Recumbent Bicycle Windshield

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Goal

- Explore practicality and aerodynamic effects of windshields on recumbent bicycles.
- Analyze windflow in in regard to comfortability of the cyclist and streamlined flow around the rider at varying speeds.
- Design an optimized windscreen that streamlines flow around the rider at both low and high speeds to maximize rider comfort.

Background

- We decided on this topic as there are many unique ergonomic consideration due to the position of the rider making it interesting to simulate and analyze.
- Recumbent bicycles date back to the 19th century as a means to make cycling more safe, comfortable, and potentially faster (for all ages!)
- Most commercial windscreens for bicycles cater to the standard bike but there are a few windwrap fairings on the market, mostly designed for speed and drag resistance rather than comfort.



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Background, cont.

- Previous papers have covered CFD and designs for adjacent vehicles…

Motorcycle windshields

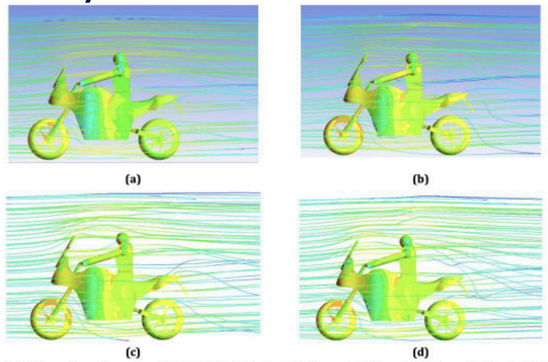
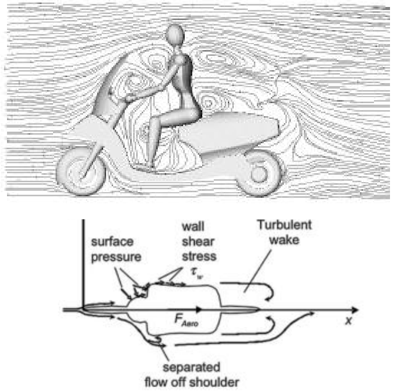


Fig.7 *Streamline motorcycle windshield (a) OEM design (b) Aftermarket design 1 (c) Aftermarket design 2 (d) Aftermarket design 3*

F. Ghazali and M. Fahmi, "Investigation of Different Windshield Designs for Aerodynamic Drag Force in Motorcycle," *Progress in Aerospace and Aviation Technology*, vol. 4, no. 1, pp. 49–56, 2024.

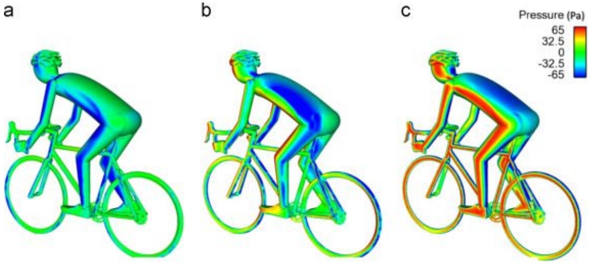
Fig. 3



Simplified diagram of the flow field around a cyclist from Martin et al. [9], highlighting the high-pressure leading surface regions and the low-pressure turbulent wake. Reprinted with permission from Human Kinetics, Inc., from Martin et al. [9], ©1999; permission conveyed through Copyright Clearance Center, Inc.

T. N. Crouch, D. Burton, Z. A. LaBry, and K. B. Blair, "Riding against the wind: a review of competition cycling aerodynamics," Sports Engineering, vol. 20, no. 2, pp. 81–110, May 2017, doi: https://doi.org/10.1007/s12283-017-0234-1.

CFD studies of cyclists,
but no windshields and not recumbent



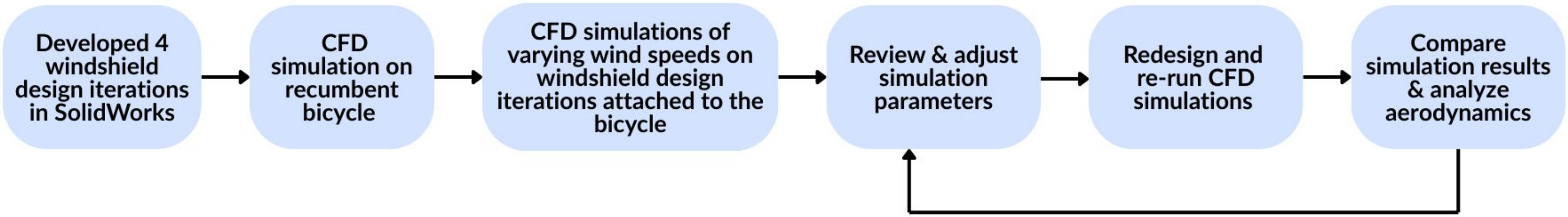
Pressure distribution on the cyclist at different crosswind yaw angles obtained from the RANS k–ε simulations.

D.M. Fintelman, H. Hemida, M. Sterling, and F.-X. Li, "CFD simulations of the flow around a cyclist subjected to crosswinds," Journal of Wind Engineering and Industrial Aerodynamics, vol. 144, pp. 31–41, Aug. 2015, doi: https://doi.org/10.1016/j.jweia.2015.05.009.

- But there have been few studies and papers that have focused on computational fluid dynamic analysis for recumbent bicycles with windshields

Methods

- Software used: SolidWorks, Ansys Fluent
- Computational/research flowchart

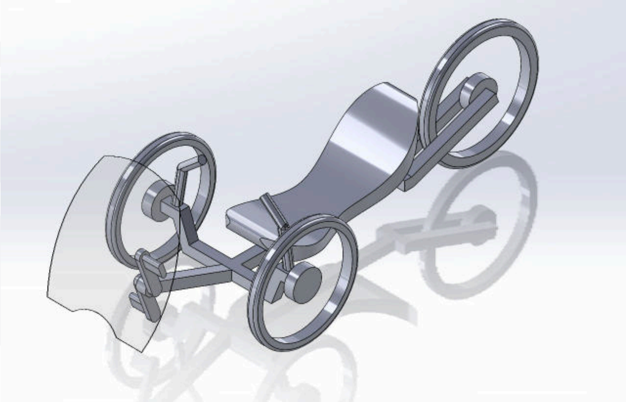


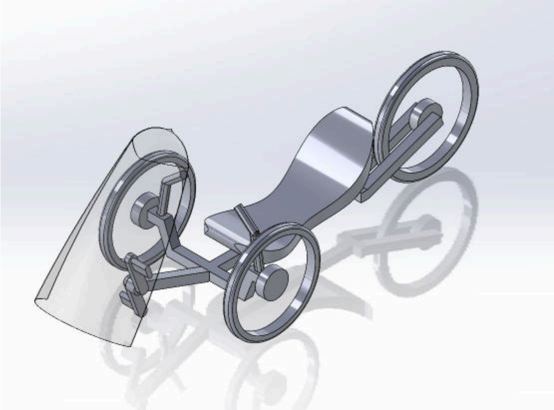
BOM

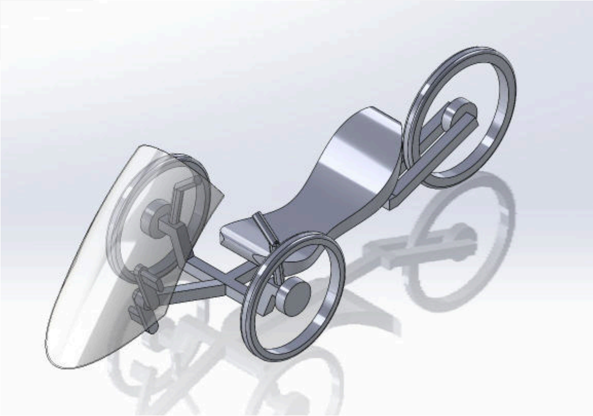
No materials used except the effort in our hearts :)

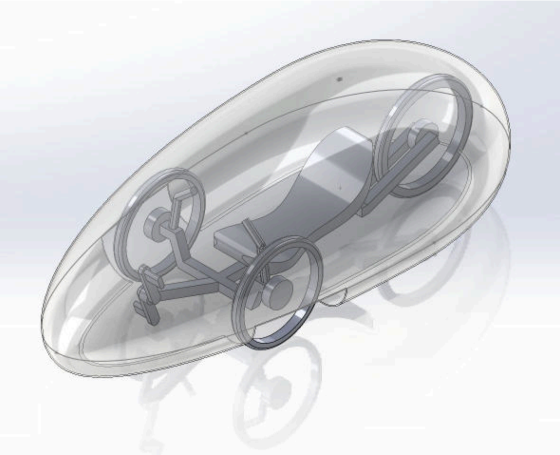
Can we get free pizza because we didn't use any of our money

