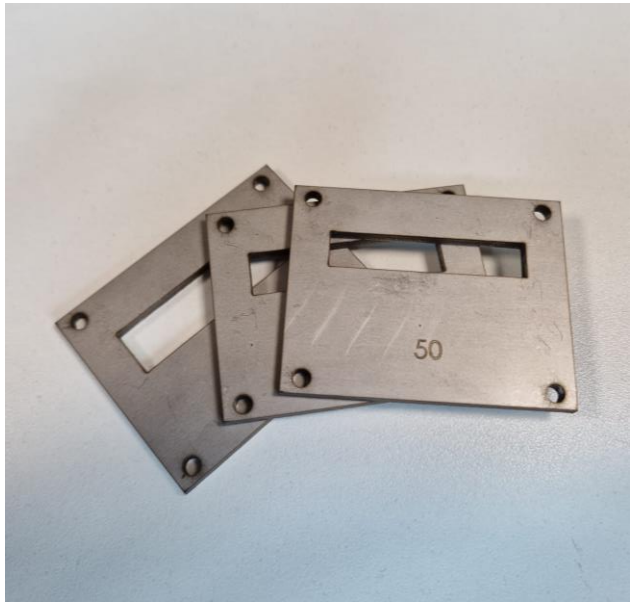

Mach 5 intake model in the test section

# Methodology

- Fixed Orifice Plates to induce inlet buzz

$$TR = (A_{th.plate}/A_{exit}) \times 100\%$$

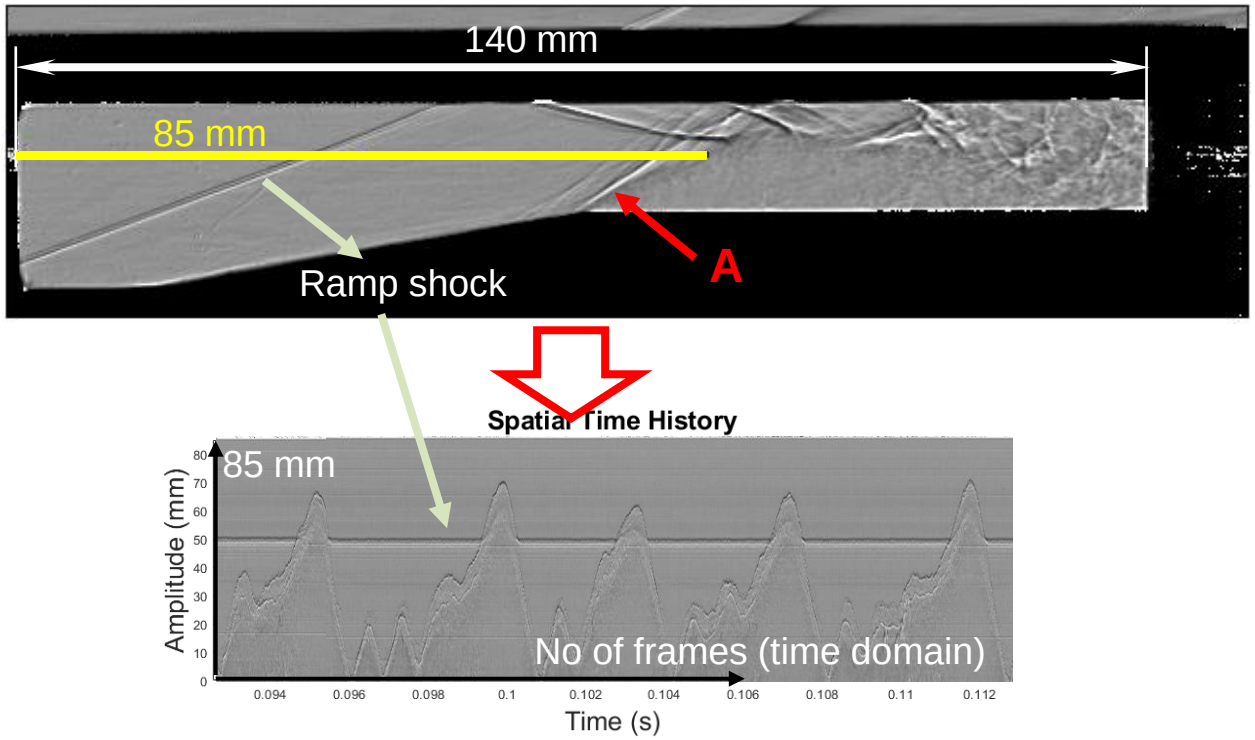
  - $A_{th}$ : The blocked area by the plate
  - $A_{exit}$ : Isolator exit area




