https://ntrs.nasa.gov/citations/20230013235

Design and Characterization of 3D Gust Generator Facility

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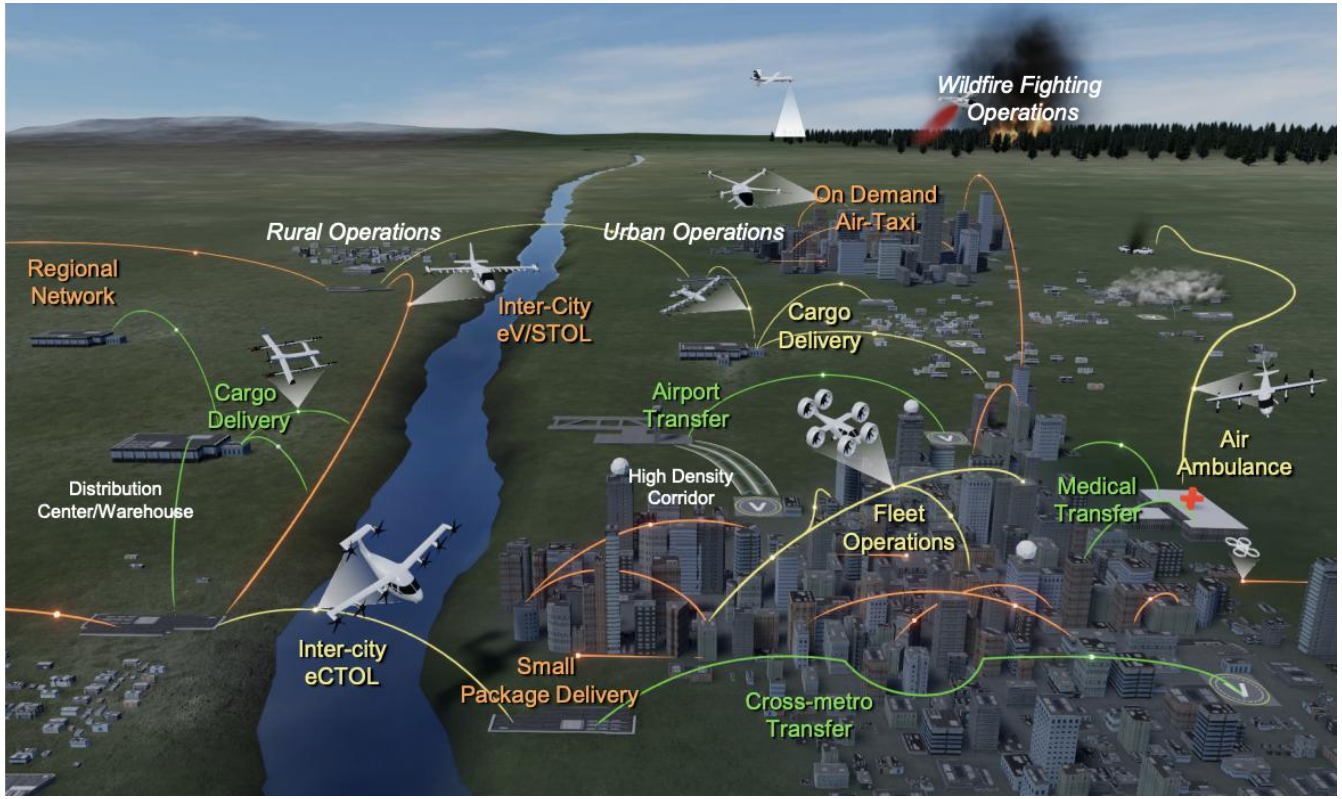
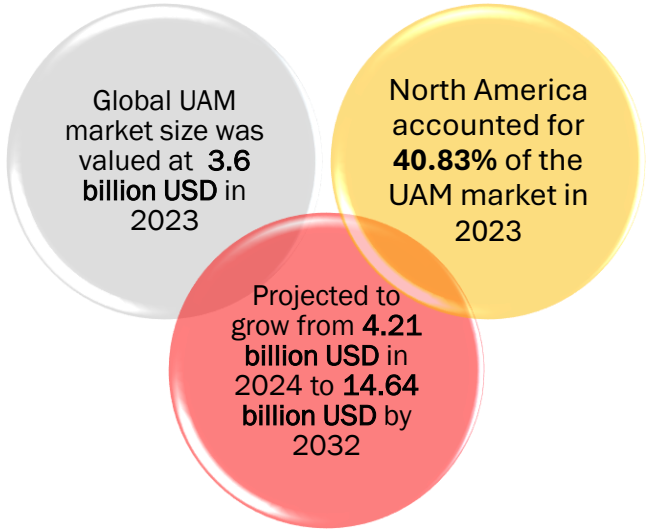
Importance of UAVs in urban environments and the future

Wide range of capabilities across urban landscapes[1]



New industry with large projected market growth[2]

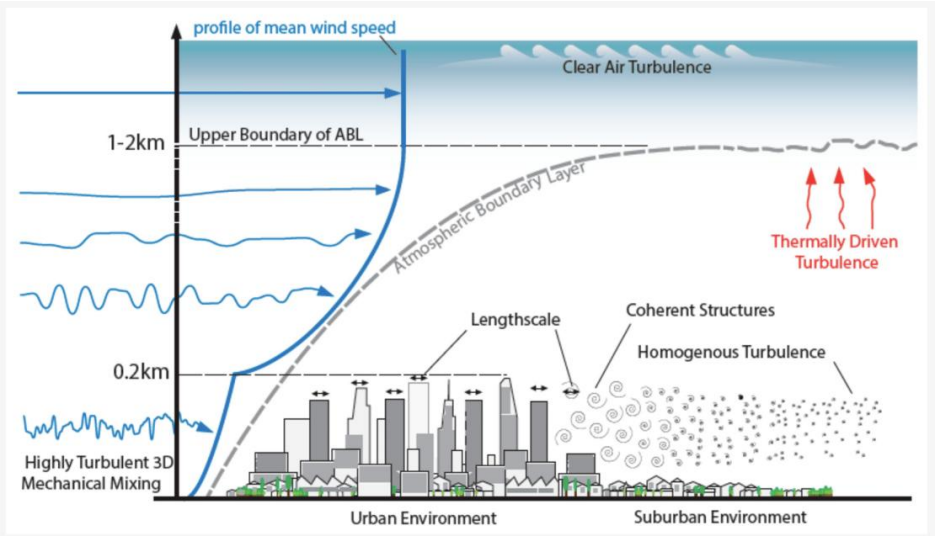


1. https://ntrs.nasa.gov/citations/20230013235
2. https://www.fortunebusinessinsights.com/urban-air-mobility-uam-market-106344

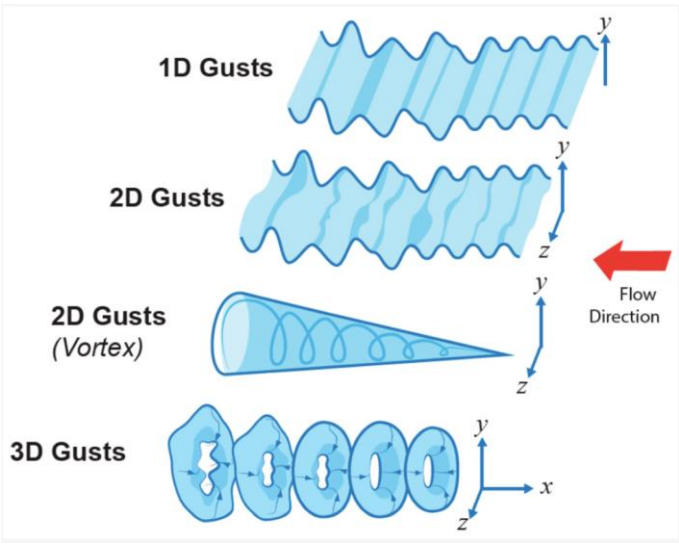
What range of gust conditions are faced by UAVs?