Models









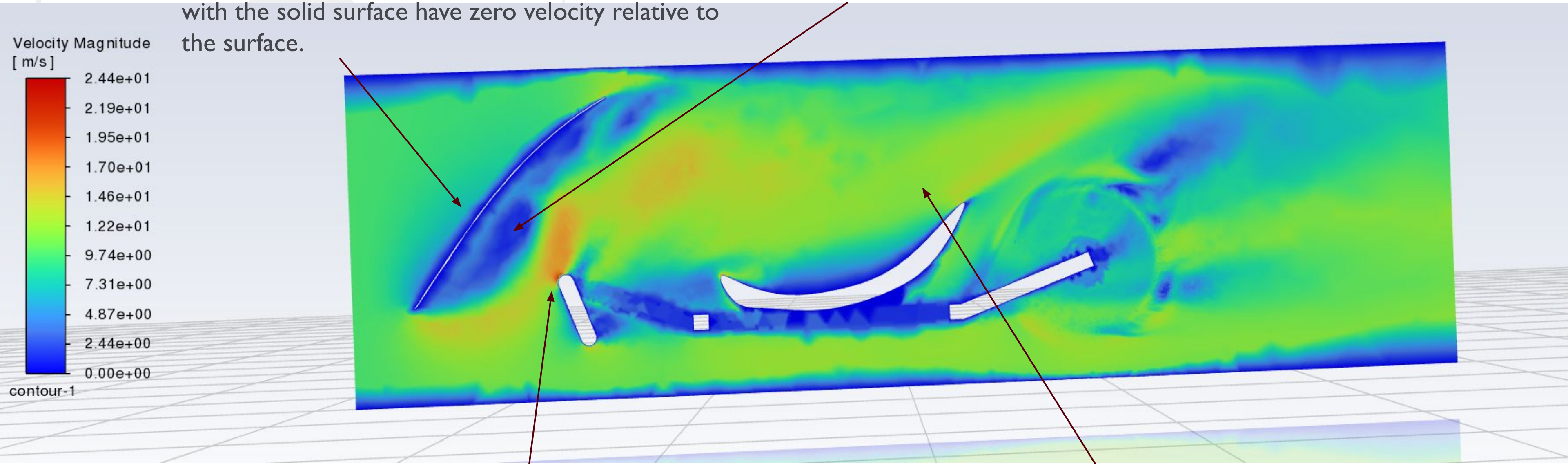
CFD Strategies

- Selected boundaries as a simple rectangular prism
- Selected default mesh (initially) for optimized run time and iteration
- Tested range of constant wind velocities representative of cycling at a relatively slow and relatively fast speed
- Visualized airflow via contour and vector plots in both 2D and 3D to capture as much quantitative data as possible

Interpreting Results

Region right before windshield can appear to have no velocity due to "no slip" boundary condition, which assumes that the fluid particles in contact with the solid surface have zero velocity relative to the surface.

Areas of low-zero velocity



Pressure build-up, areas of high velocity

This is the area we primarily care about (the riders head)

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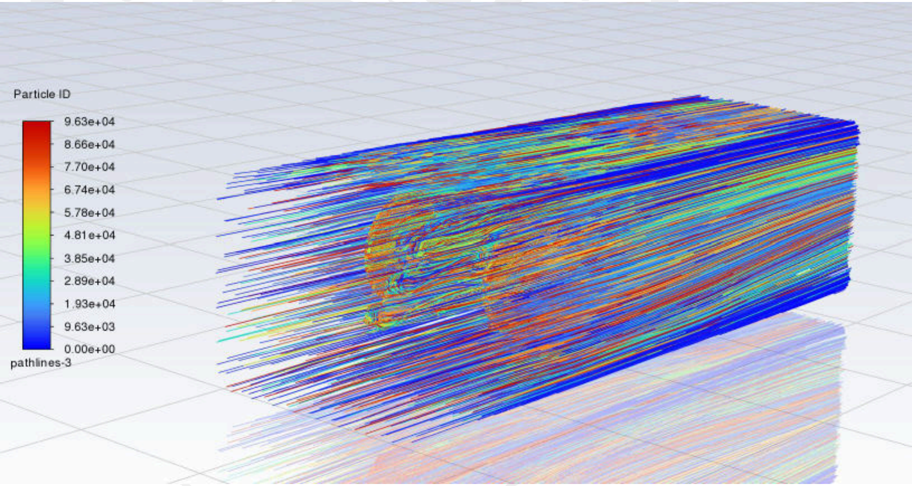
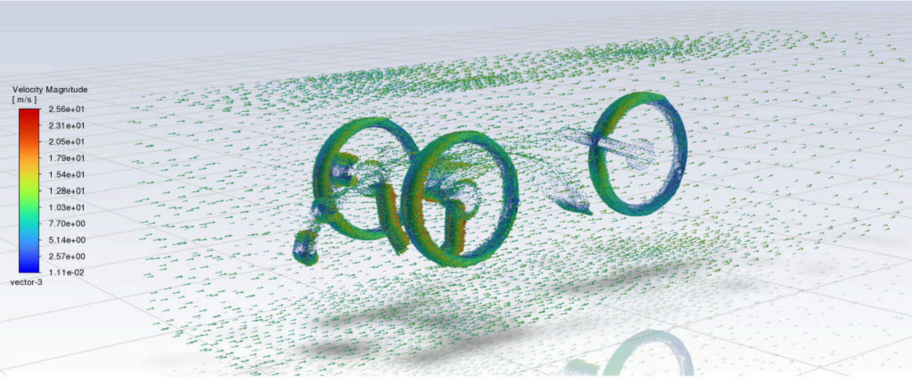
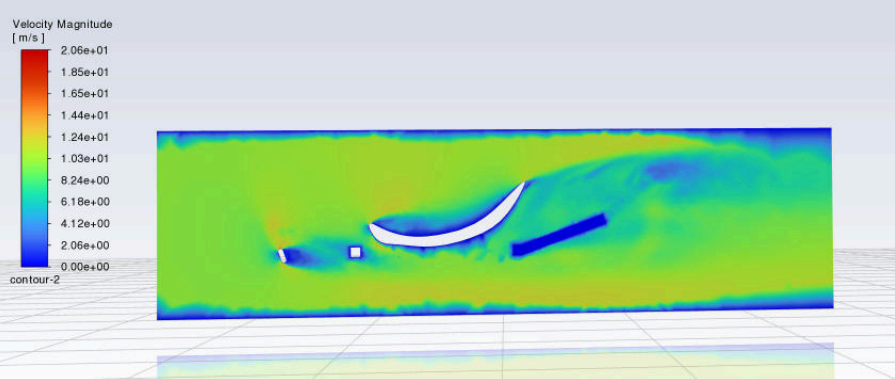
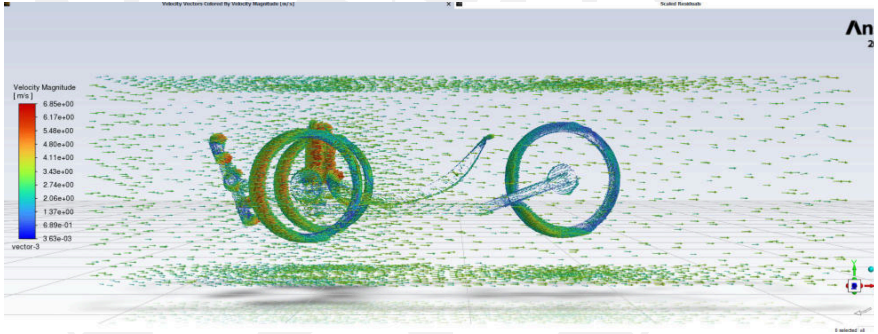
Results (no shield, 10m/s)