- Cases with TR:
  - 0%, 28%, 30%, 40%, 50%

- Imaging: Schlieren – 66k fps

# Methodology

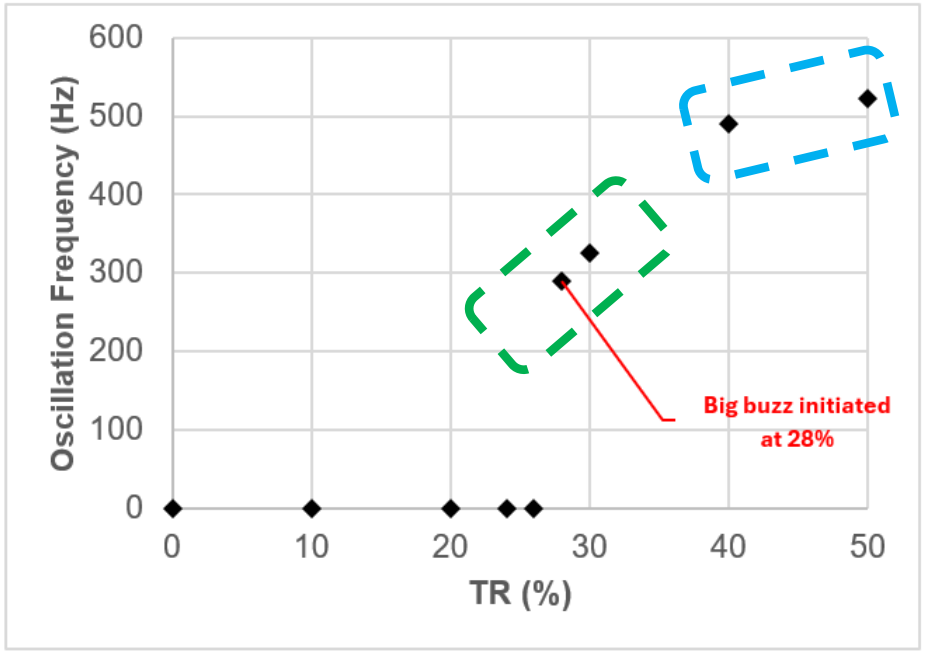



1. Normalising raw schlieren data to a wind-off image
2. Extracting 1D profile of each image
3. Stacking and producing shock profile over time
4. '3x3 Sobel' edge detection to get shock position
5. Obtain max. intensity index for each line
6. Applying a moving median filter
7. Conversion to physical units (mm)
8. Plotting spatial time history
9. Applying Welch method to plot PSD
10. Generate spectrogram by spectral analysis

