# Particle Image Velocimetry (PIV) Experimental Analysis of a Flow Control Structure

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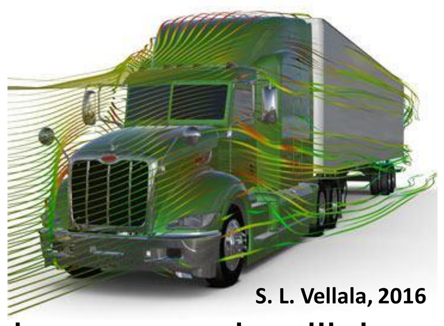
## Motivation & Objective

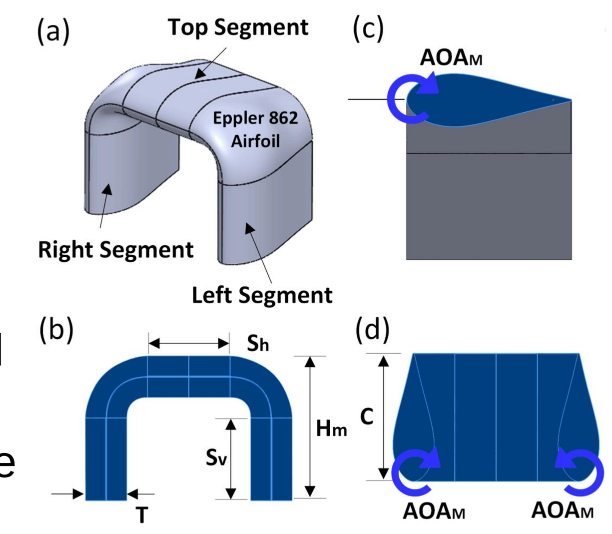
- Skin-friction drag (SFD) in turbulent boundary layers (TBLs) creates a large amount of energy loss in transportation industries.
- An implementation of a flow control scheme can reduce SFD in TBLs.




- A passive method of controlling TBLs is proposed, utilizing advancements in additive manufacturing technology.
- The objective of the study is to demonstrate the flow control capabilities of larger mock-up Micro Airfoil Structure (MAS).

## Micro Airfoil Structure (MAS)

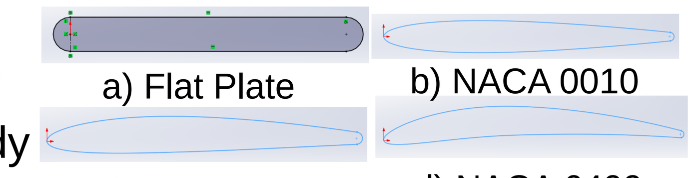
- 3D-printed structure with two side segments and a top segment (a).
- Structure segment height, width, and thickness can be manipulated (b).
- Angle of attack (AOA) of each segment may also be manipulated ((c) & (d)).
- Standard airfoil geometries may be incorporated for each segment.



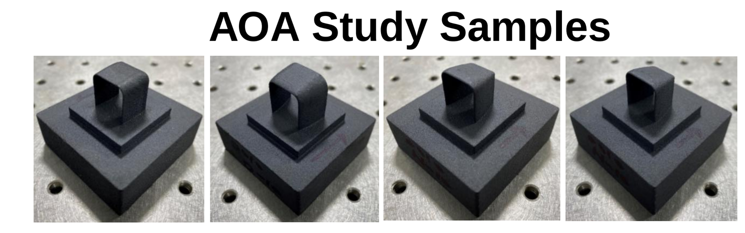

## Experimental Conditions

- Geometry Study
  - Flat Plate, NACA 0010, NACA 2410, NACA 6409
- Angle of Attack (AOA) Study
  - 5° Diffuser, 10° Diffuser, 5° Nozzle, 10° Nozzle
- Inlet Velocity: 3.1 m/s
- ΔT: 15 microseconds
- Capture Rate: 5 Hz