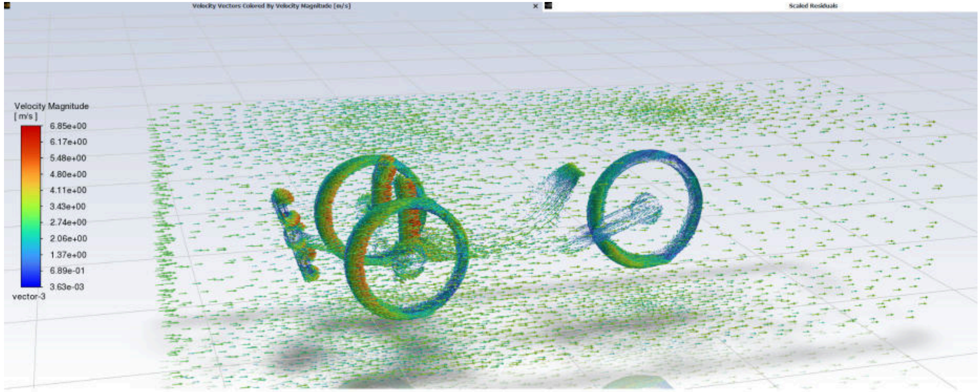


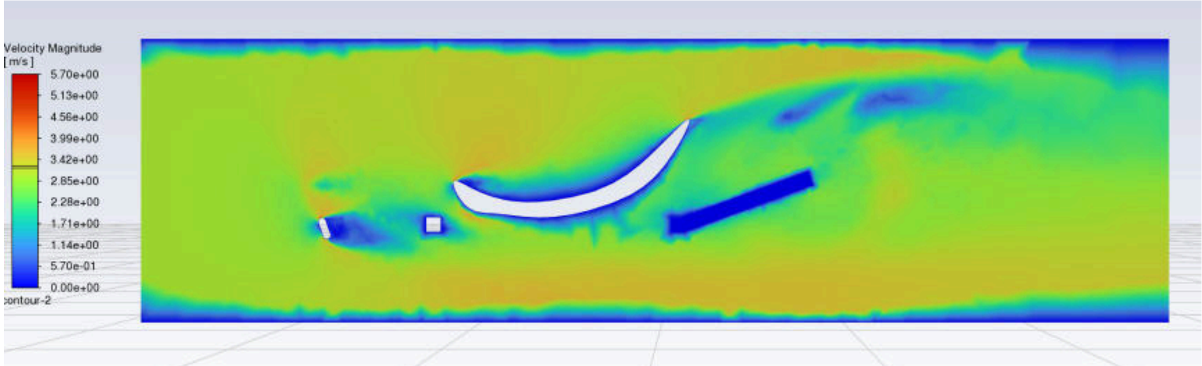




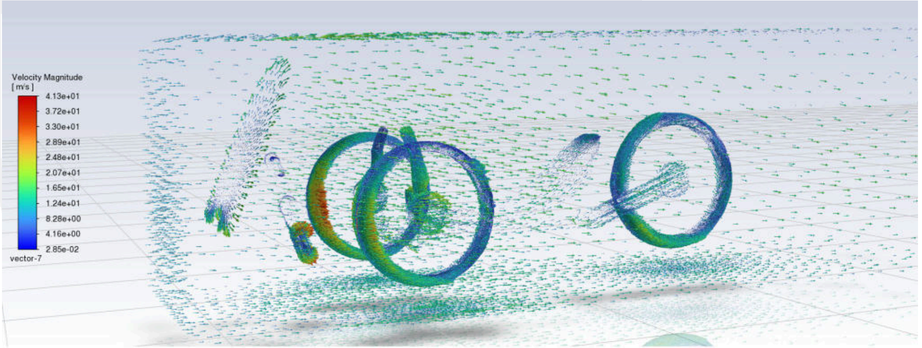
Results (no shield, 3m/s)

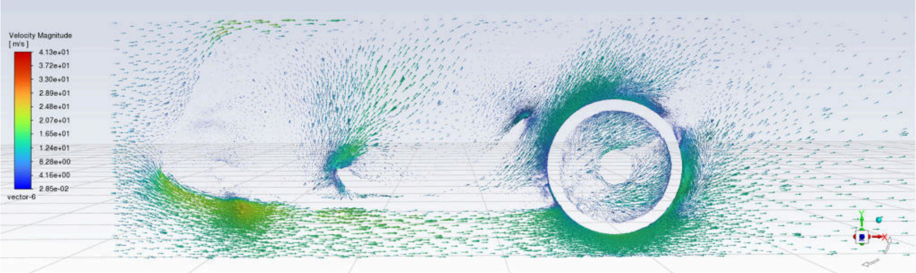


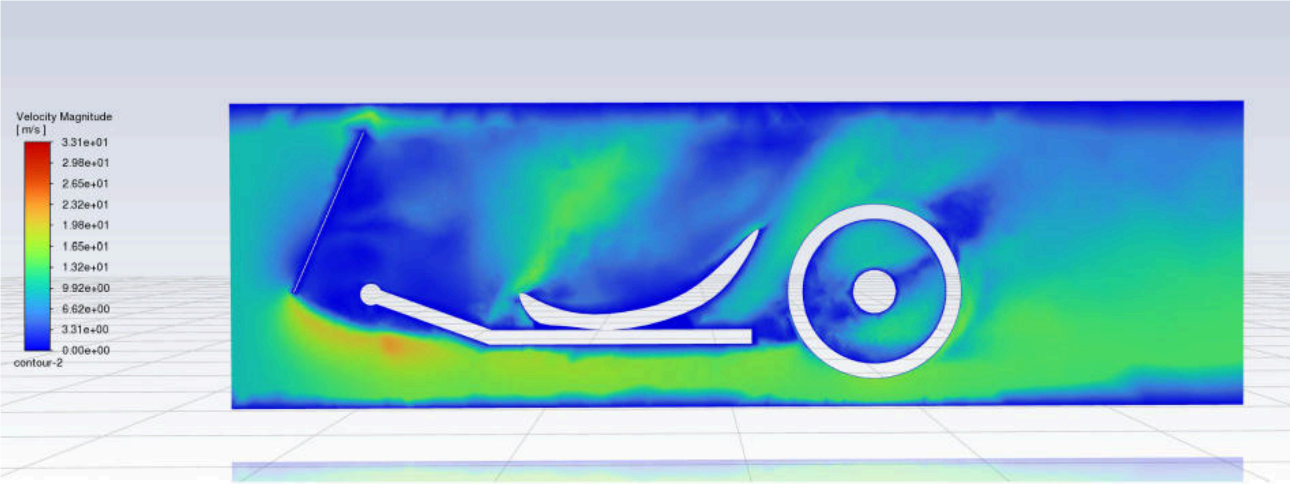




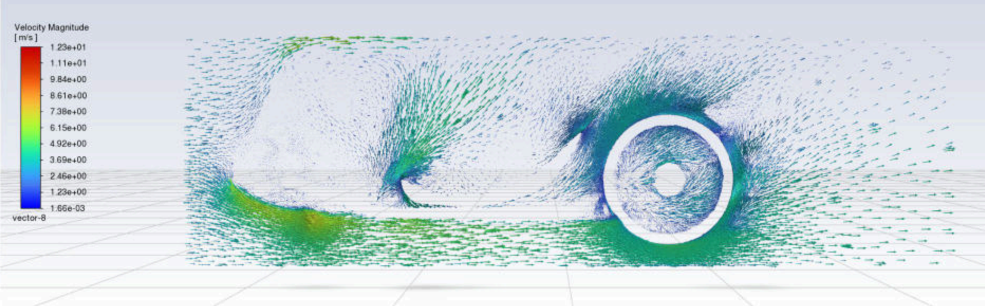
Results (flat shield, 10m/s)

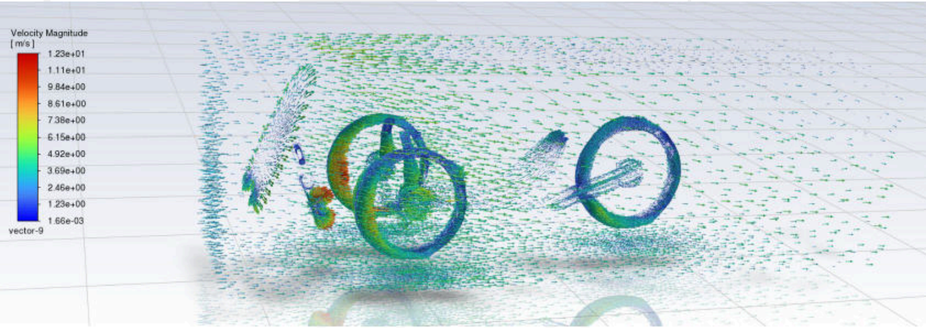


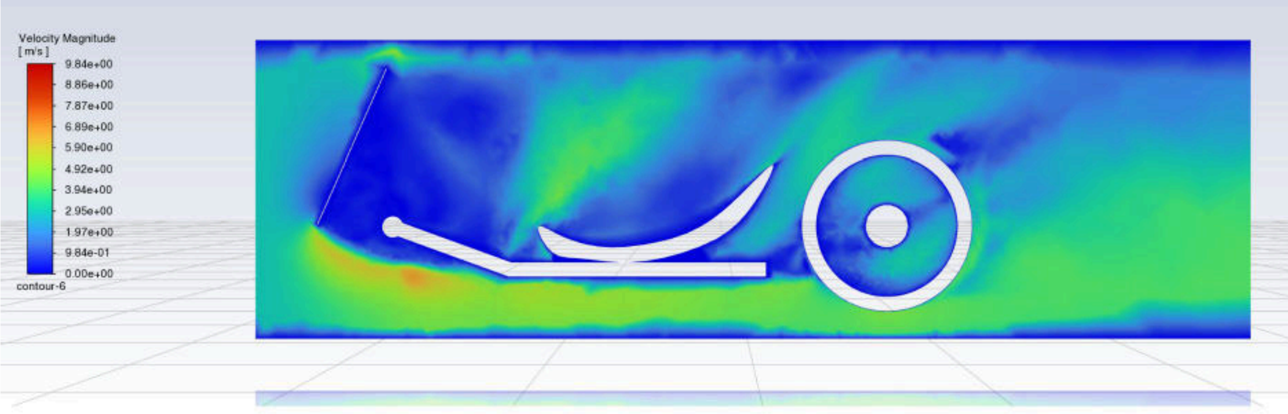




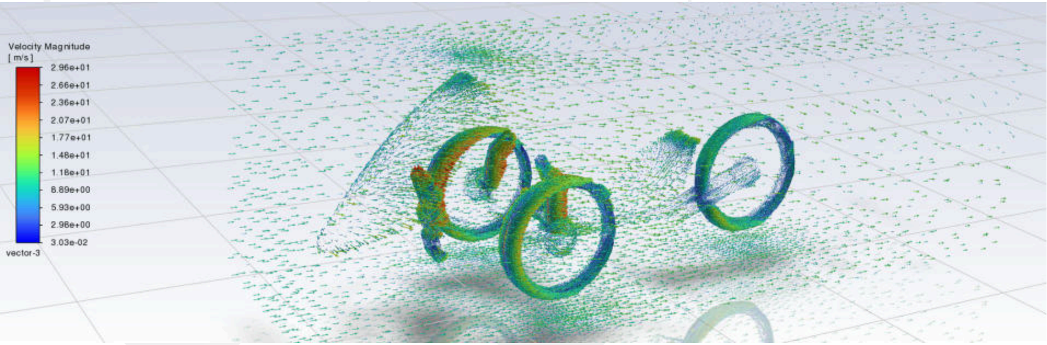
Results (flat shield, 3m/s)