Understanding what gusts occur from the perspective of UAVs is crucial for replicating flows in a test environment to improve control systems used by UAVs

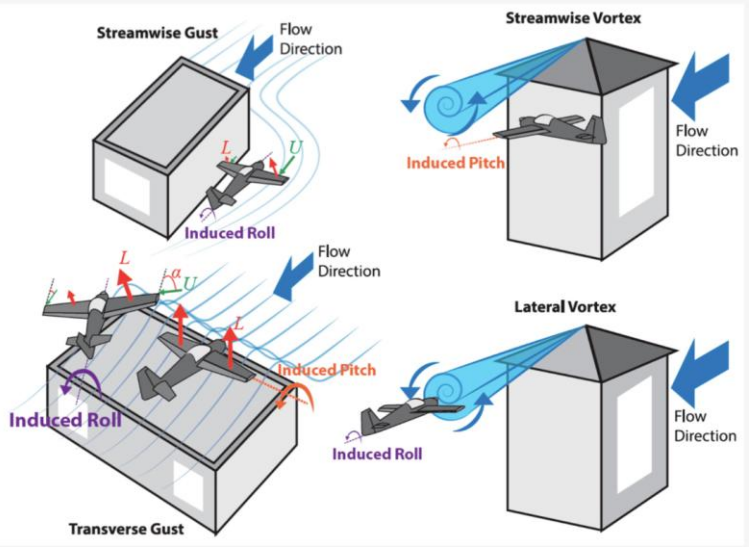
Coherent structures produced by urban environments



Dimensionality of Gusts becomes complex



Flow around buildings generated by gusts

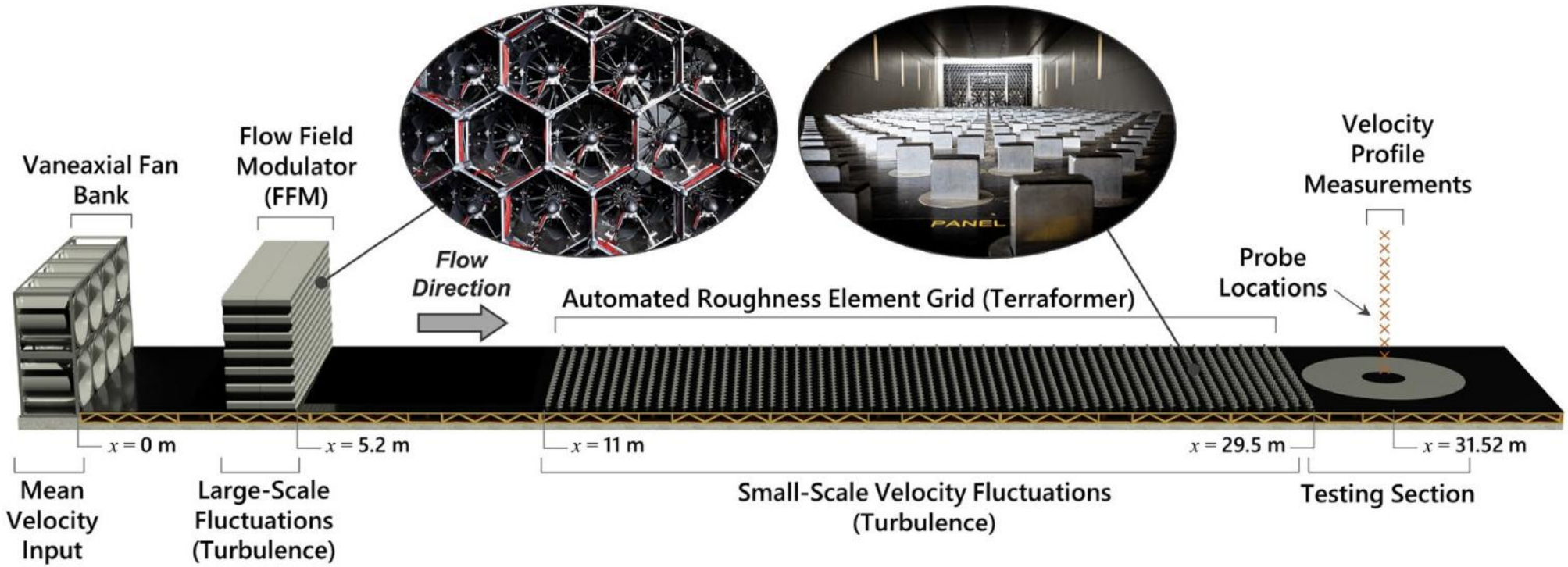


Gusts Encountered by Flying Vehicles in Proximity to Buildings, A. Mohamed, et. al, Urban Air Mobility (UAM), 2022

Current Solutions are limited by dimensions

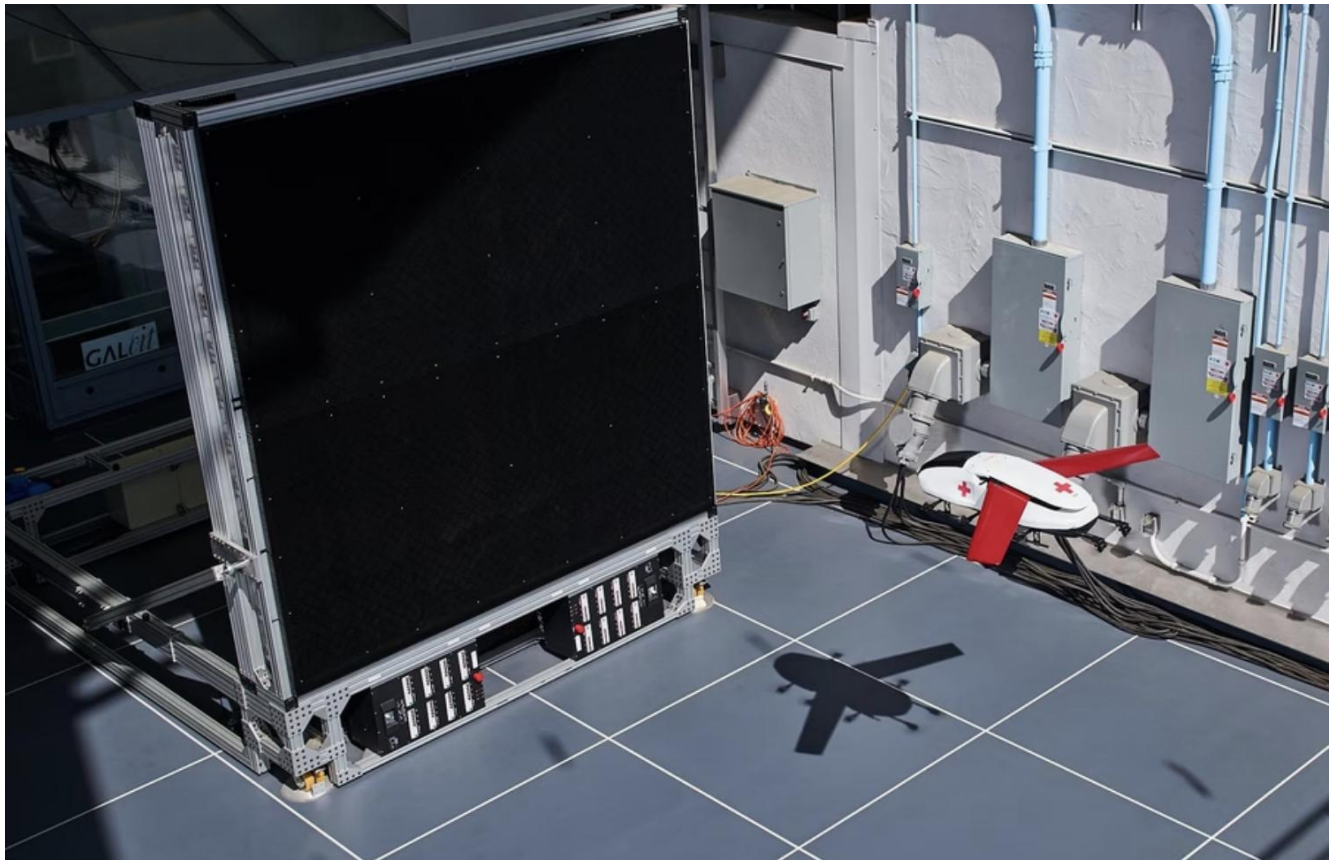
Limited to 1D and 2D gusts with airflow moving in one general direction

Additional turbulence generation is possible with additional features



Automated large-scale and terrain-induced turbulence modulation of atmospheric surface layer flows in a large wind tunnel, N. Mokhtar, et. al, Springer Nature 2023

