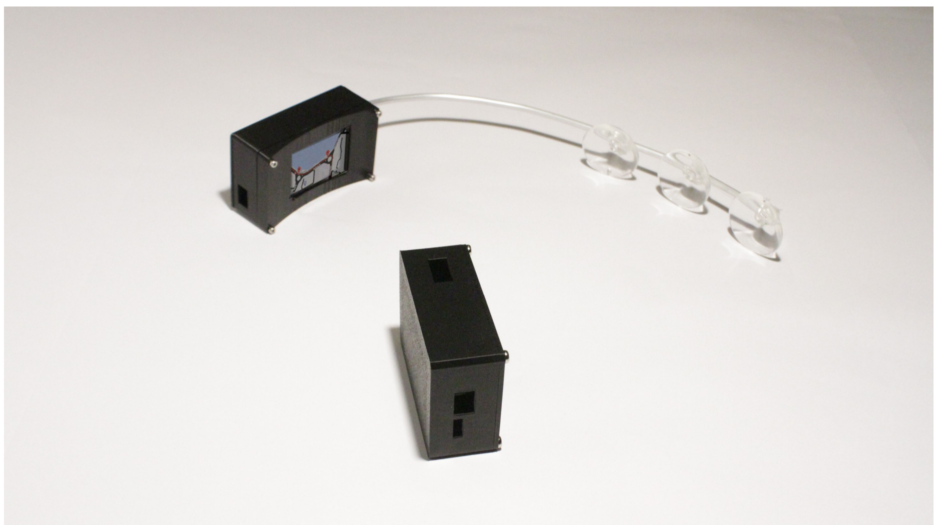
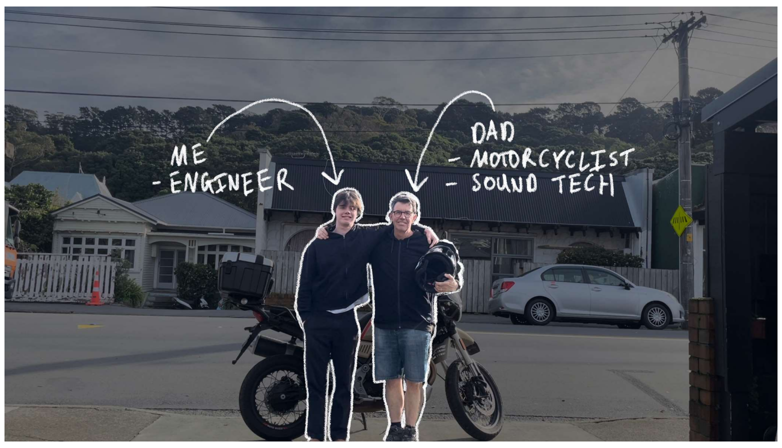
Motorcycle safety and navigation revolutionized: Halo-Vision increases the safety of the rider by providing turn-by-turn directions, as well as indicator notifications on a heads-up display.



Bookmarks

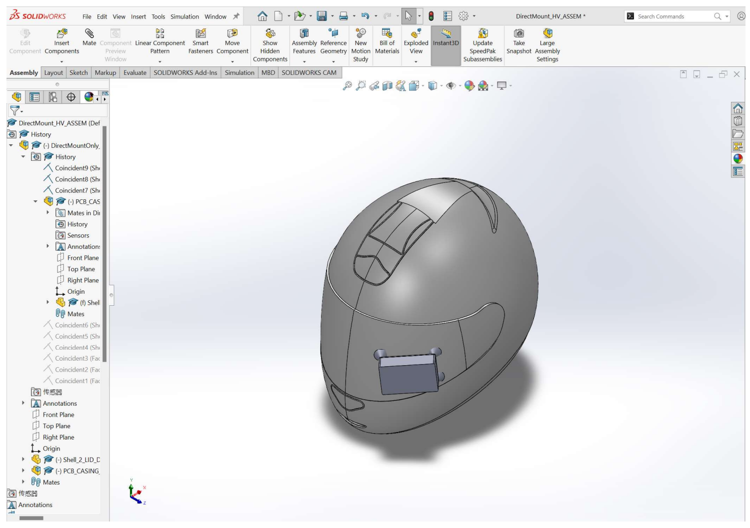
I understand that you may not want to read everything, but don't worry! I have thought of this. I have summarized the important points from each section and included page bookmarks if you wish to read more about each section.

Why, What and How (Page 3):



Several motorcycle accidents involving family members were the catalyst for Halo-Vision. It started as just a basic 'indicator broadcaster,' making it clear for the user when their indicators were enabled.
This has evolved into a heads-up display built from two custom PCBs that interact with a mobile app, allowing you to receive turn-by-turn GPS instructions and much more.

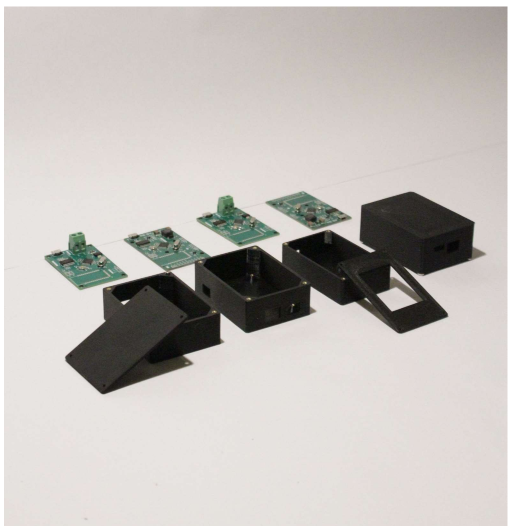
Skills I Learnt:



Production skills:
- KICAD, Easy-Eda (Circuit design)
- Solidworks, Fusion360 (3D printing, device and mount modelling)
- Autodesk CFD (Safety analysis)

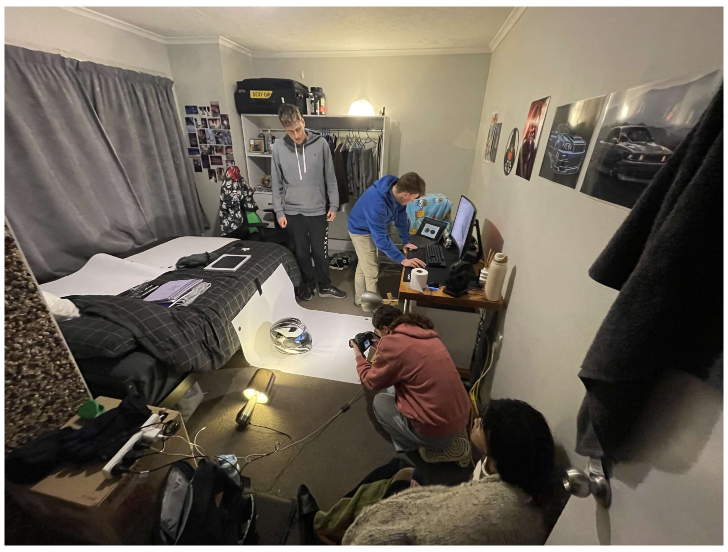
Practical skills
- Designing with the intent of production
- Communication
- Learning not to bite off more than I can chew

The Hardest Bit (Page 4):



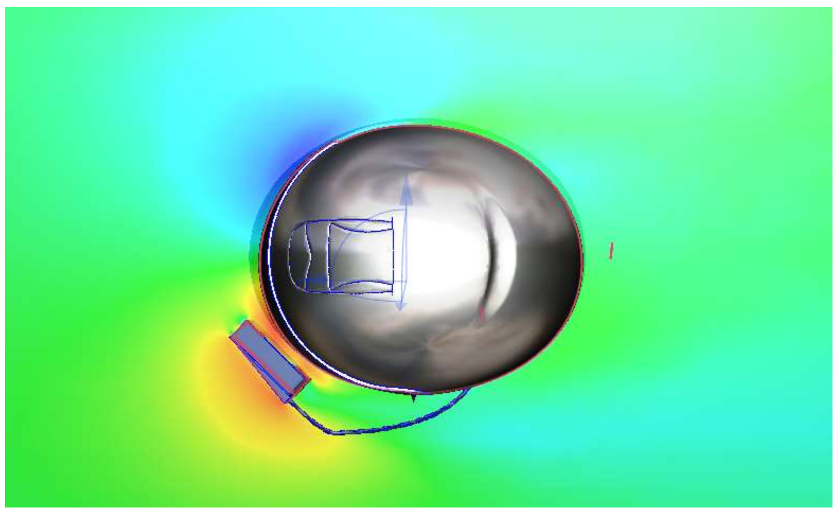
Ensuring the PCBs functioned correctly was the most challenging aspect of this project. I dedicated countless nights to soldering, programming, and troubleshooting, often ending up destroying several PCBs in the process. The most inconvenient issue I faced during this stage was the missing bootloader on the device's microcontrollers. This was because I had incorrectly connected the communication pins to the microcontroller in the schematic sent to the PCB manufacturer, which meant I couldn't upload or test code. I feel obliged to mention that without feedback from Professor Phillipp Hof, this wouldn't have been possible in the given time frame

My Favorite bit:



My favorite part was working with other people. I wouldn't have been able to complete this project without help from individuals like Joel Bannister (App Developer), Phillip Hof (Technical Systems Support at UC), Daniel Morris (TA at UC), Bruce Pancrutt (Lion Capital CEO), Lisa Bowman (Project Manager), Allan McInnes (Lecturer at UC), Yasir Ahmad (Senior Embedded Systems Engineer), Sayeem Uddin (Website Developer), and many more.

Fluid Dynamics (Page 6-10):



- The CFD test results do not agree with my hypothesis.
- There was a large variation in drag, lift, and lateral force between the benchmark and the different mount designs.
- Conversely, the direct mount showed only a slight increase in drag and lift (~6% across all speeds) but had a 133% increase in lateral force compared to the benchmark.
- The lateral force results are easily understood when looking at isoVolumes and planes. However, I need a better understanding of how to interpret my results to determine whether the plane and isovolumic simulations agree with the wall calculations.

Everyone trusts the wind tunnel results, except the person who conducted the test. As for CFD simulations, no one trusts the results except the person who performed them." - r/CFD

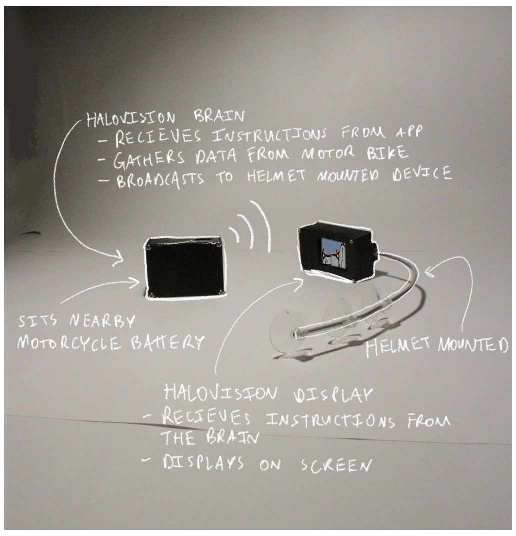
My Story:

Several accidents involving my friends and family served as the catalyst for Halo-Vision. Initially driven by the need to address issues with indicators and navigation-based distractions, the project quickly evolved into something much greater. This project is dedicated to preventing accidents and making the roads safer for everyone.