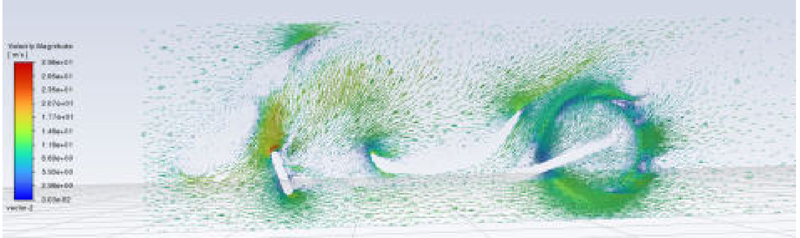


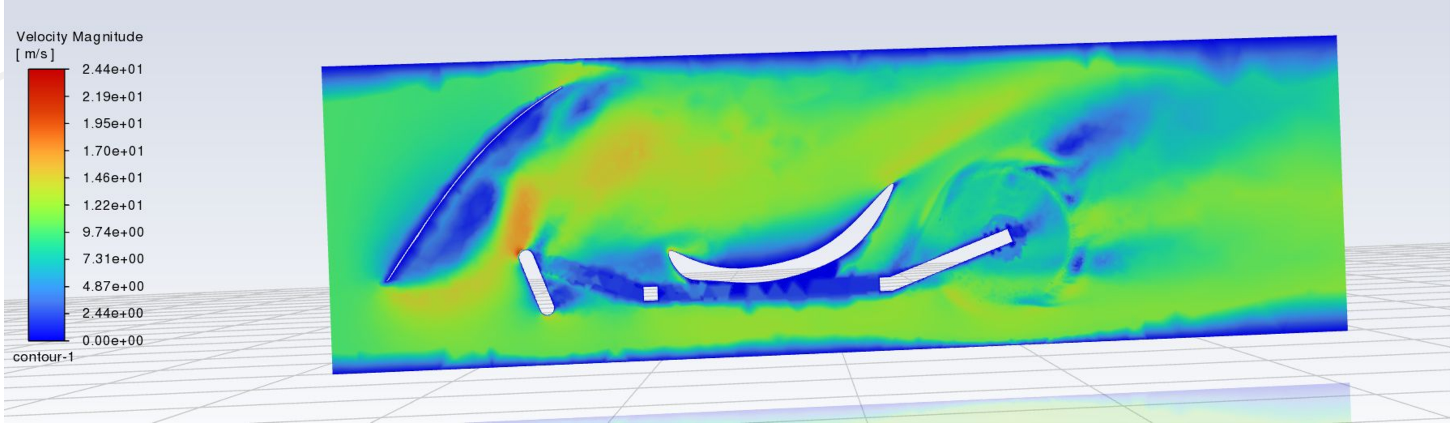




Results (curved shield, 10m/s)







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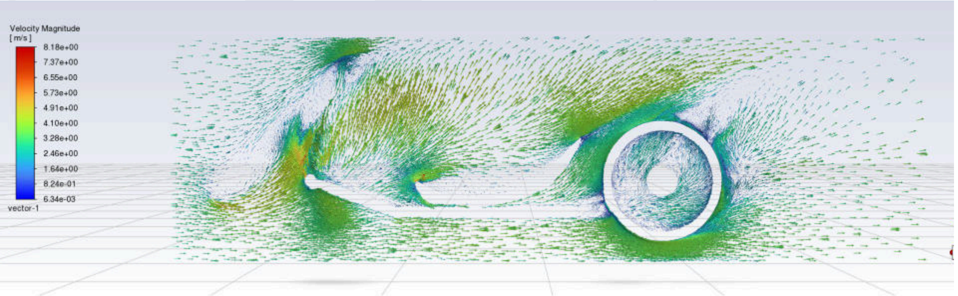
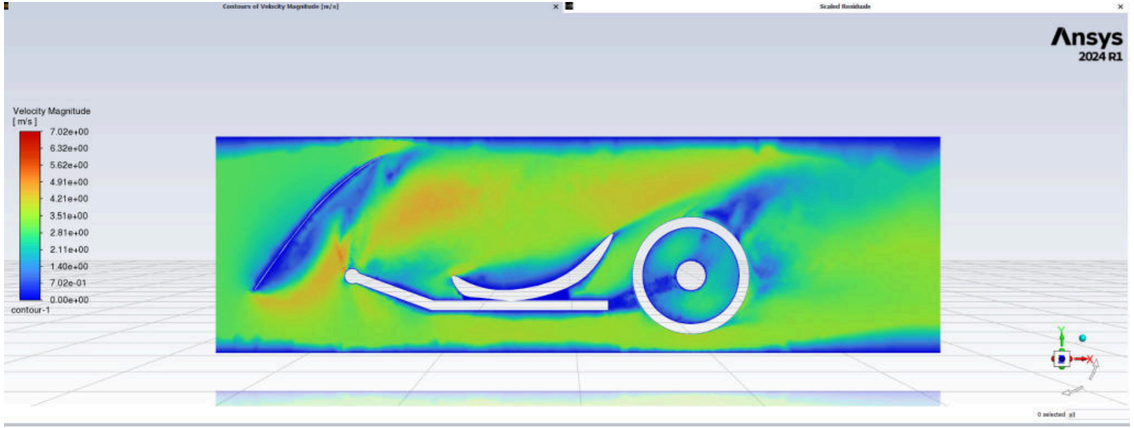
Results (curved shield, 3m/s)





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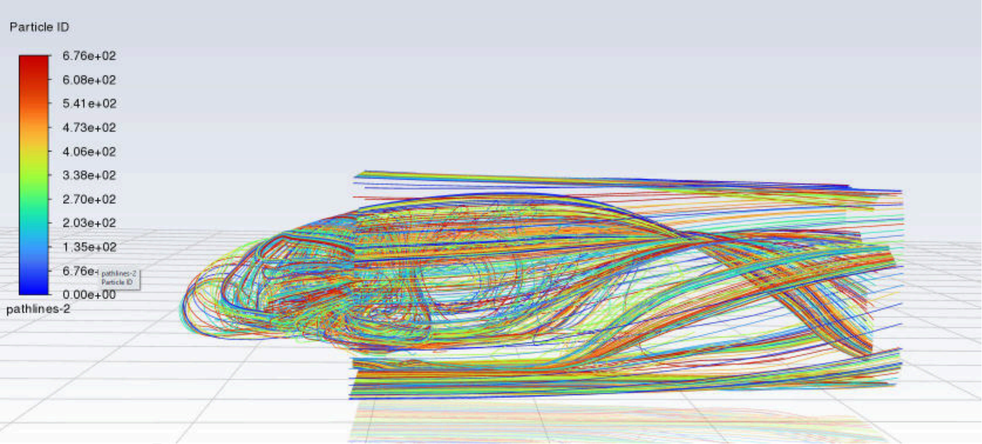
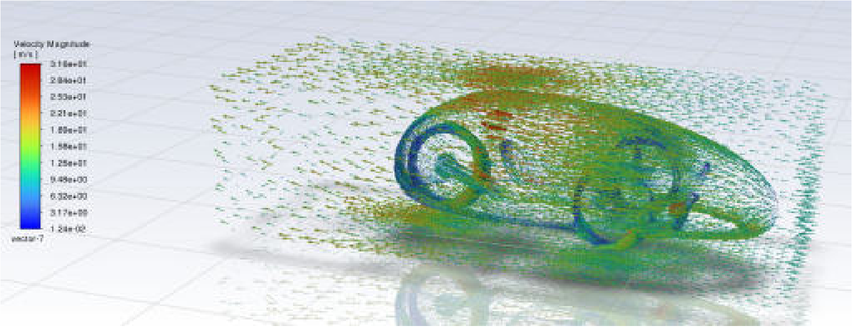
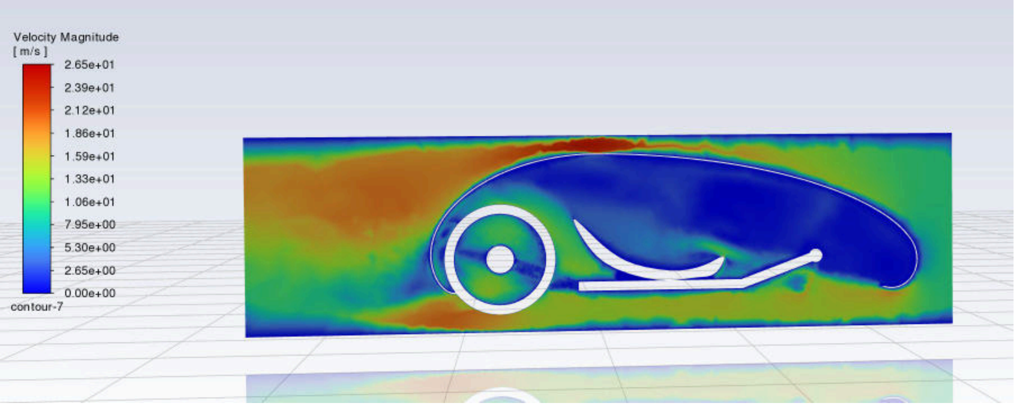
Results (velomobile, 10m/s)