# Result and Discussion

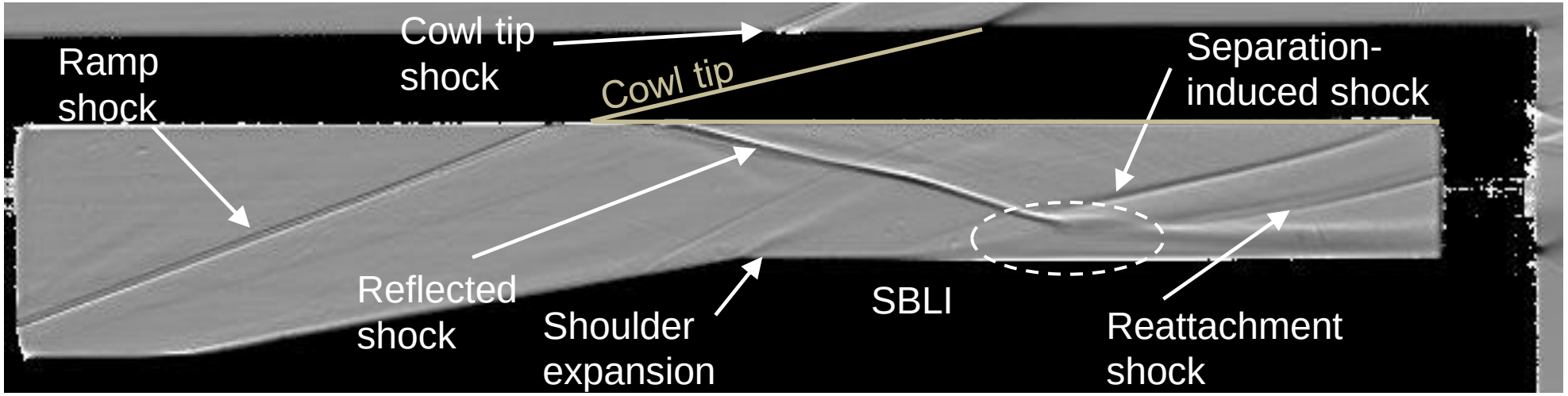
## Outline

- Temporal Analysis
  - TR=0% Schlieren
  - TR=28% & 40%
    - Time history and Schlieren
- Spectral Analysis
  - 3D PSD Waterfall Plot
  - TR=28% & 40%
    - PSD + Spectrograms

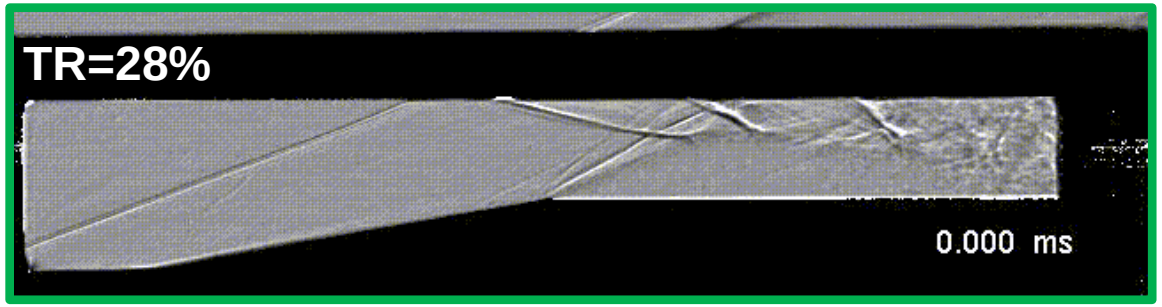


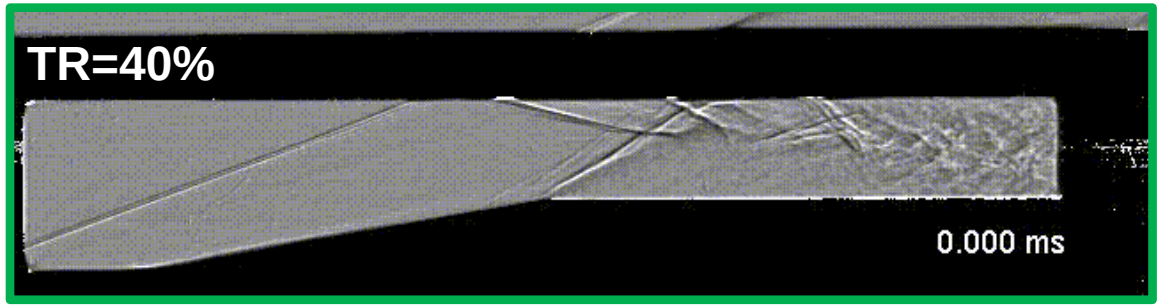
# Result and Discussion

- Temporal Analysis
  - TR= 0% (fully-open case)