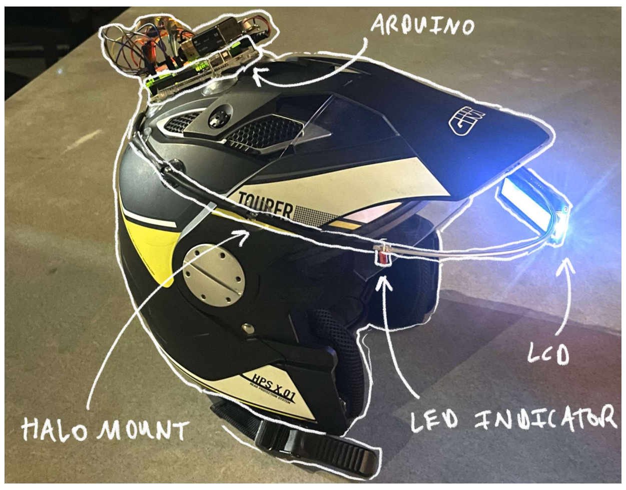
How?

Halo-Vision comprises two devices: a brain and a helmet-mounted display. The brain is connected to the app on the user's phone, the display, the motorcycle battery, and the motorcycle's indicator lines.

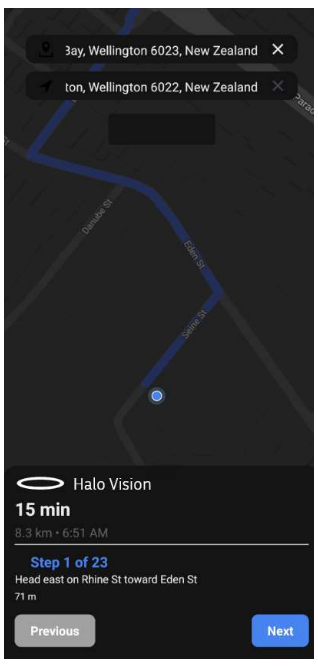
Through this setup, the brain gathers and relays real-time information from the Halo-Vision app and the motorcycle's indicators. This information is then transmitted to the helmet-mounted display, allowing the user to access turn-by-turn directions as well as indicator notifications while operating the motorcycle. All data transfer processes are managed via Bluetooth.

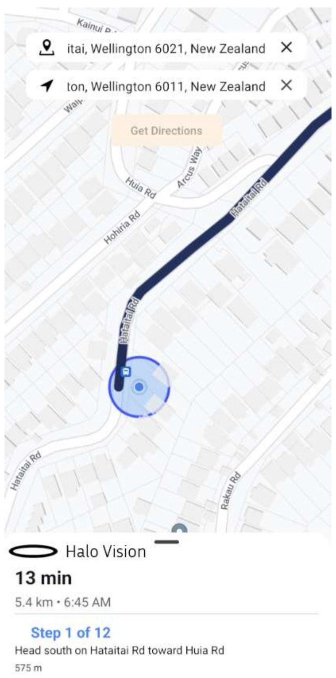


Where the design process began:



Over the summer of 2023-2024, I embarked on a project that began with initial sketches of the product, followed by a thorough evaluation of various designs. After refining the concept, I developed a prototype using two Arduino microcontrollers for a wireless setup. This was a significant challenge as I had never used an Arduino before. Additionally, I created a basic app for the prototype that allowed users to input a location and receive crude, text-based directions.