**Geometry Study Cross Sections**



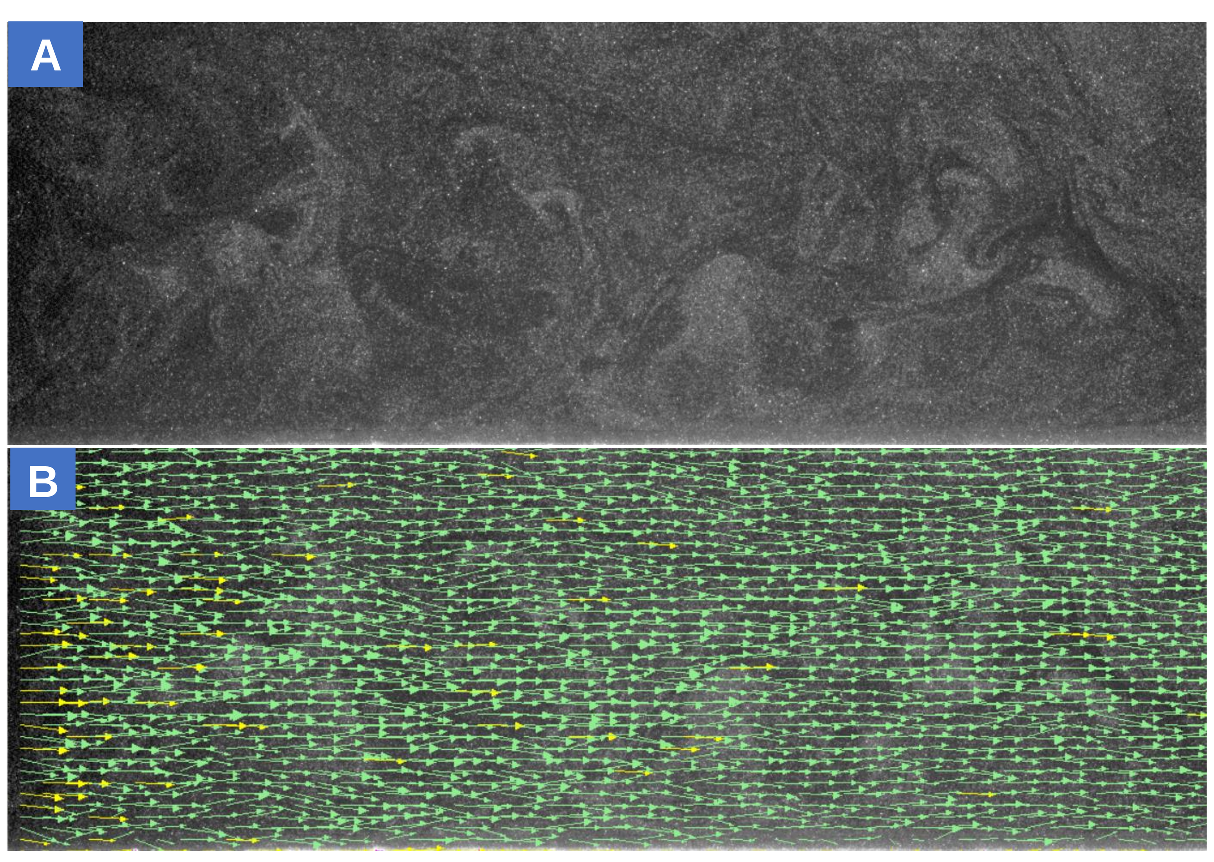

**AOA Study Samples**



A) 5° Diffuser B) 10° Diffuser C) 5° Nozzle D) 10° Nozzle

## Particle Image Velocimetry (PIV)

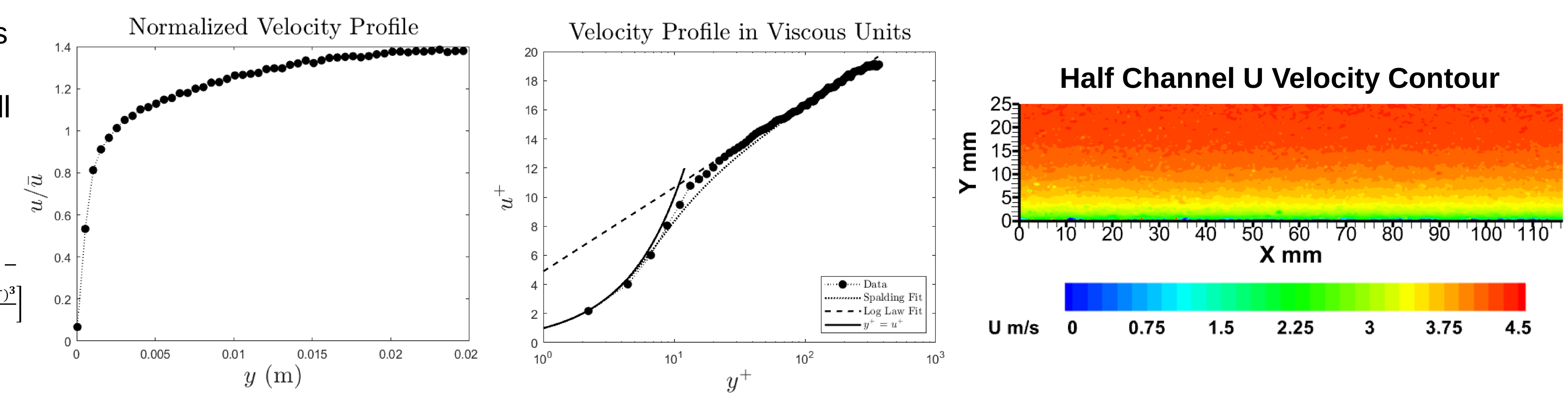
- "Tracer" seed particles are introduced into the flow; in this case, olive oil droplets.
- A laser sheet illuminates the seed particles in the flow.
- High-speed CCD camera takes two image "captures" concurrently with a small amount of time between the two captures (ΔT).
- The software can detect the displacement of specific particles between the two captures.
- Knowledge of particle displacement and time between captures allows for the creation of flow velocity vector fields.