Fan Array Wind Tunnels (FAWTs) allow for additional flow modulation



https://cast.caltech.edu/facilities

Range of turbulent airflow is more easily replicated using PWM speed-controlled computer fans

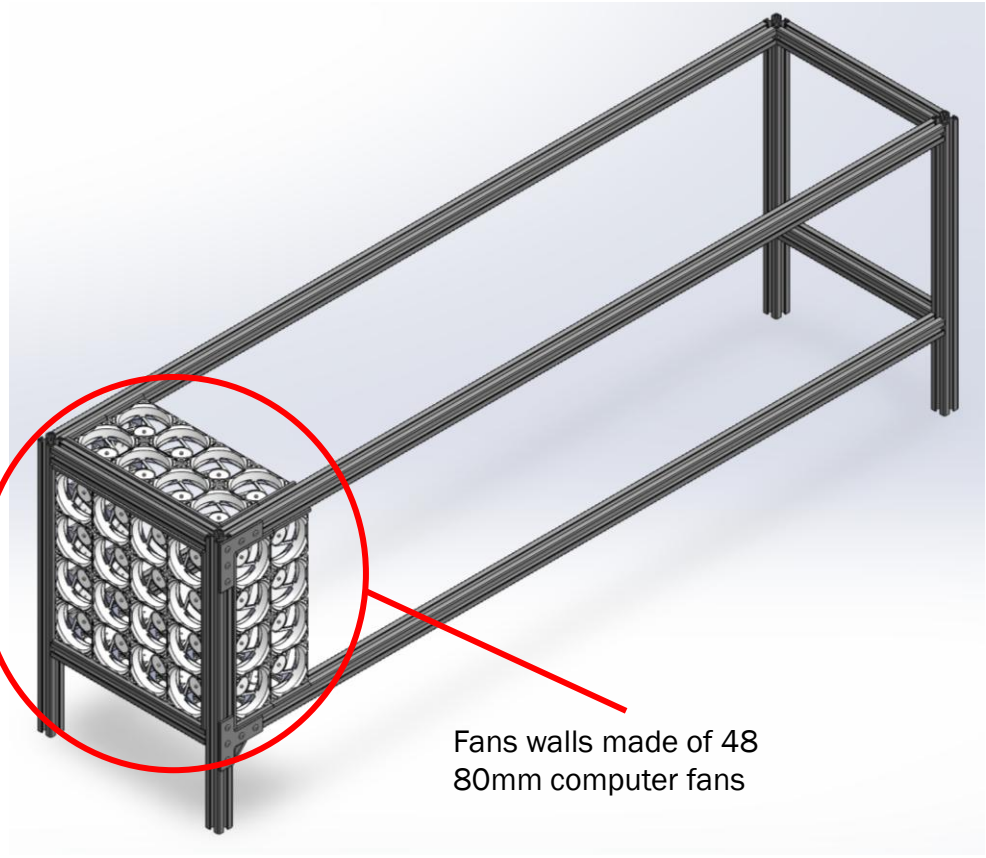
Facility design using a wall rather than a tunnel can create more freedom to introduce external conditions such as weather

Flow is still limited to moving in one direction with current facilities allowing us to understand 1D and 2D gusts easily, but not 3D

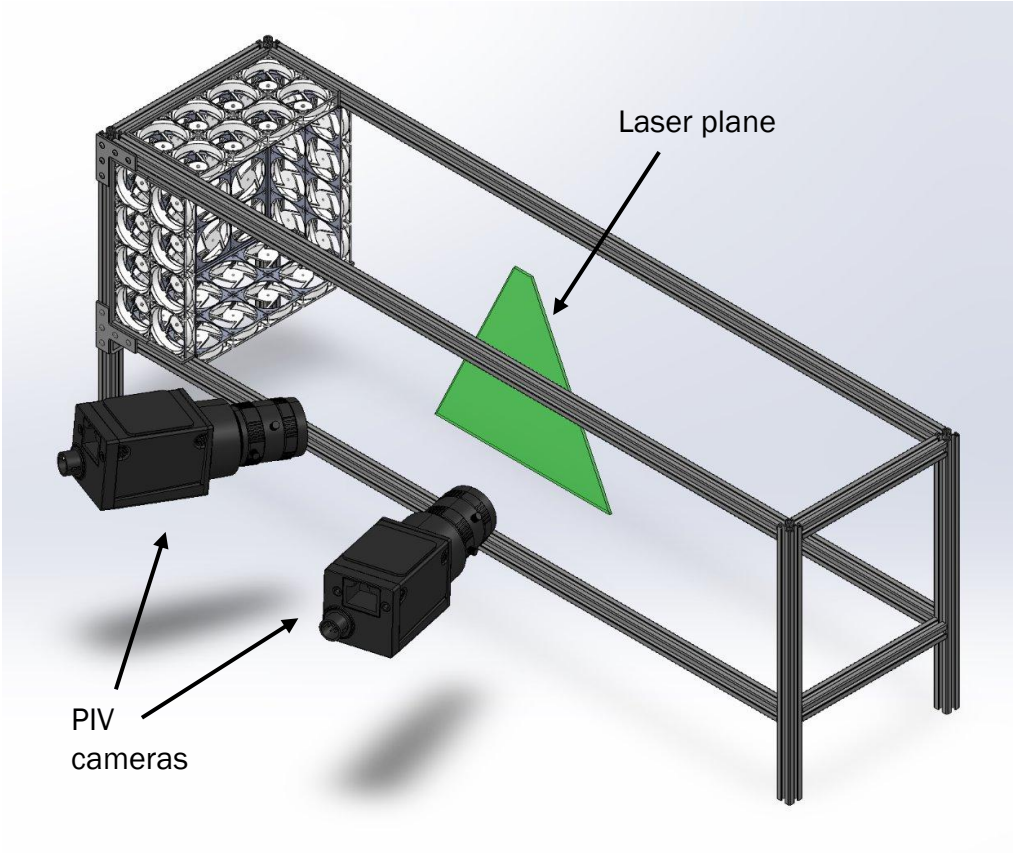
New solution that works in 3D

Array of independently controlled computer fans

Approximate 1ft x 1ft test section prototype



Flow studies that record seed particles moving downstream using particle image velocimetry (PIV)

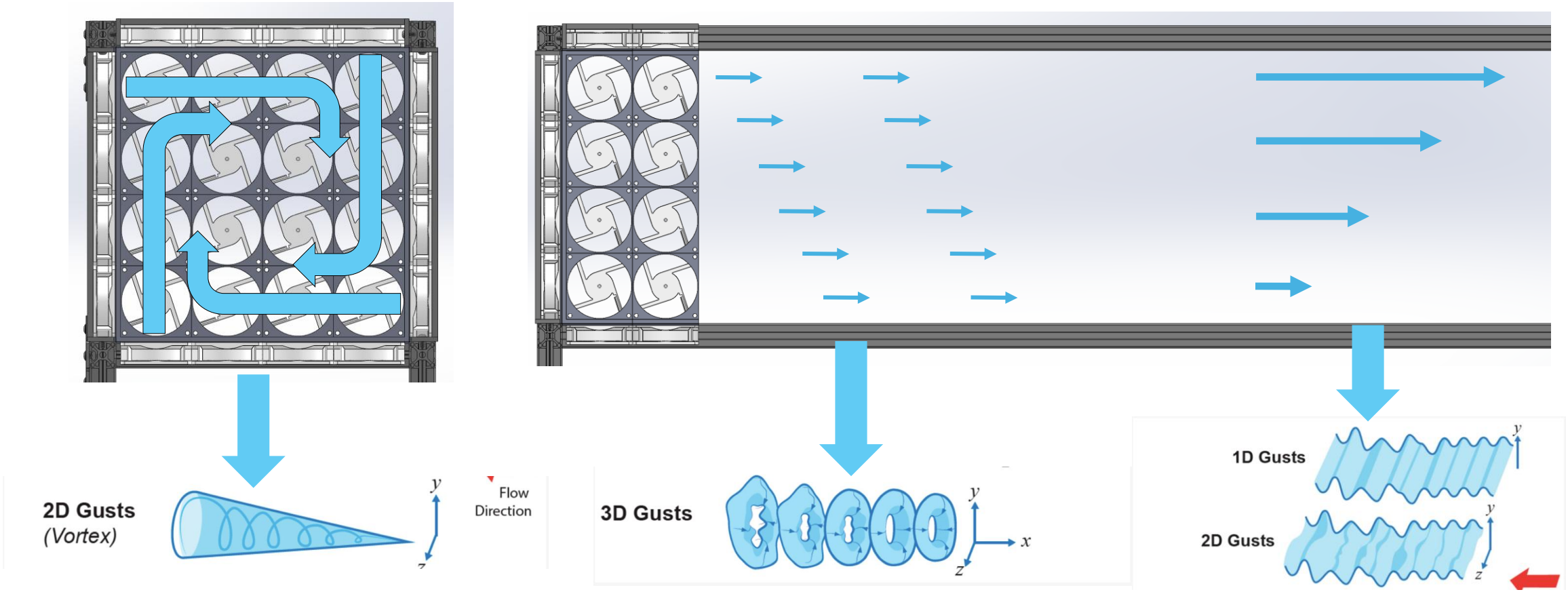


What gust formations are possible from a 3D gust generator?