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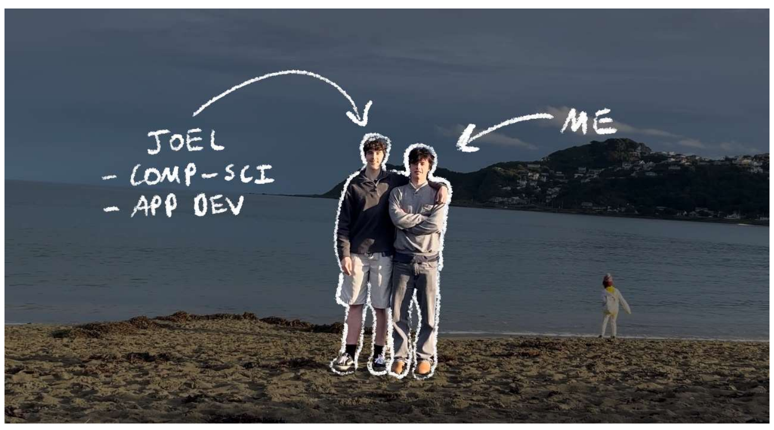
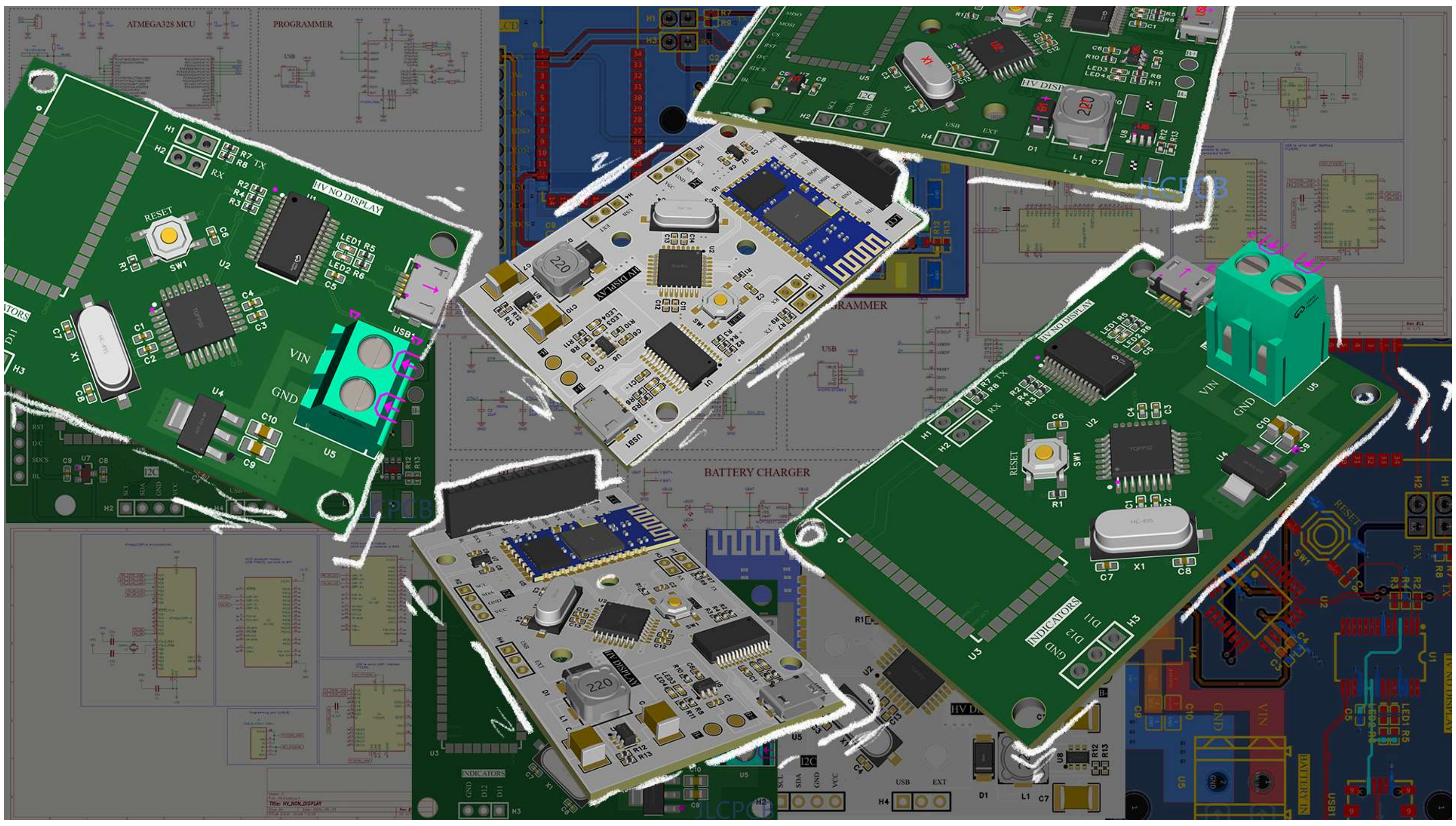
During the redesign stage, app developer Joel Bannister improved the app by making it more visually appealing, fixing many bugs, adding light and dark modes, and updating the mapping API to Google's latest map and direction API. The app now functions similarly to most GPS navigation apps, creating checkpoints at set distances along each route. These distances are determined by the speed from the next checkpoint, ensuring the user receives instructions in time. Users can input a location, and the app broadcasts an image feed with step-by-step instructions to the Halo-Vision display. I would like to say a huge thank you to Joel for being great to work with; he pulled so many all-nighters to get it done in time.



Finalizing the prototype:

Testing the initial prototype revealed several limitations in real-world applications: it was not power efficient enough, the footprint was too large, and the overall cost was higher than desired. Additionally, the display could only show 16 characters. To address these issues and elevate the project, I transitioned to designing and producing two custom PCBs (Halo-Vision Display and Halo-Vision Brain). This shift offered multiple benefits:



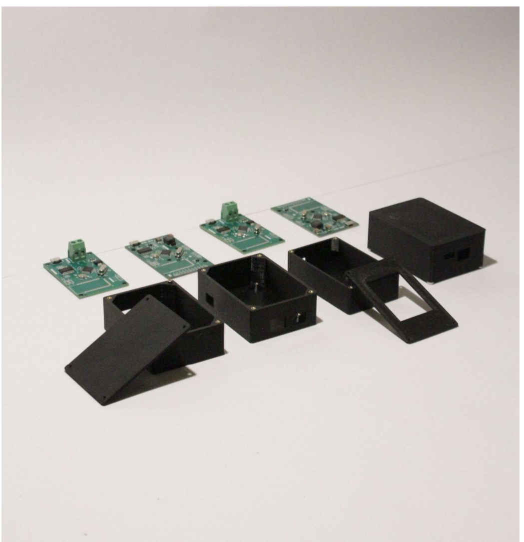
1. **Enhanced Efficiency and Optimization**: The custom PCB design enabled me to optimize power consumption and minimize the footprint, making the device more suitable for practical use.

2. **Cost Reduction**: By selecting only the necessary components and eliminating redundant features, I was able to significantly reduce production costs.

3. **Ownership and Branding**: Designing my own PCB allowed me to create a product that is uniquely my own, enhancing the professional appeal and theoretical marketability of the device.

4. **Technical Growth**: The process of designing and producing a custom PCB extended my electronics knowledge, providing hands-on experience with advanced design techniques and manufacturing processes.

5. **Better Display Capabilities**: The custom PCB design allowed for improved display capabilities, enabling the device to show more detailed information, including images and video.