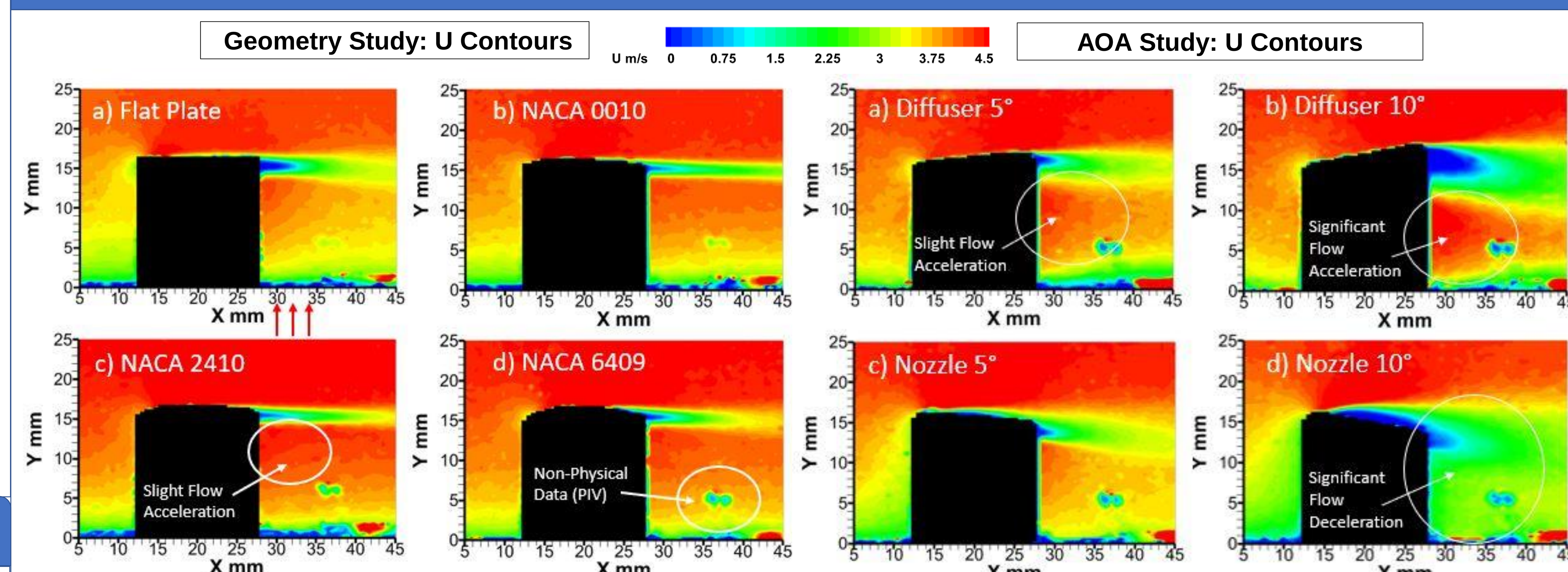

**A) Single Image Capture, B) Resolved Vector Field**

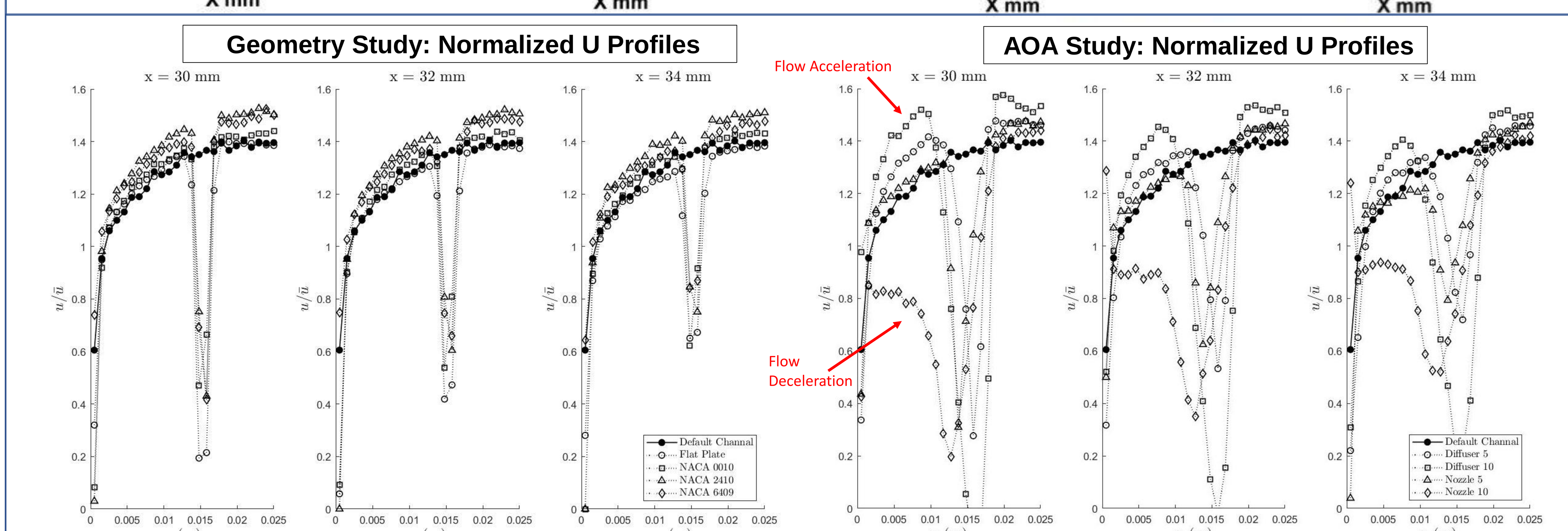
## Baseline Channel Condition

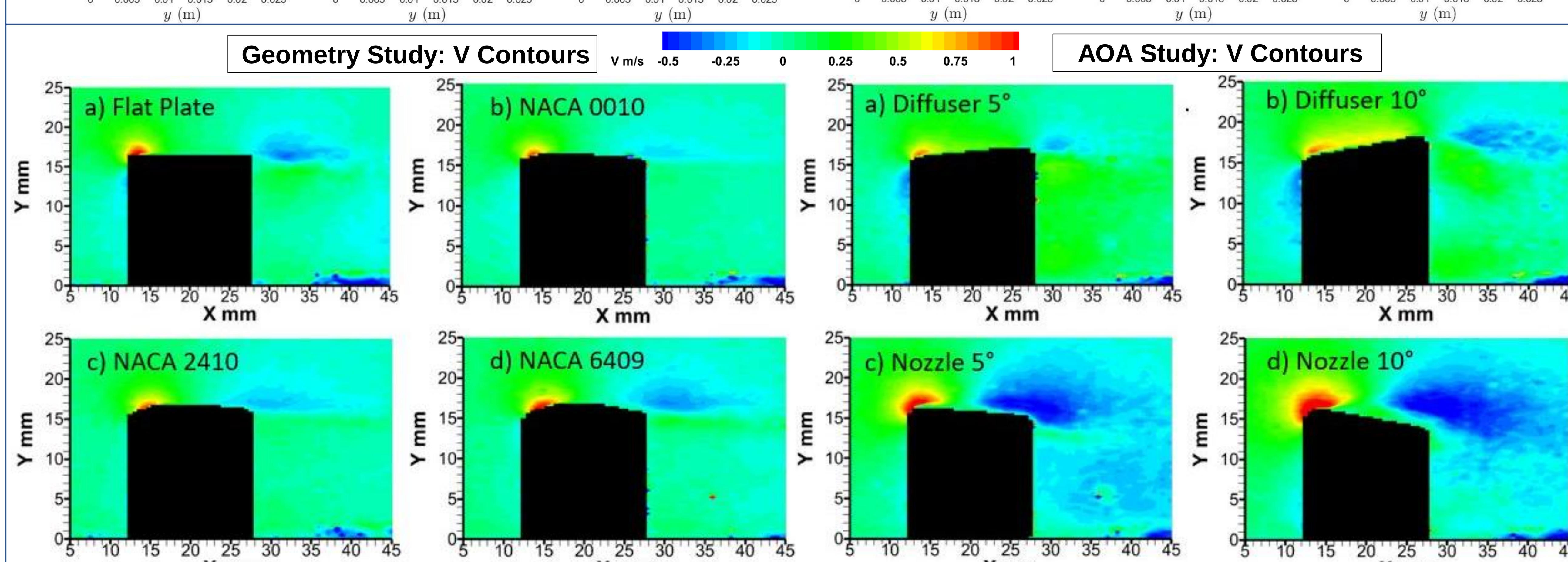
- Flow matches accepted log law of the wall and Spalding fit equations.
- $u^+ = \frac{1}{\kappa}\ln(y^+) + B$
- $y^+ = u^+ + e^{-\kappa B}\left[e^{\kappa u^+} - 1 - \kappa u^+ - \frac{(\kappa u^+)^2}{2} - \frac{(\kappa u^+)^3}{6}\right]$
- $\kappa = 0.4, B = 4.9$