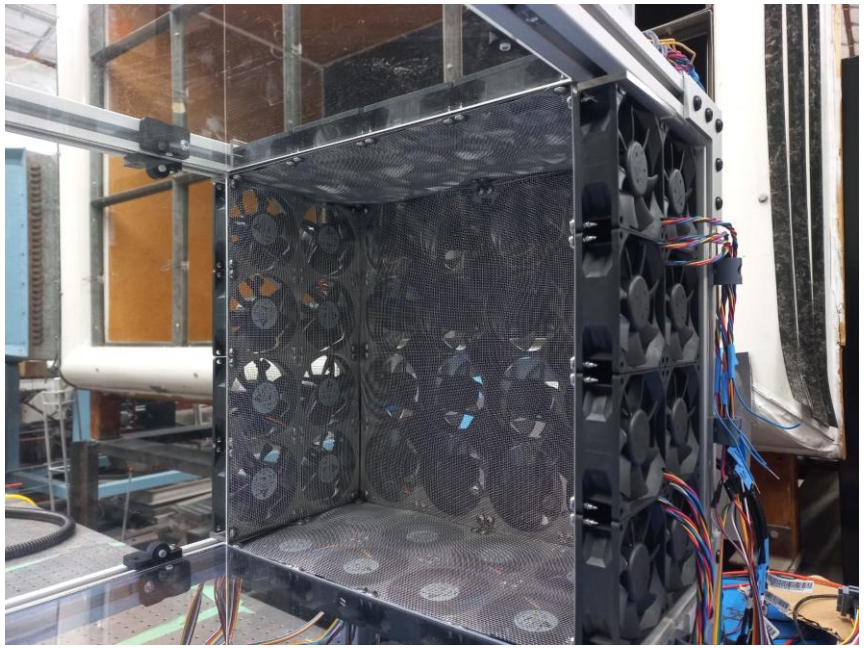
Orient fans speeds to induce a range of flows from different directions

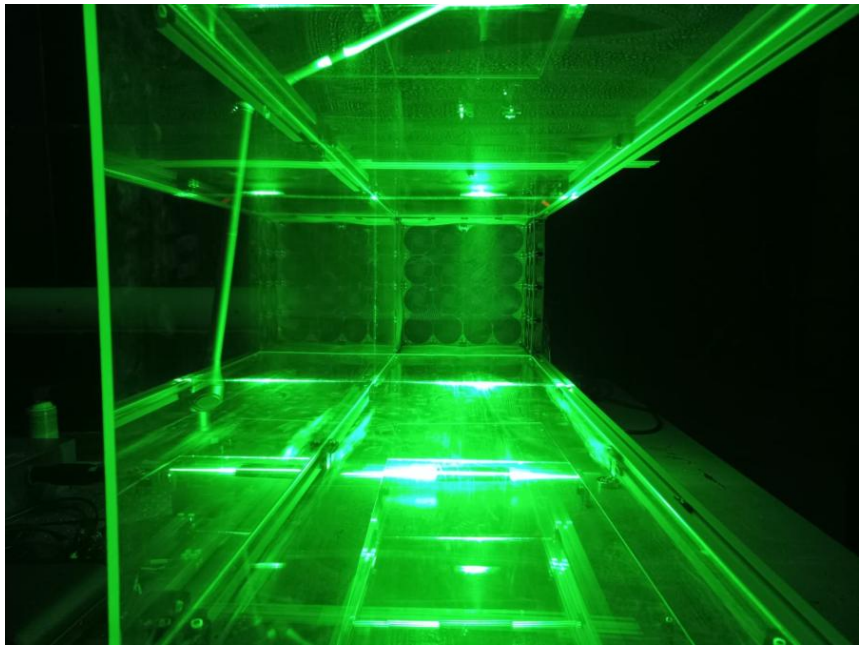
Set timers in the software to initialize bursts of airflow

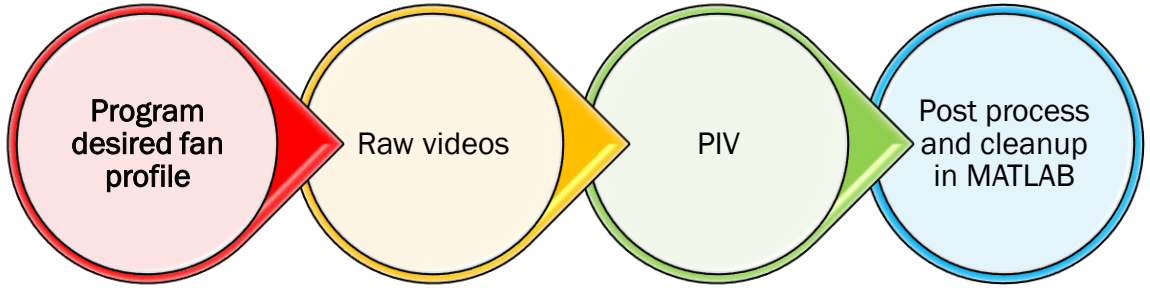
Control back wall flow speeds to control uniformity