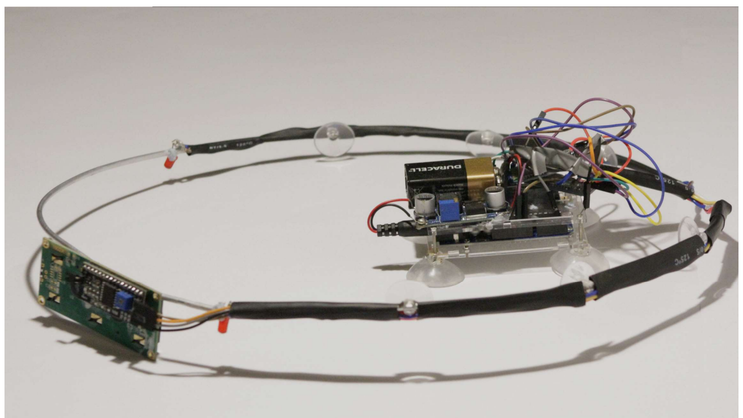
This transition to custom PCBs not only addressed the limitations of the initial prototype but also advanced the project toward a more polished, efficient, and market-ready product. For me, this was the hardest part of the project.

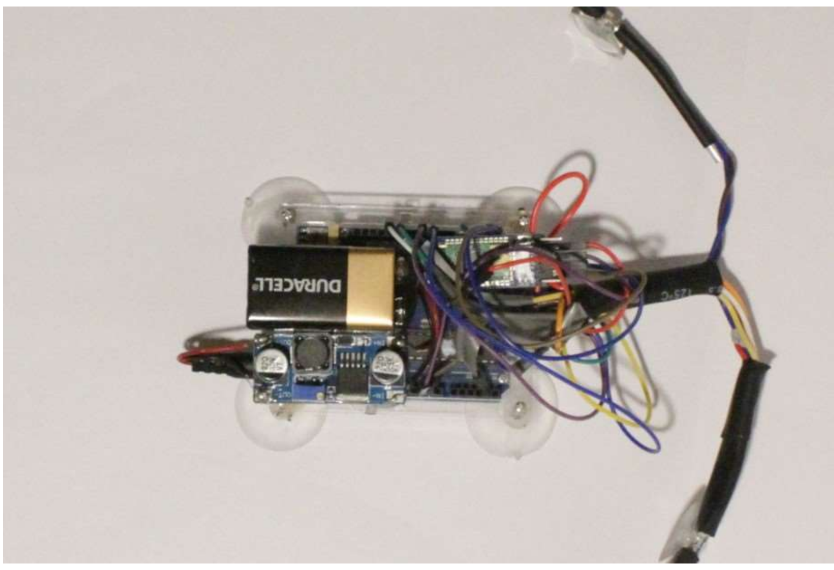
The most inconvenient issue I faced during this stage was the missing bootloader on the device's microcontrollers. I had incorrectly connected the communication pins to the microcontroller in the schematic sent to the PCB manufacturer, which meant I couldn’t upload or test the code. To get around this, Phillip Hof and I soldered connections to these pins and 'burnt' a bootloader onto each microcontroller.

The most difficult design challenge was getting the battery charging loop to work with the USB interface (FT232RL). The requirement was for the battery to be charged while the device was being used as a programming port (plugged into the computer). Additionally, the current embedded system design has flaws surrounding the Bluetooth communication between the brain and the display. I am currently waiting for a set of SMD-HC05s to arrive to resolve this issue.

Mount design:

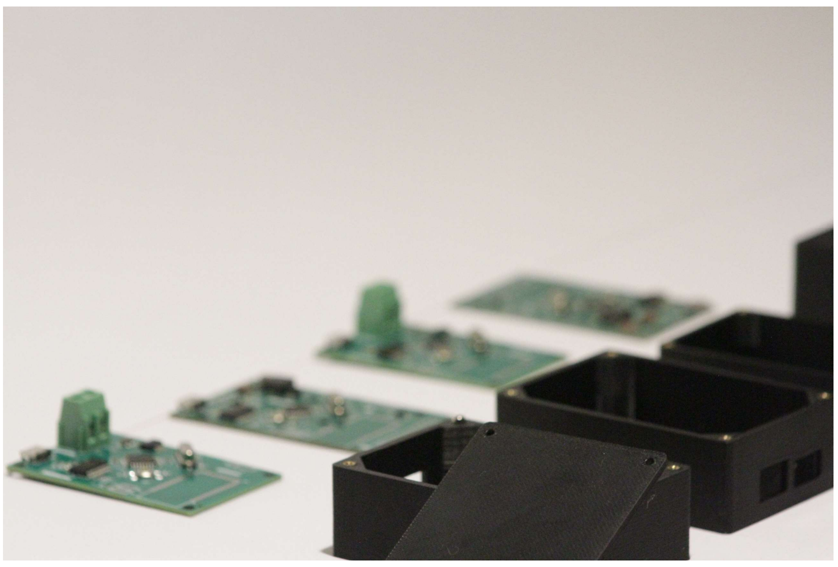
My initial mount design used an off-the-shelf acrylic Arduino casing in combination with suction cups and alloy tubing to mount the screen and microcontroller to the helmet.

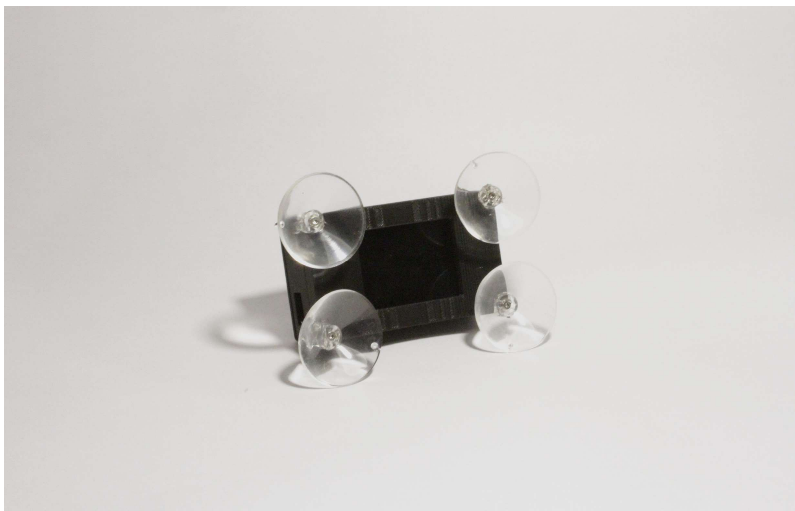




For the new PCBs, I decided to design, and 3D new print casings and mounts.