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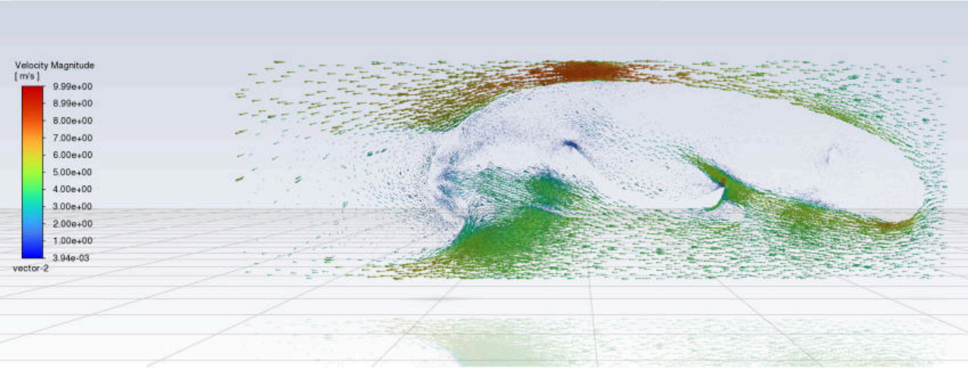
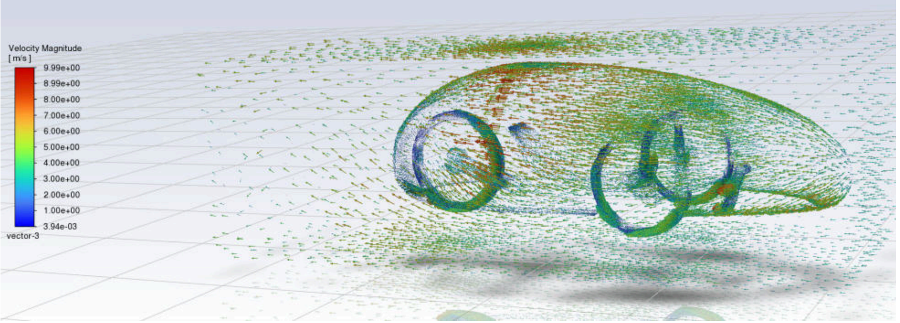
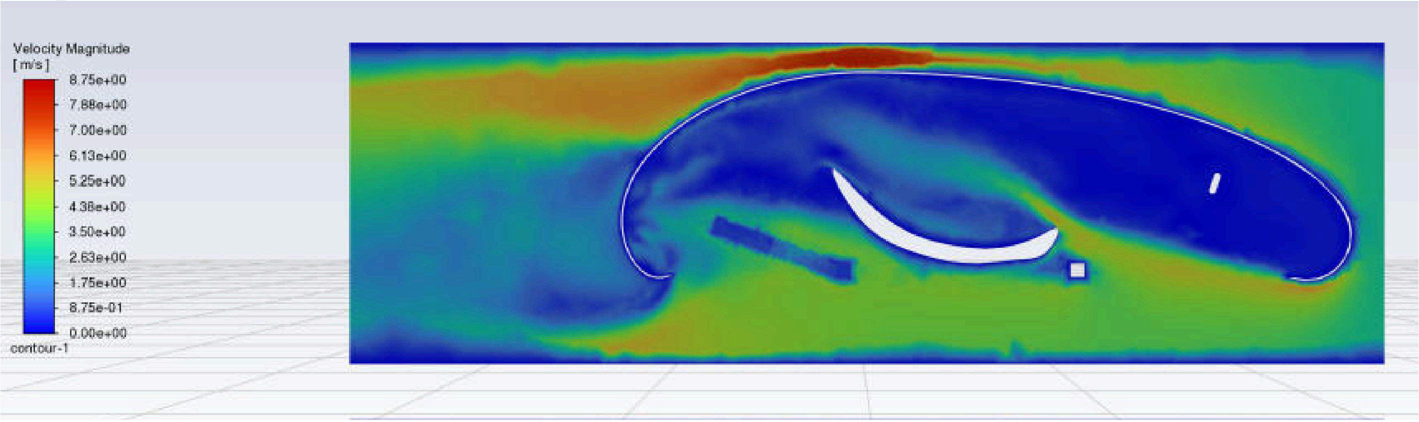
Results (velomobile, 3m/s)







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Analysis

- Velomobile is clunky and inconvenient but controls air flow the best.
- Both windscreens visually seem to aid in the comfortability of the rider from frontal air flow but don't streamline flow around the rider very well.
- Flow speeds up around the flat edges of each of the shields so flat edges need to be minimized near the rider.

Iteration

- Noticed windflow under the screen so counteracted with rounded portion below
- Tried to streamline air flow by creating rounded corners and streamline flow completely around the rider without becoming too much of a hindrance.
- Realized that CFD boundary conditions were poorly set (not accounting for the ground and too low of a ceiling). Also improved mesh quality for better results

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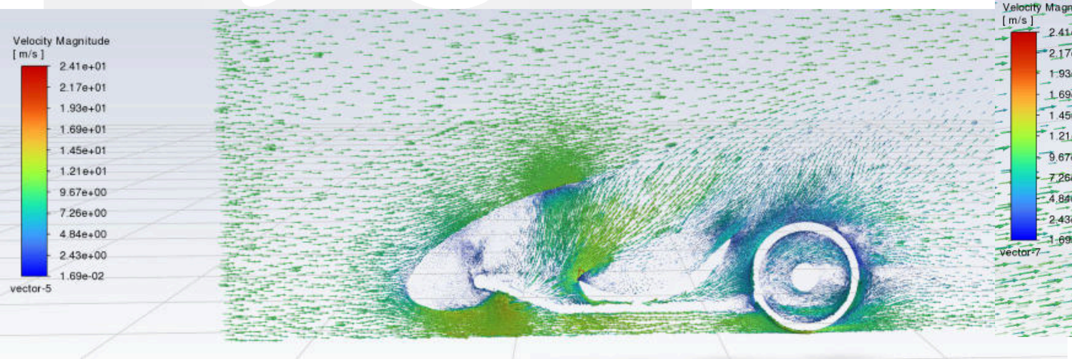
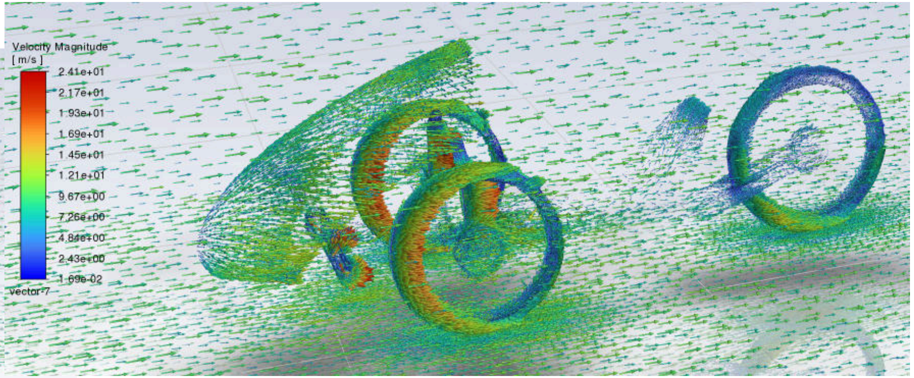
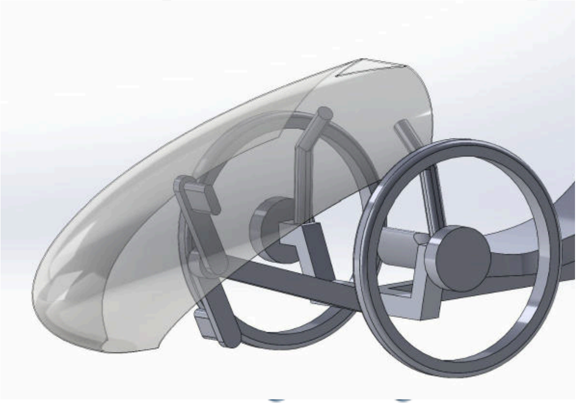
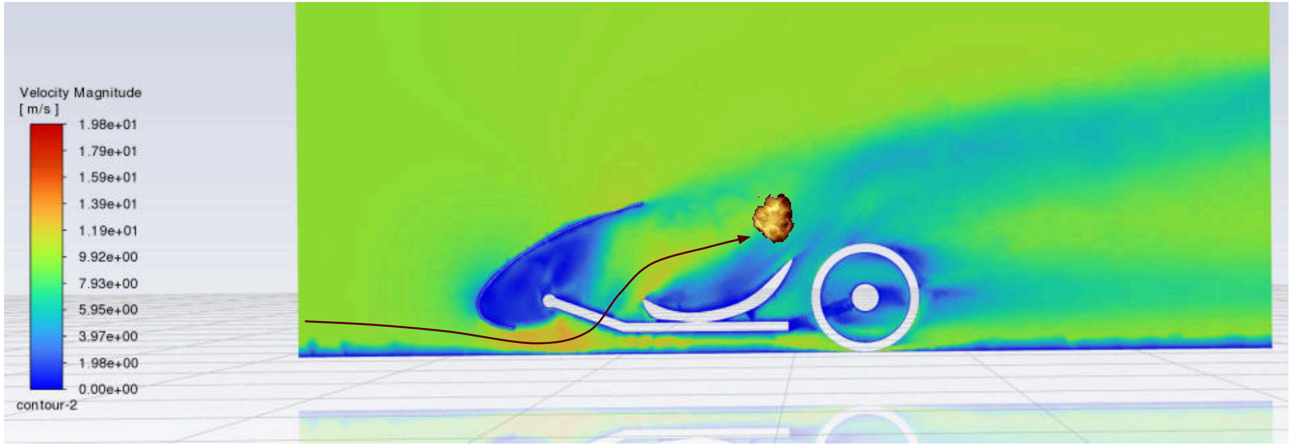
Iteration 1 Results