Experiments to map fan speeds to coherent gusts

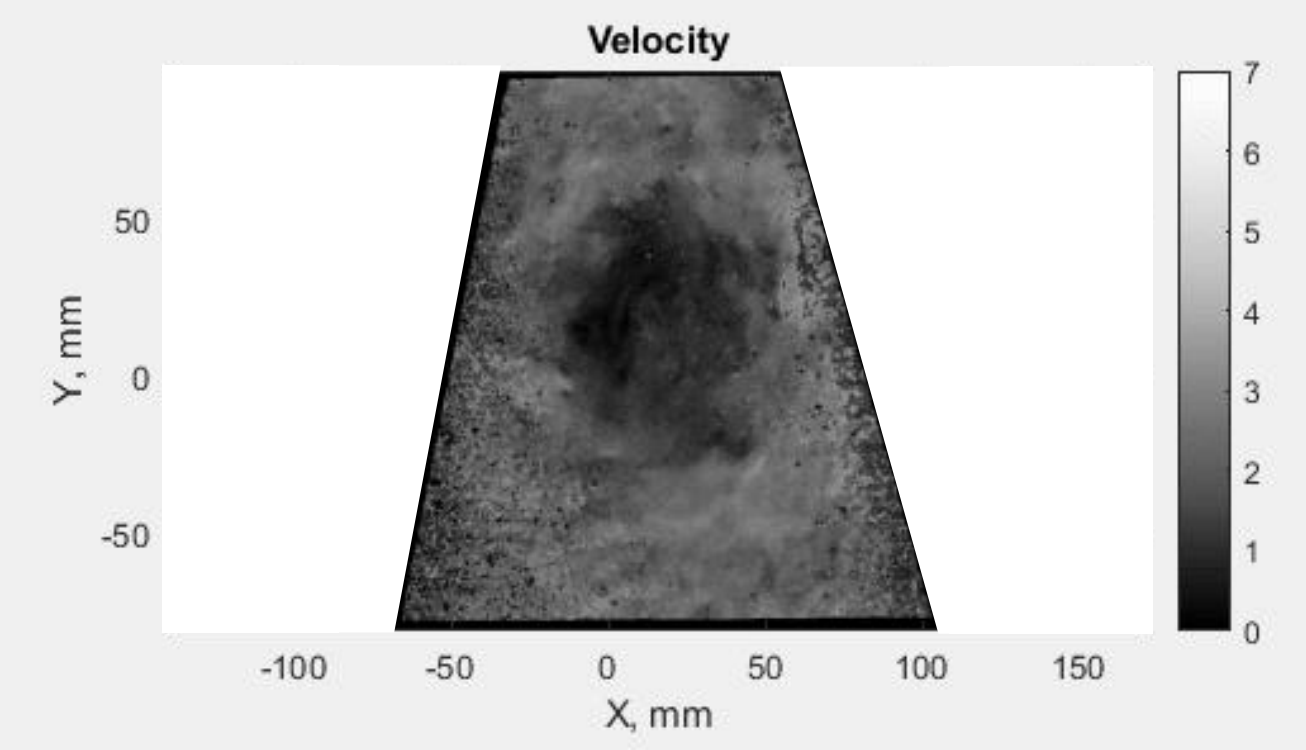




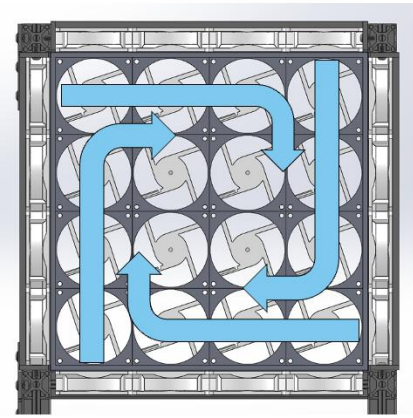


Structures Generated

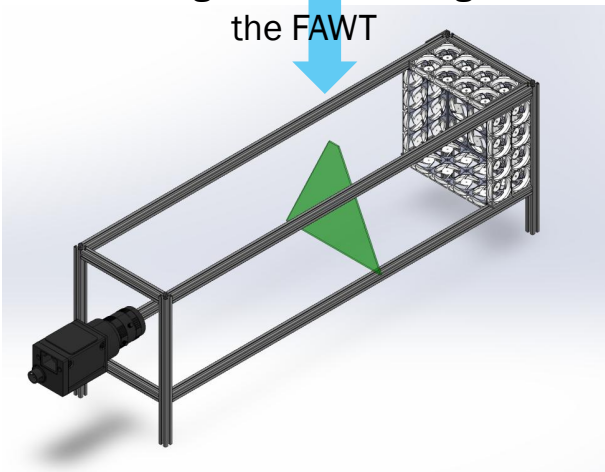
Though the time response of the fans is big to resolve and control structures with smaller time scales in this setup, few structures have been generated.



The velocity field on the cross section of the FAWT

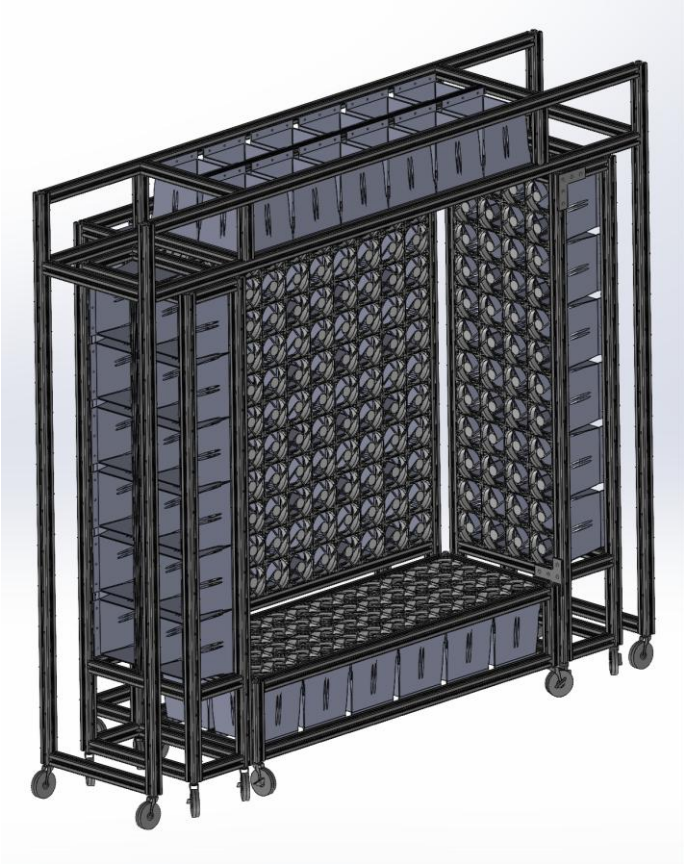


These recordings are a cross-section of the flow using Planar PIV with a single camera facing down the FAWT

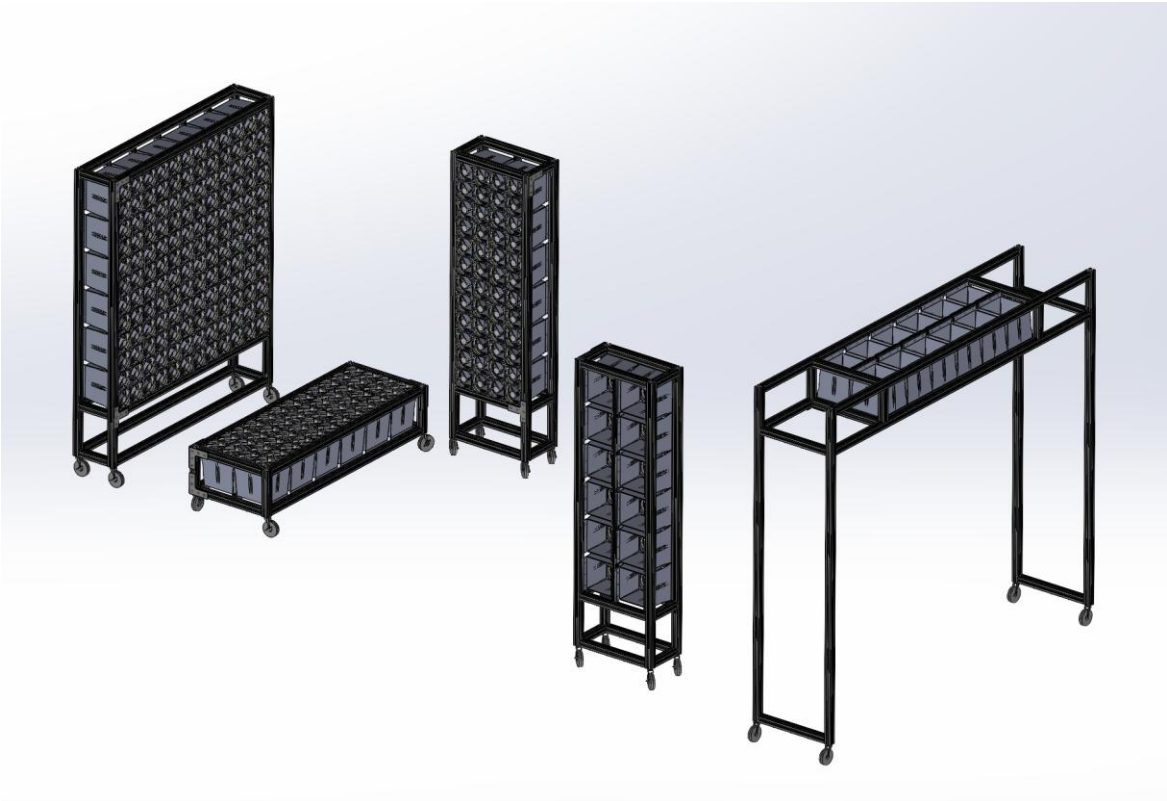


What about scaling up this facility?