As I had never 3D printed anything before, I decided to reach out and contact Stacy from Mahi Ta Engineering for advice. Throughout the dozen or so prototypes, both Stacy and Micheal gave excellent design feedback allowing me to understand why things broke, and why things didn't print properly, and ultimately helped design and produce safe, functioning casing and mounts.

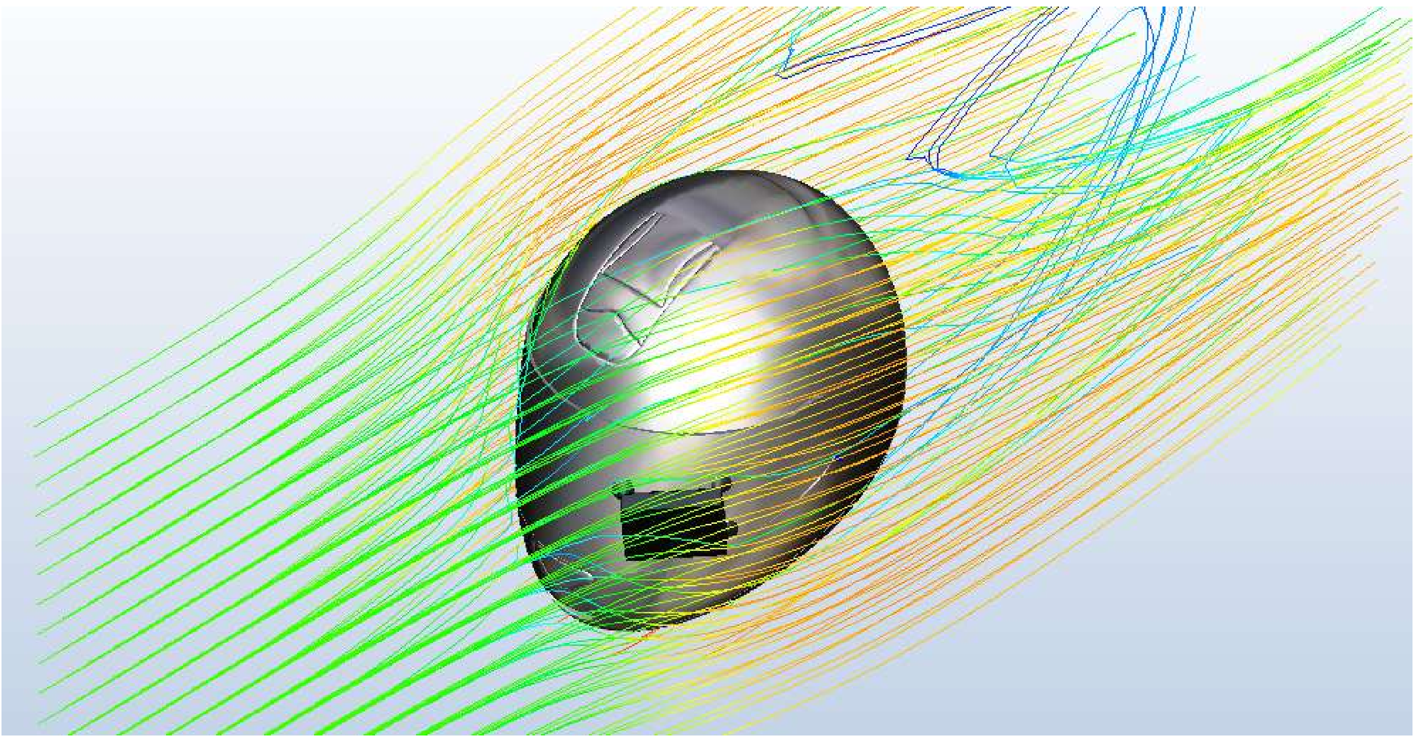




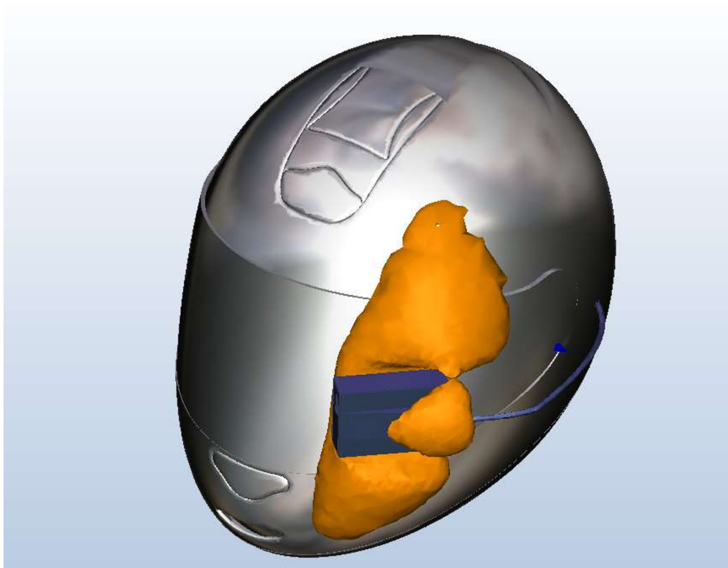
I decided to create two new mount designs: one focused on lower-speed travel, such as city commutes, where ease of use of the helmet and device is more necessary than aerodynamics. This first mount shared a similar design to the initial, complete halo prototype, thus it was dubbed the HaloMount (far right of the bottom image). The second mount is focused on high-speed travel, such as highways; this mount would be attached directly to the visor and was thus dubbed the Direct Mount (far left of the bottom image). The benefit I had in mind when designing the Direct Mount was a simpler design that would negatively affect the aerodynamic performance of the device less than the HaloMount.