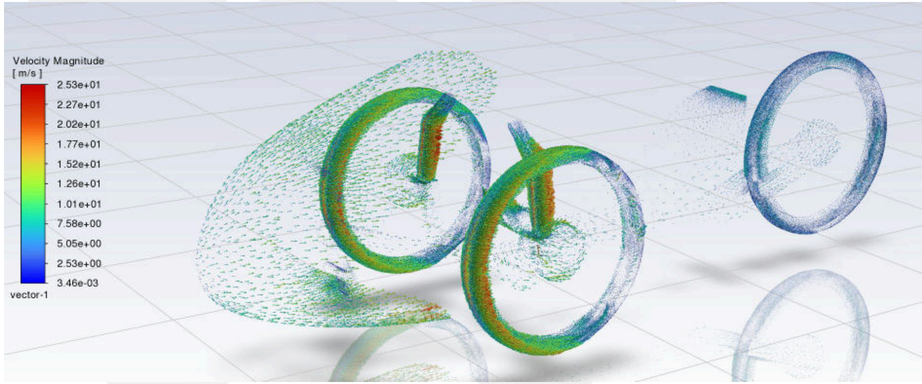


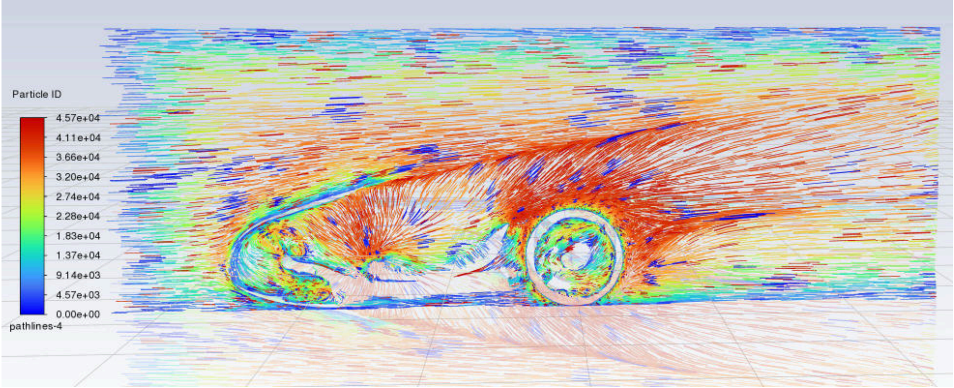




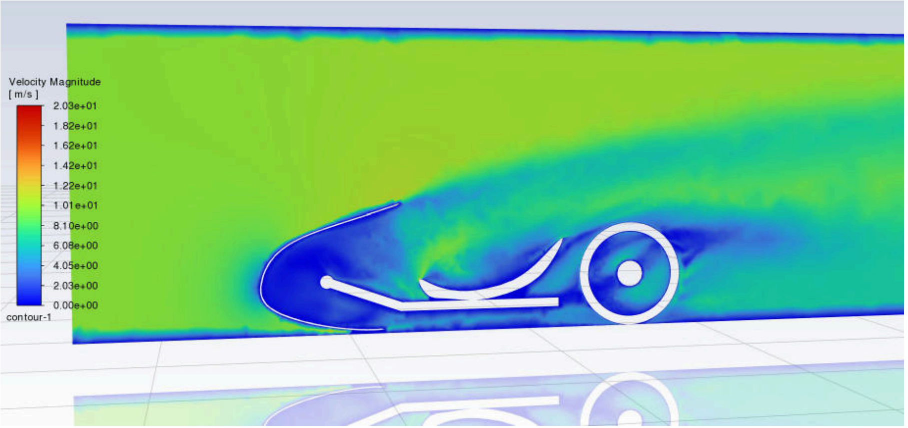


Iteration 2 Results





- Still airflow from the bottom…



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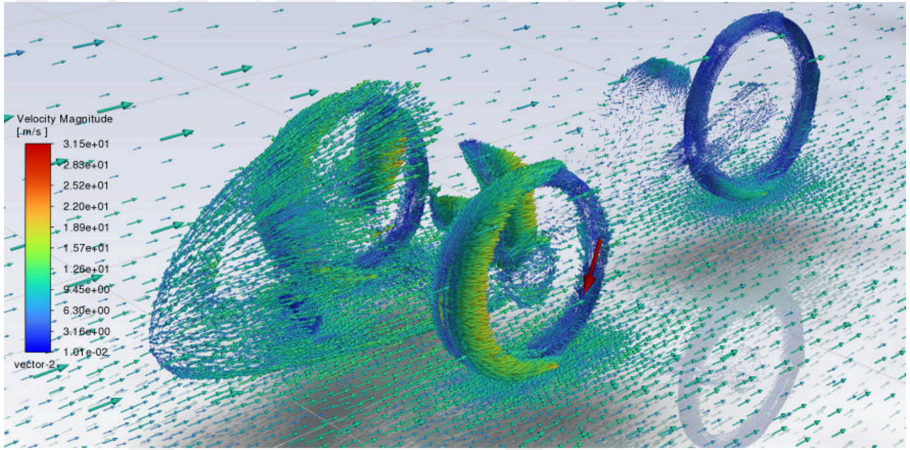
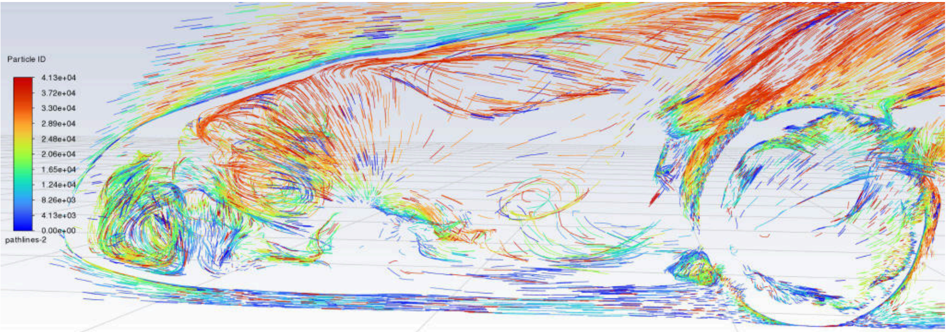
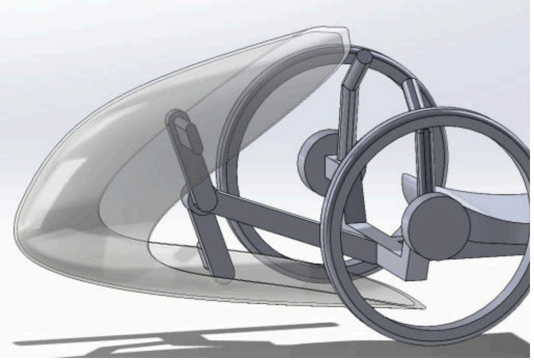
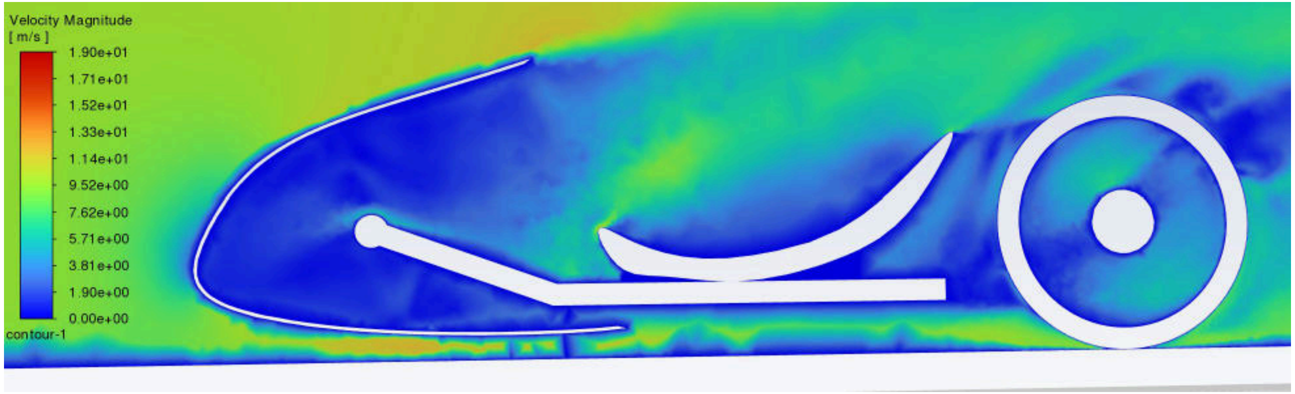
Iteration 3 Results