## Results

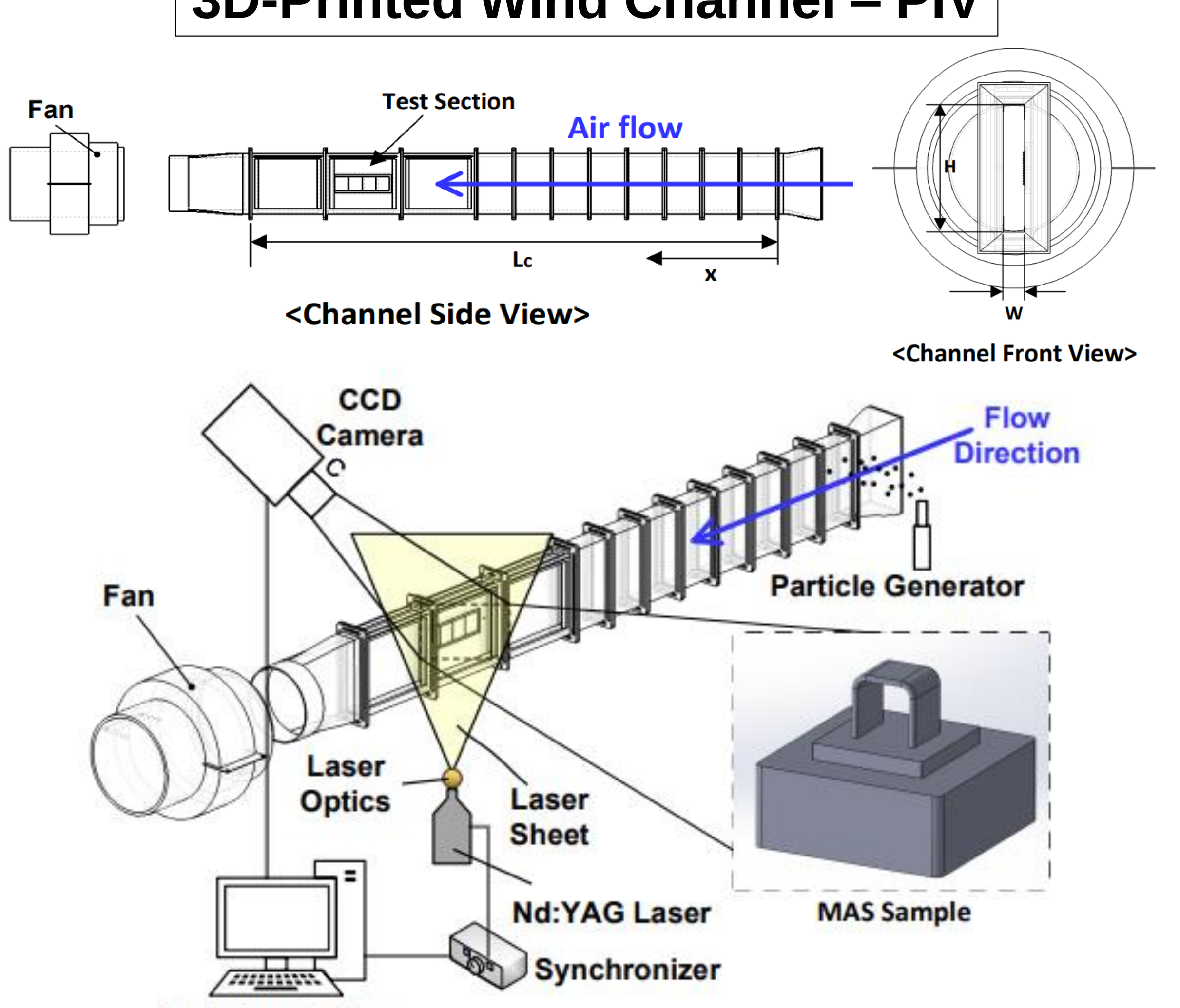



## Experimental Setup

**3D-Printed Wind Channel – PIV**




- W = 50 mm, H = 400 mm, Lc = 3 m
- Fully developed TBL at the test section.
- Minimum inlet velocity of 3.1 m/s.
- 1000 image pairs captured for each sample – post processing produced time averaged results.

## Conclusions and Recommendations

- Diffuser MAS accelerated flow, while nozzle MAS decelerated flow; the inverse of initial estimations.
- Nozzle MAS impacted V velocity significantly more than diffuser MAS.
- The flat plate MAS geometry was found to perturb channel flow the least of the tested geometries.
- Further studies are required using smaller MAS samples to confirm flow control characteristics and behaviors closer to the wall.

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