Safety testing:

IMG_CFD1



IMG_CFD2



An experienced motorcyclist suggested that this design could create a lot of turbulence, which made me want to test the designs.

Before testing, I decided to construct two requirements to understand the safety of the different mount designs. My hypothesis was based on these requirements.

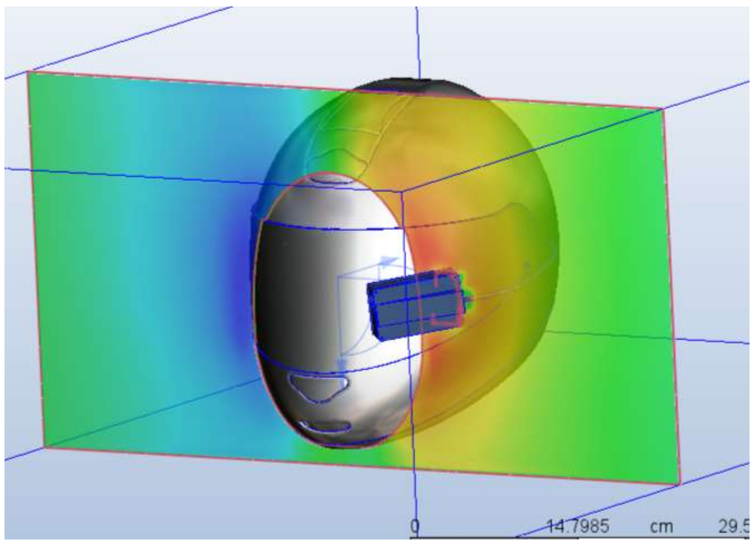
(1) Cannot exceed a lift force, drag or lateral force difference of 5% from the benchmark helmet.

(2) No high-frequency changes in pressure and air velocity changes. (To avoid turbulence)

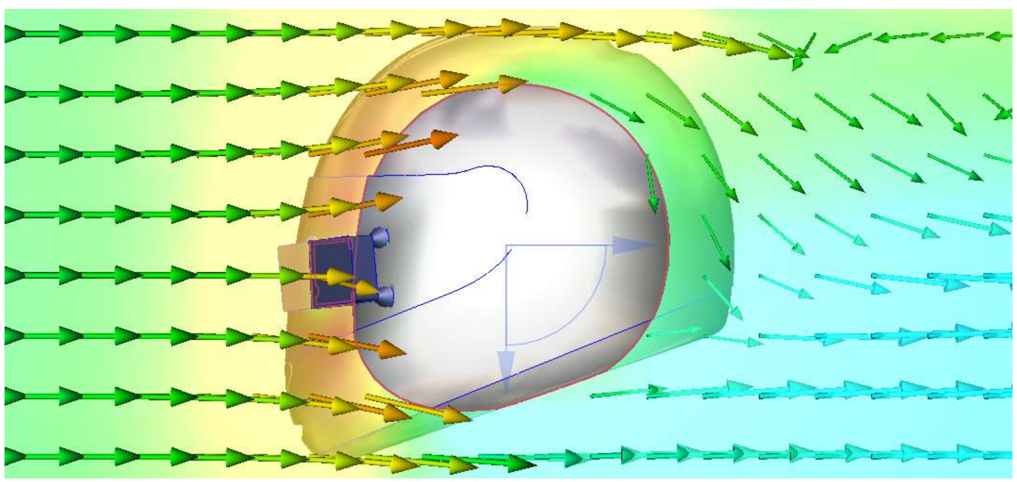
Hypothesis: Direct mount and Halo-Mount will both meet the requirements, having little effect on both the drag and lift force on the helmet. However, I think the HaloMount will create more lateral force compared to the direct mount. I think this because:

- **LIFT:** There will be a small change in lift for both models because:
    - The design lacks closely spaced horizontal planes along the same axis wind is loaded from. I think this will prevent the formation of 'lift zones', where high pressure is above the object and low pressure is below.
- **DRAG:** There will be a small change in drag for both models because:
    - The surface area facing into the wind load doesn't increase much with their addition due to both designs small physical footprint. DRAG = 1/2 pv^2 * F.SA, the small increase in F.SA will result in a small increase in DRAG.
- **TURBLUENCE:**
    - I think there is bound to be some turbulence on the HaloMount, but less on the direct mount. I think this because the HaloMount has space between the visor and the helmet where air can flow.

IMG_CFD3



IMG_CFD4



Each of the mount designs (as well as a benchmark helmet) was tested in Autodesk CFD at varying wind loads. Wall calculations, along with flow and pressure analysis, were conducted at these different speeds.

Wall calculations were used to determine drag, lift, and lateral force. Pressure planes and iso volumes were employed to understand the different designs by verifying the wall calculations. This allowed us to see how each design differently affected the flow of fluid and how areas of low or high pressure impacted the rider's safety.

Safety Analysis

In this analysis, my goal was to determine which mount design performed closer to the initial, benchmark helmet, as well as whether these mounts met the requirements and therefore agreed with my hypothesis. I will start with a quote from r/CFD: "Everyone trusts the wind tunnel results, except the person who conducted the test. As for CFD simulations, no one trusts the results except the person who performed them." With that said:

- This analysis is driven mainly by personal interest and curiosity.
- The results provided here offer only a ballpark understanding of how the different mounts at various wind loads affect forces on the user.
- These results should not be used professionally to determine whether the product is safe to be manufactured and mounted.