~4.75 ft x 4.75 ft test section comprised of 336 computer fans with speeds up to ~14 m/s

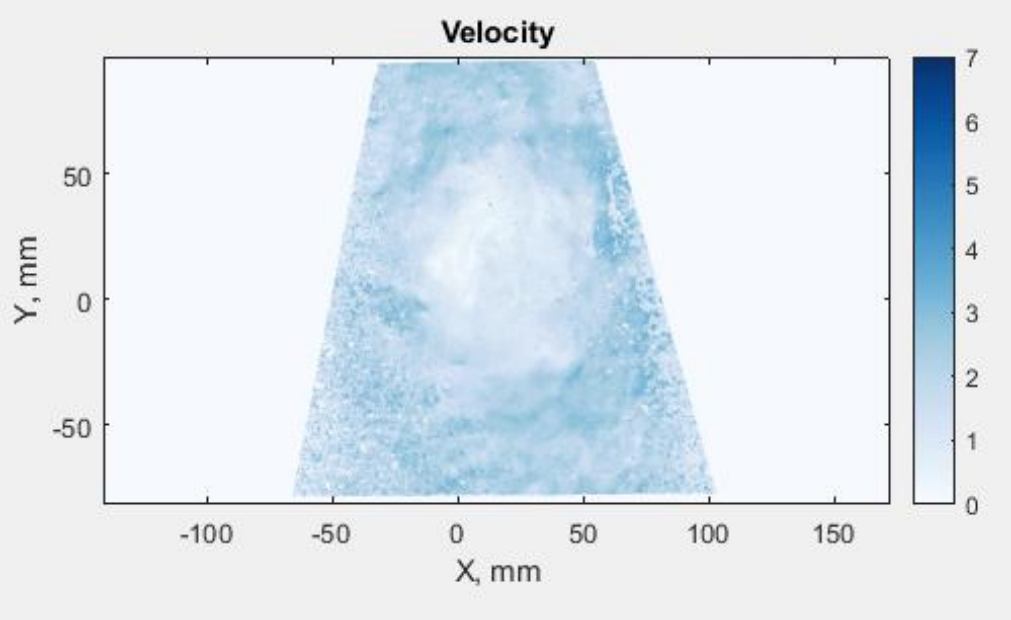


Individual walls that can be arranged in any configuration to achieve finer flow control

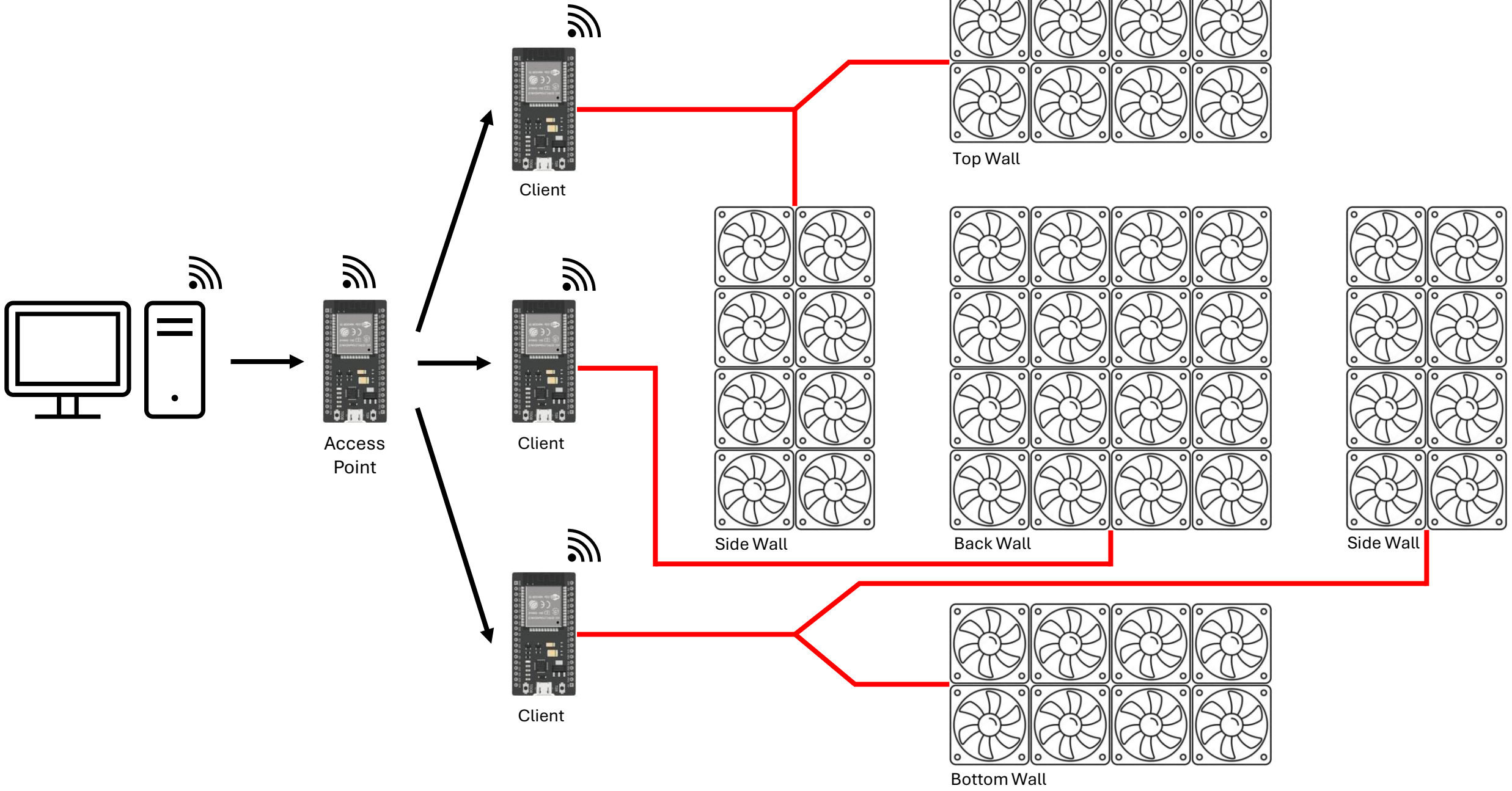


Ongoing work

- What insights can be gained from these results:
  - We've demonstrated 3D helical vortices in our lab prototype facility are produced using this fan algorithm
  - Next steps are scaling this prototype facility to enable batch tests of urban air vehicles subjected to flight relative turbulence
  - Mapping fan parameter space to flow parameter space