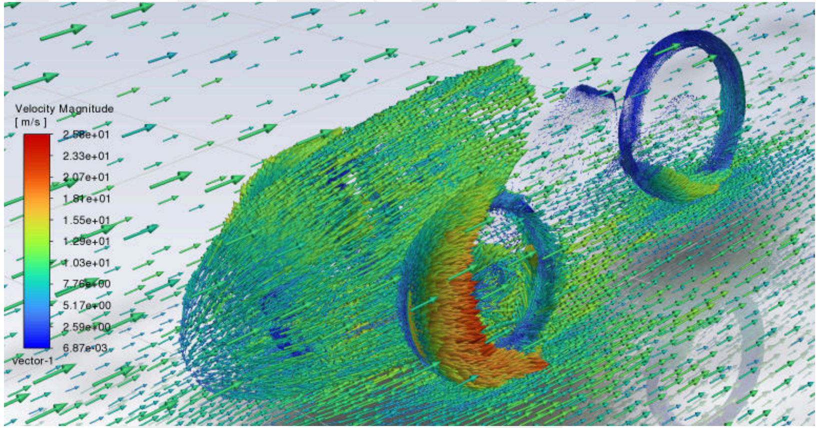


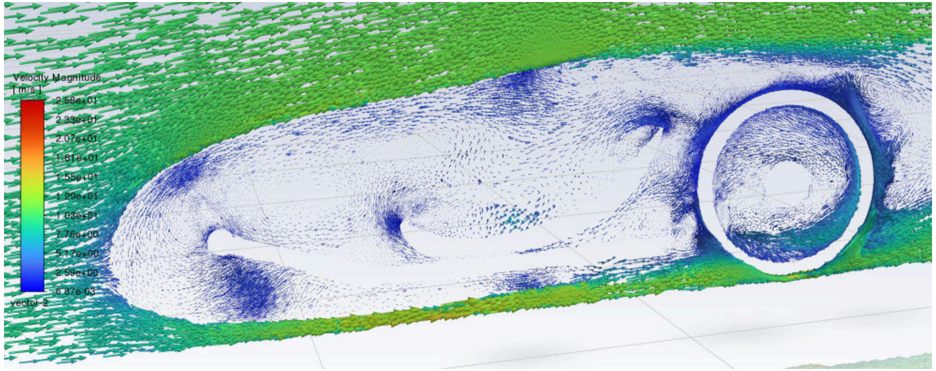
Now it's coming from the top

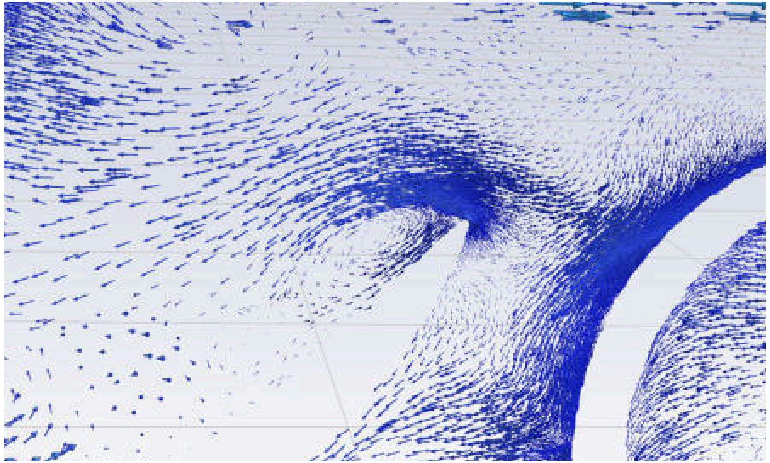


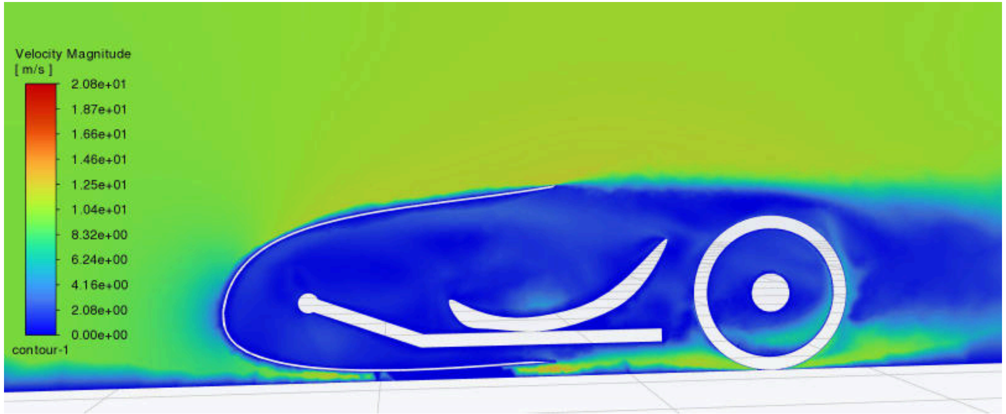


Iteration 4 Results

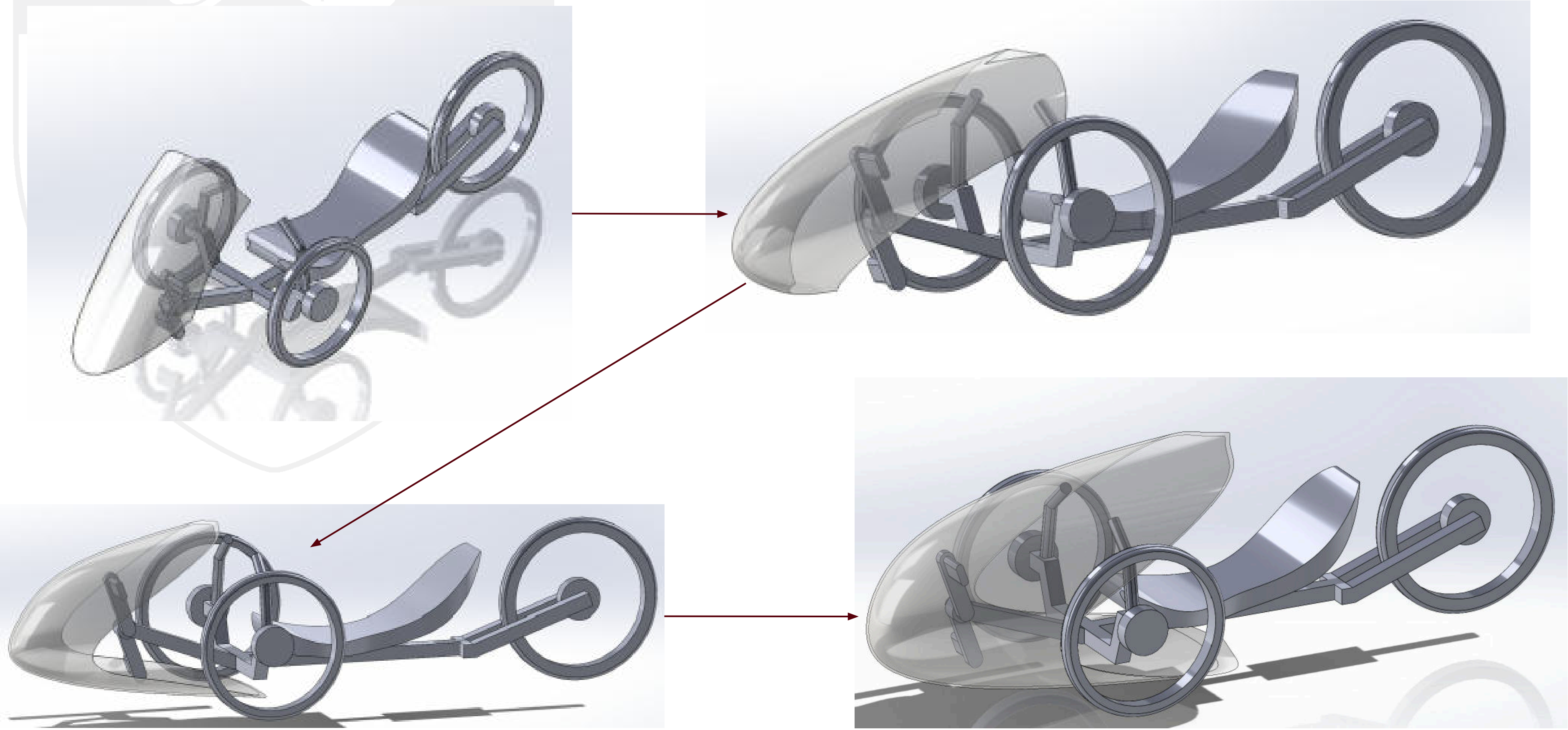




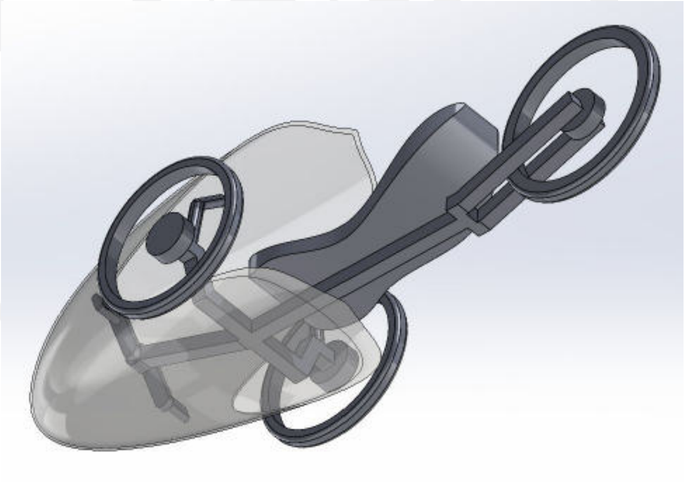


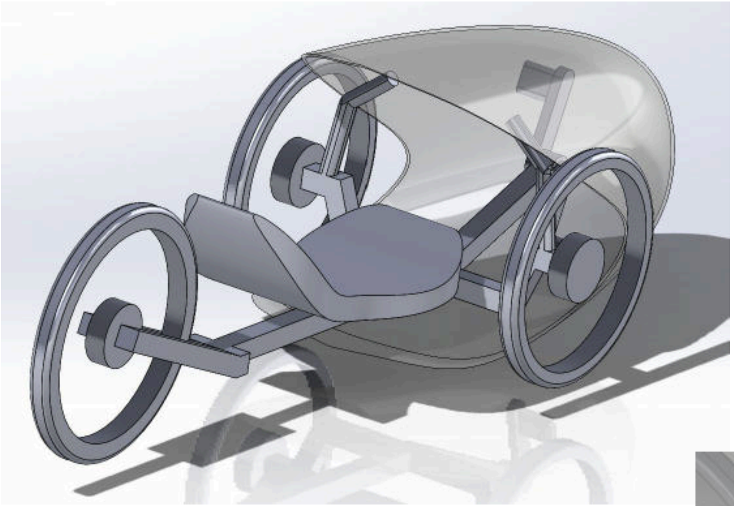


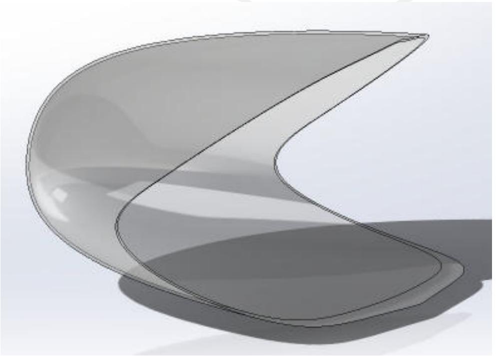
Iterations

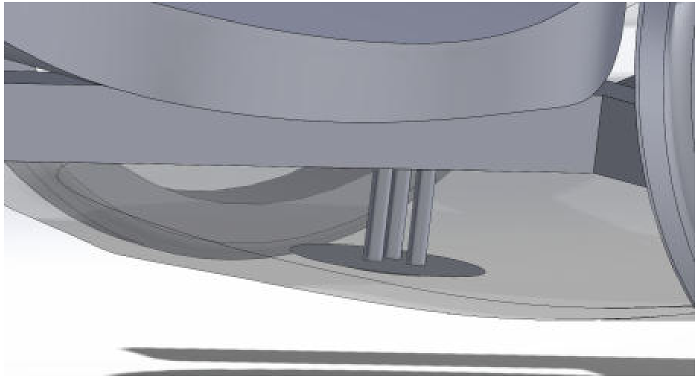


Final Design

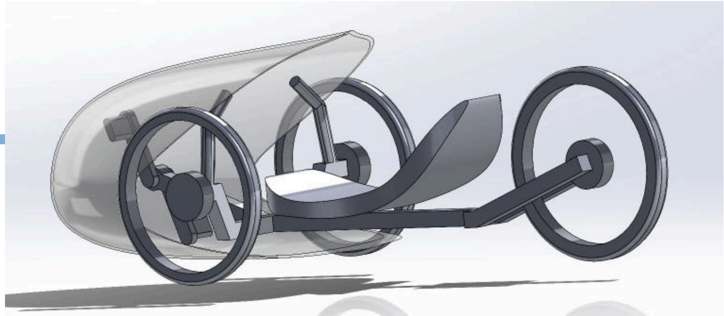








Final Design Notes



- Minimizes airflow around most of the riders body effectively
- Rider is still able to easily enter and operate bicycle
- Helps minimize drag, keep clothes from getting wrinkled, and improves riding experience

Conclusions

- We learned a lot about CFD and the aerodynamics of a bicycle in a broader sense.
- We analyzed the effects of a variety of shapes on streamlining air flow and made design decisions based on this information.
- Considering the comfortability of a rider and general maneuverability and ease of access, we were able to iterate a windscreen that incorporates these aspects to produce a smoother ride for the casual recumbent biker.

Lessons Learned

- Learning Ansys is a process, not an assignment. The only way to learn is to experiment.
- Acquiring significant quantitative data is difficult and while qualitative data is easier to acquire it can be misleading.
- Establish explicit results that we are looking for ahead of time.
- Spend more time and effort on the CFD inputs to create better simulations rather than more simulations.
- There is no perfect solution

Next Steps

- Optimize study parameters
  - Explore k–ε simulations (which should better capture flow separation and model the turbulent flows around cyclists, at a computational cost) and compare
    - Two equation model that solves for turbulent kinetic energy (k) and its dissipation rate ε
- Run quantitative analysis on drag vs comfort to reach an efficient equilibrium.