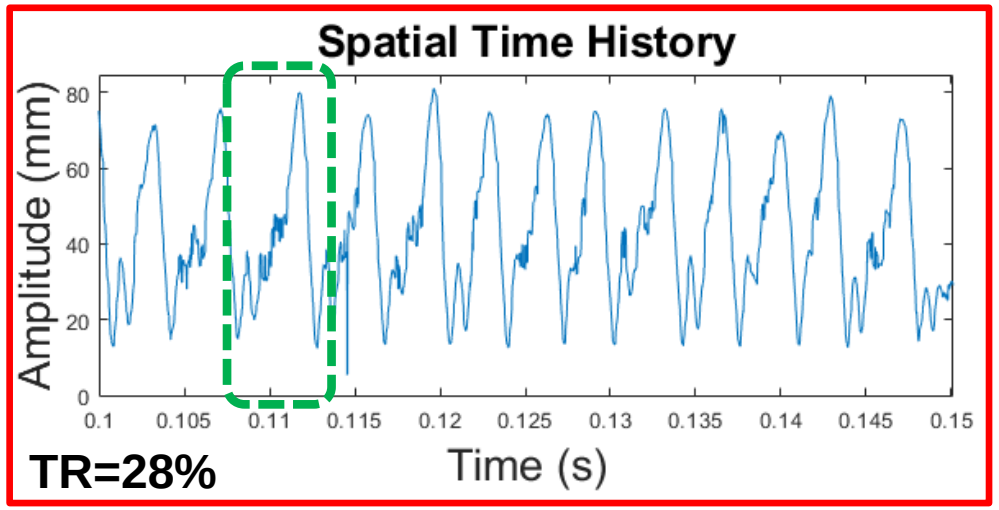


# Results and Discussion

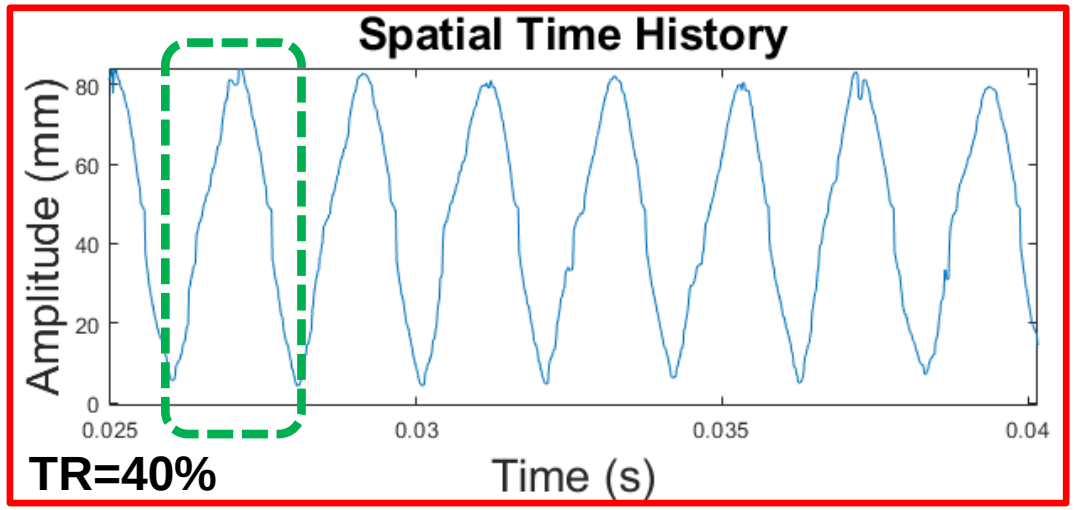



- Bi-stable mixed buzz pattern




- Pure big buzz oscillations

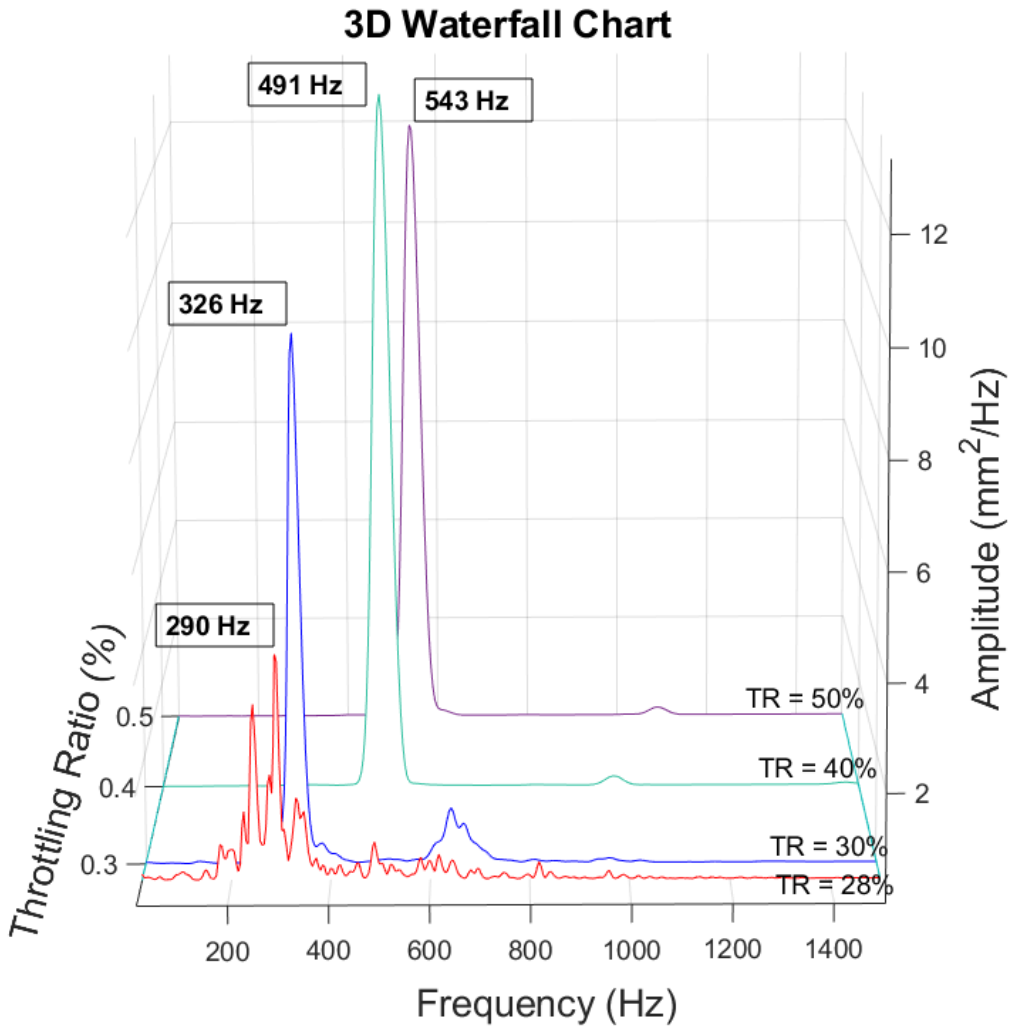


# Result and Discussion

- Spectral Analysis
  - 3D PSD Waterfall Plot

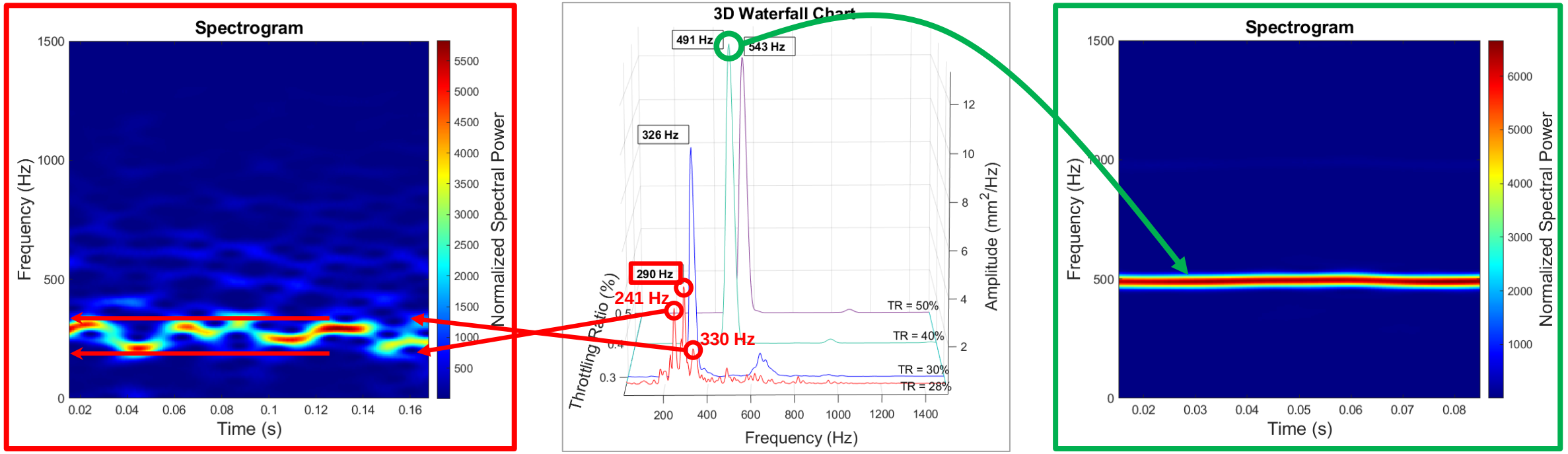
    - The chart represents the PSD diagram for all cases.

    - Cases TR= 28%, 30%, 40%, 50%



# Result and Discussion

- Spectral Analysis
  - PSDs and Spectrograms



# Conclusion

- Stable inlet flow until a critical blockage (28%).
- At TR=28%, unique bi-stability: low amp. buzz is precursor of big buzz in each cycle.
- Big buzz frequency ~290 Hz, modulating (245-330 Hz) in a non-stationary mode.
- Low amp. buzz initiates instability and drives shock system.
- Insights aid future high-speed intake design and control.

# Acknowledgments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