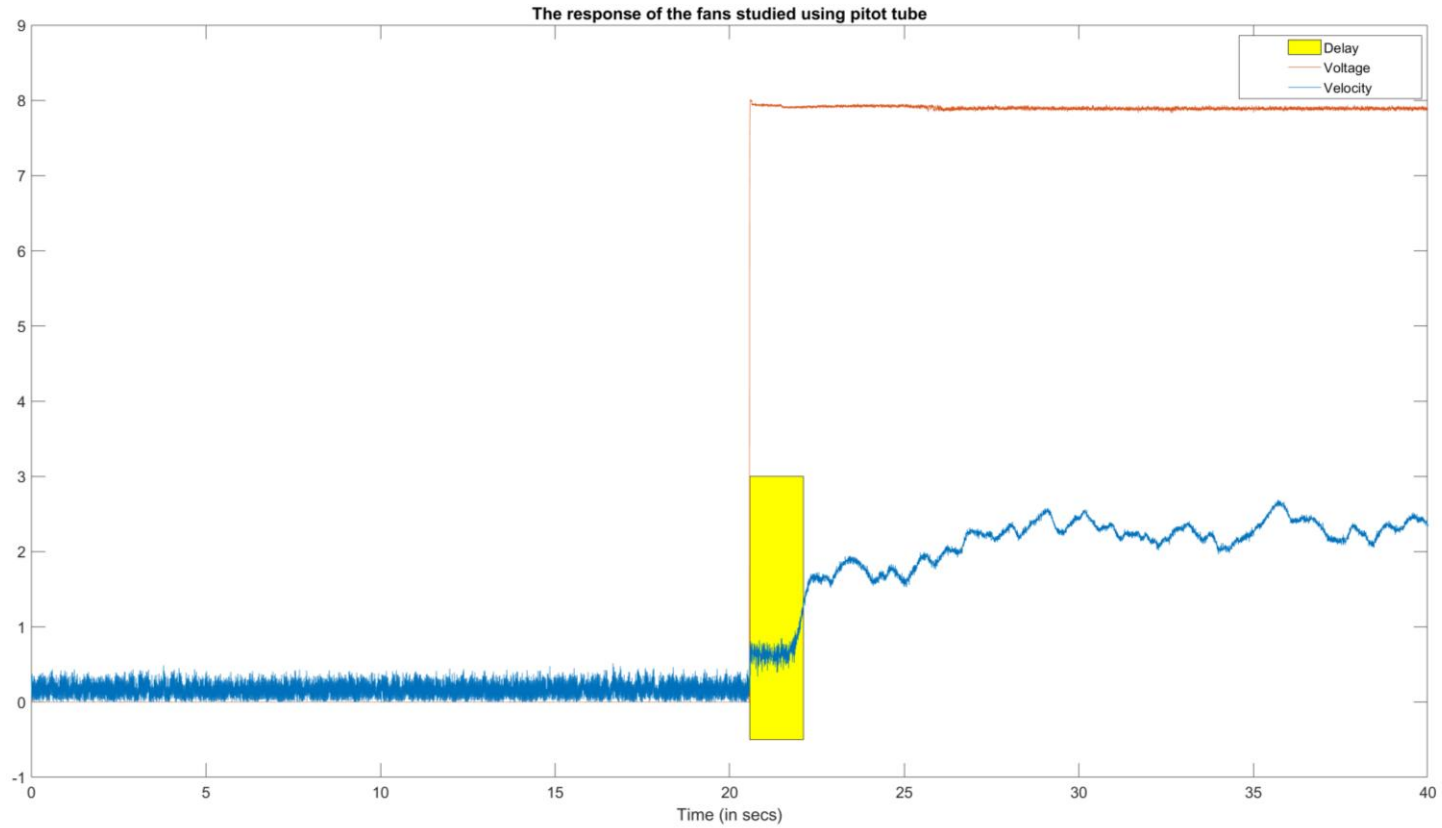


Backup Slide


Client
Top Wall
Access
Point
Client
Side Wall
Back Wall
Side Wall
Client
Bottom Wall

Extras: Response of the present prototype

Necessary to understand signal response time from computer and time delay for a specified flow speed to reach a certain distance downstream

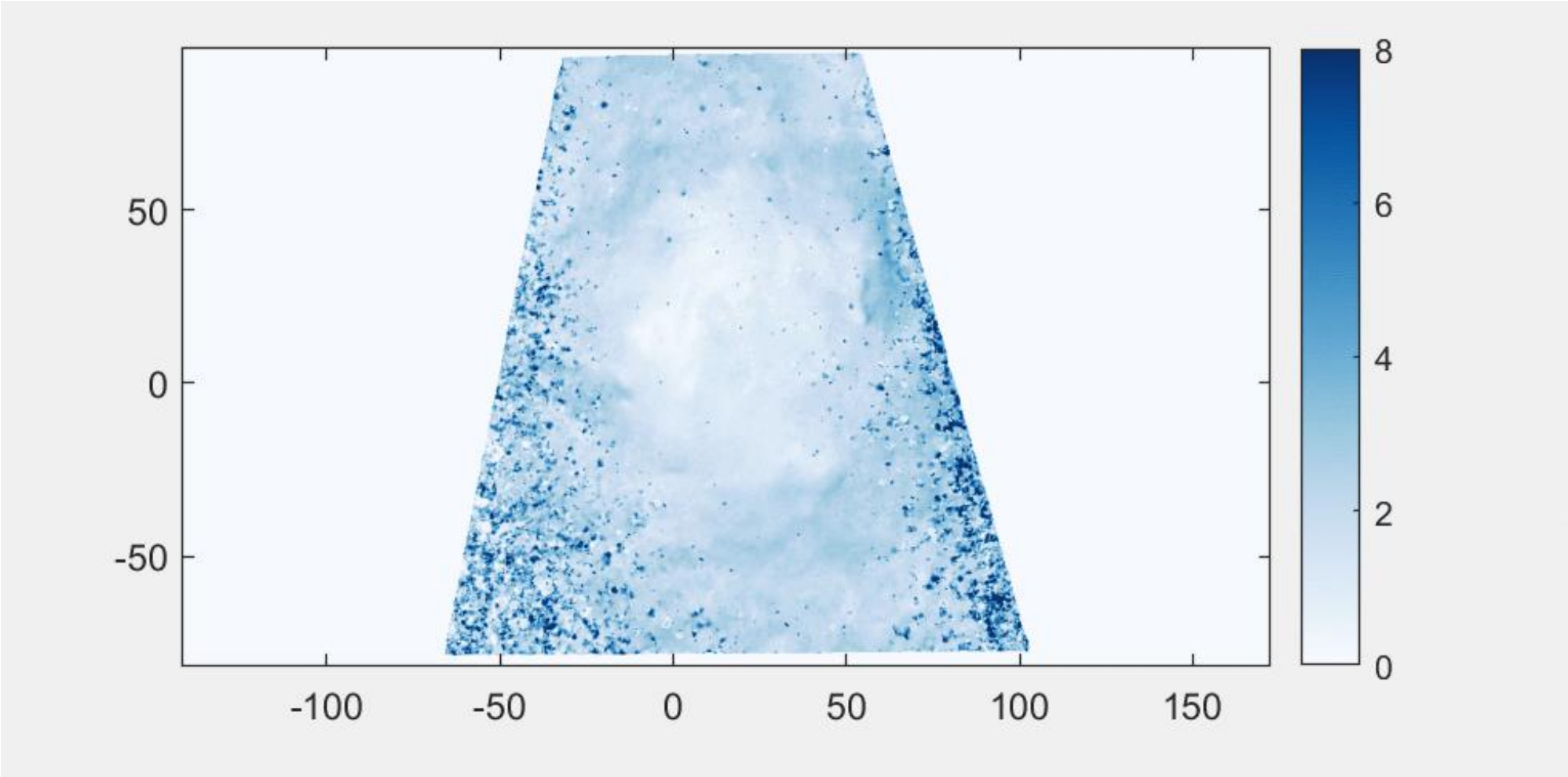


The pitot tube was kept 560 mm from the fan panels.

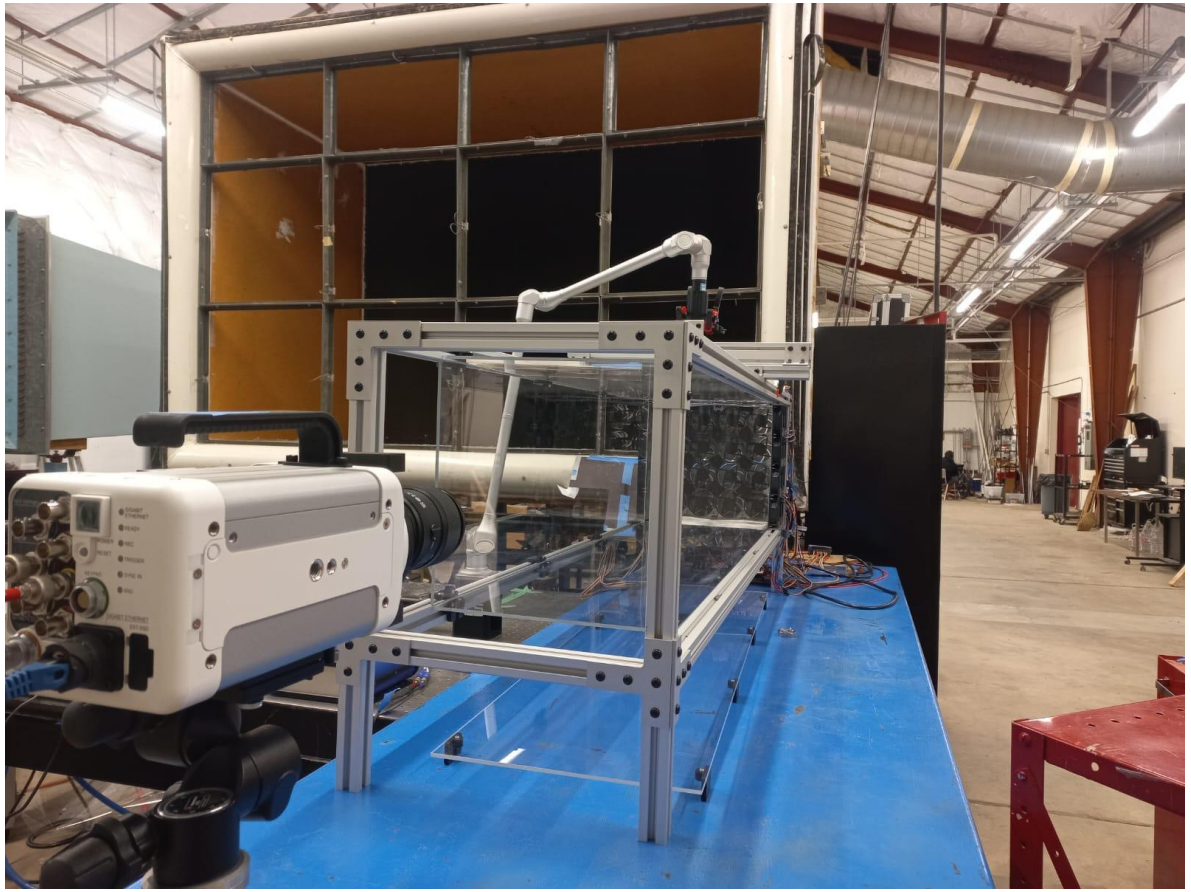
The expected delay for step input: .2435s