- Prototype to test real-world efficacy with varying materials and manufacturing processes.
- Ensure structural integrity of supports and effects of cross flow.
- Receive real feedback from riders.

				March				April			
Task Description	Start Date	End Date	Completion	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Pitches											
Choosing Ideas	10-Mar	19-Mar	Completed								
Making Slides	10-Mar	19-Mar	Completed								
Presentation	19-Mar	19-Mar	Completed								
Proposal											
Track & topic definition	24-Mar	24-Mar	Completed								
Background & benchmarking	24-Mar	24-Mar	Completed								
Skills	24-Mar	24-Mar	Completed								
Resources & Facilities	24-Mar	25-Mar	Completed								
Budget	24-Mar	25-Mar	Completed								
Open Questions	24-Mar	25-Mar	Completed								
Write Proposal	26-Mar	26-Mar	Completed								
CDR											
Updated timeline	30-Mar	2-Apr	Completed								
Modeling update	30-Mar	2-Apr	Completed								
Research different sizes/shapes of v	30-Mar	3-Apr	Completed								
Create multiple design iterations	30-Mar	5-Apr	Completed								
Investigate mounting mechanisms	30-Mar	5-Apr	Completed								
Presentation	7-Apr	7-Apr	Completed								
Presentation											
Finalize mounting mechanisms	5-Apr	10-Apr	Completed								
Run CFD on model	7-Apr	13-Apr	Completed								
Run CFD on design iterations	13-Apr	17-Apr	Completed								
Make presentation	12-Apr	17-Apr	In Progress								
Demonstration	12-Apr	17-Apr	In Progress								
Evaluation of next steps	13-Apr	20-Apr	In Progress								
Goal/background	15-Apr	26-Apr	In Progress								
Methods	17-Apr	26-Apr	In Progress								
Financial report	19-Apr	26-Apr	In Progress								
Presentation	21-Apr	28-Apr	In Progress								
Important Dates											
Pitches		19-Mar	Completed								
Proposal		26-Mar	Completed								
Progress Check/CDR		7-April	Completed								
Presentation/Product		28-April	In Progress								