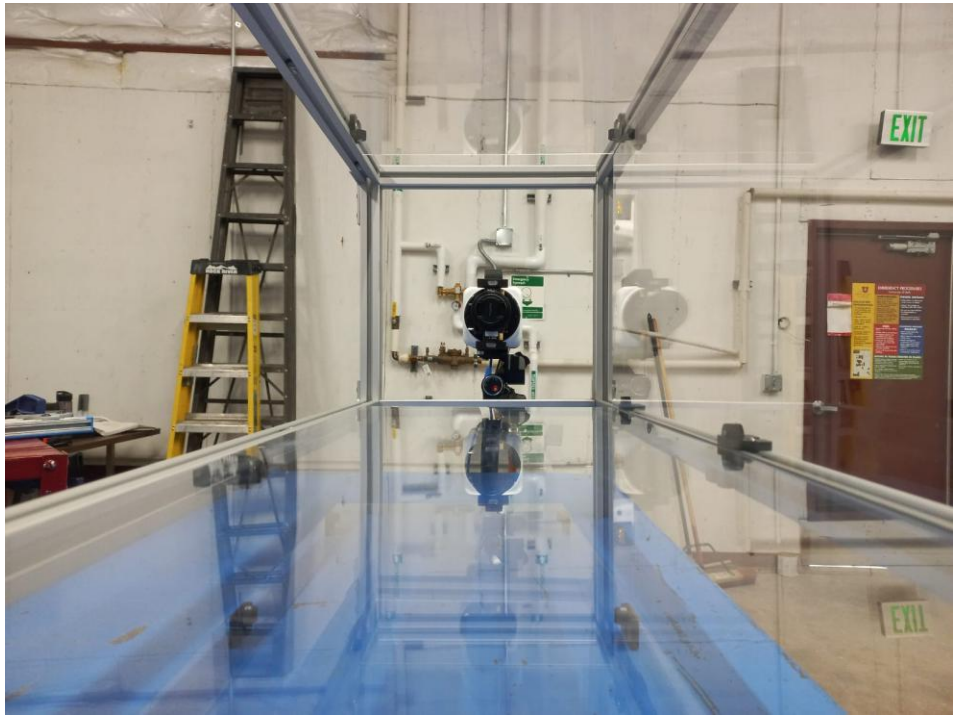
The measured delay for step input: 1.537s

Extras: Blue Helical Vortex (raw MATLAB gif)



Current Prototype





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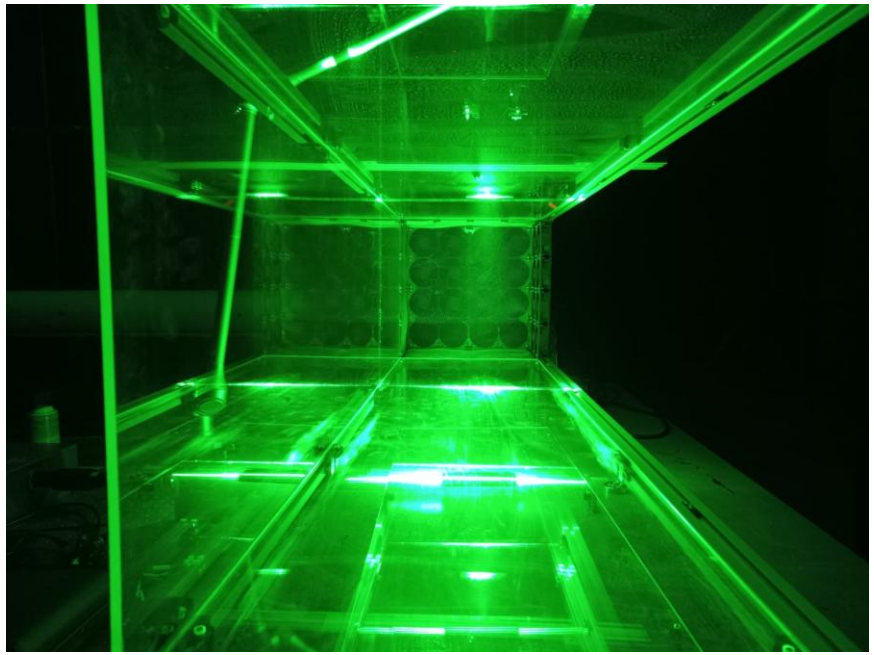
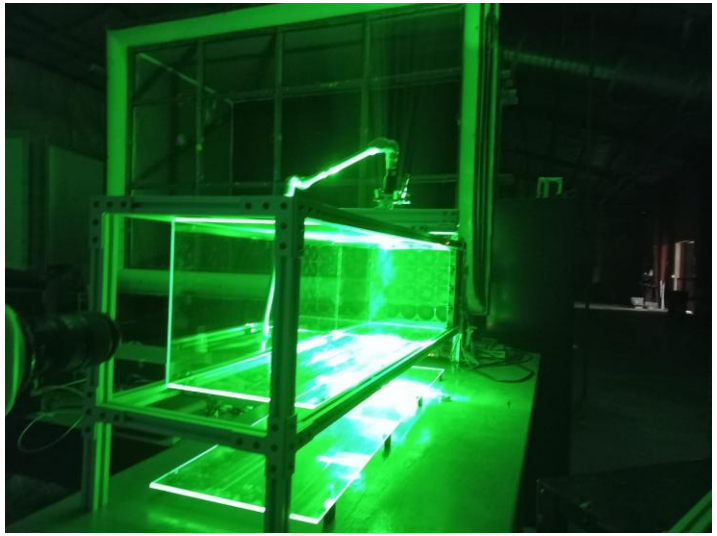
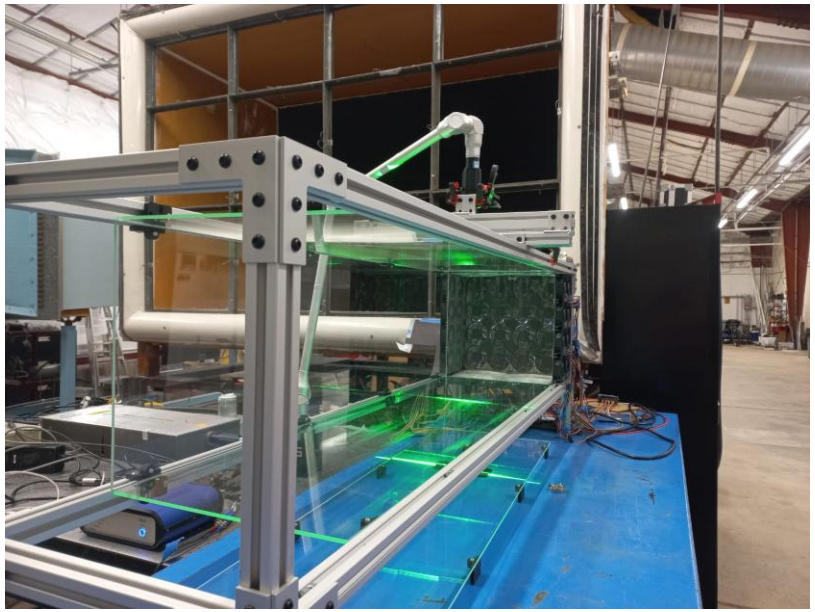
PIV Setup







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Extras: Characterization of Prototype