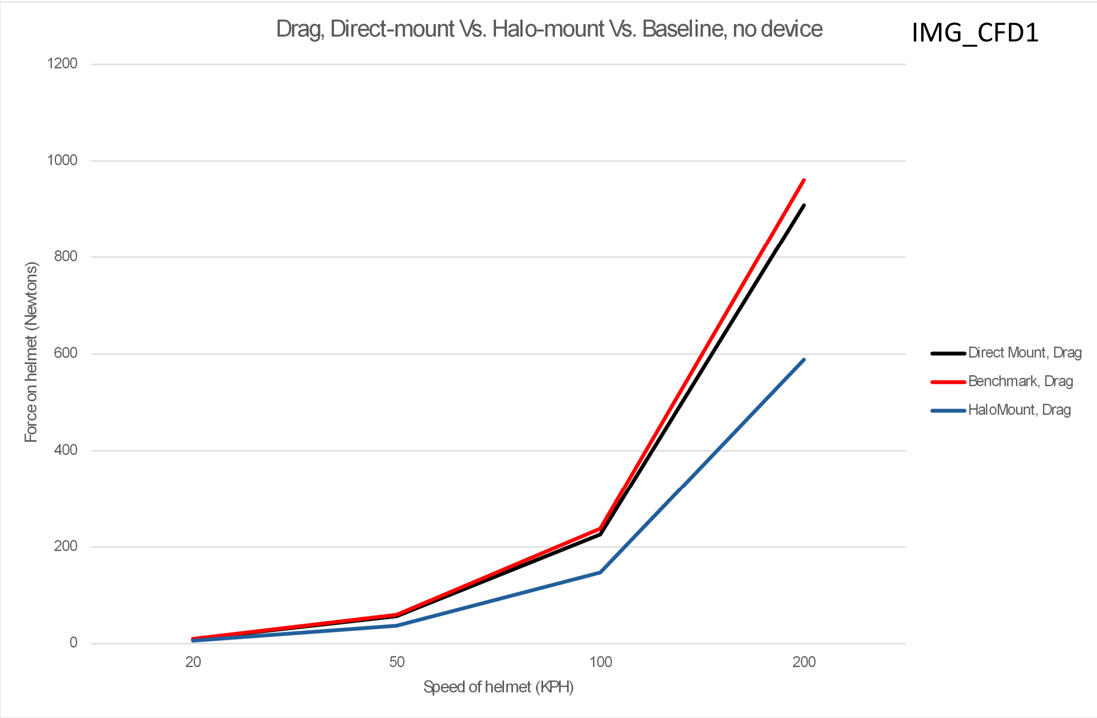
Note: The simulation settings have been included in the analysis conclusion.

Section 1. Wall Calculations Analysis

Section 1.1. Drag analysis
The plot describing drag shows that in the CFD tests, there was a maximum difference of 5.6% in drag between the benchmark model and the direct mount across all speeds.

The average difference in drag between the direct mount and baseline model was 5%. Whereas the average difference in drag between the Halo Mount and the benchmark helmet was 51%. The reason for a significantly lower drag is discussed in the final section of the analysis

The average difference between the Halo-Mount and direct mount was 162%; this difference was largest at the maximum speed.

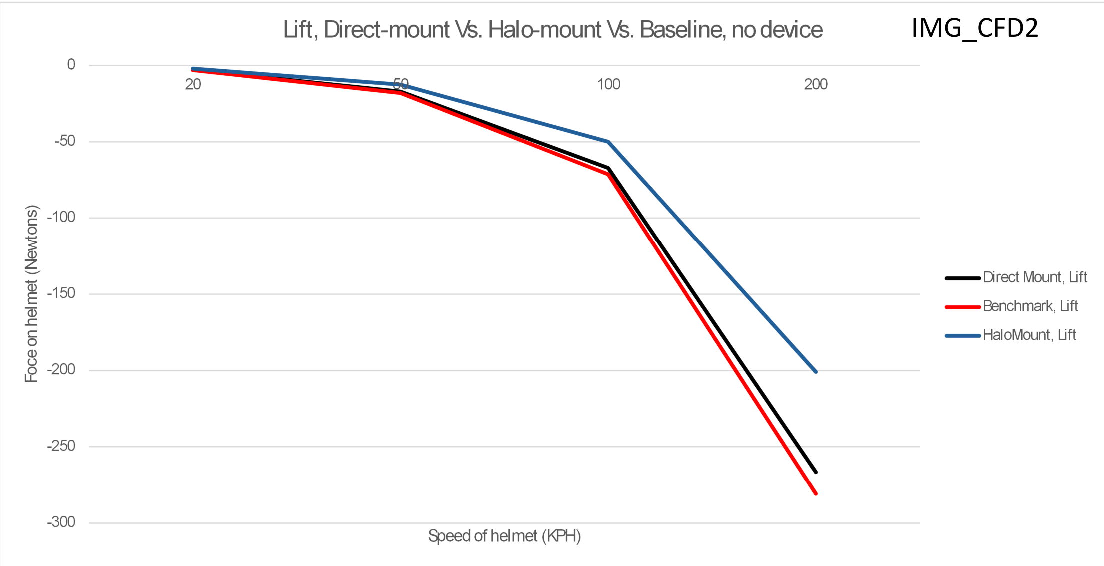


Section 1.2. Lift analysis

The plot shows there was less downforce for the Halo-Mount compared to the direct mount and baseline helmet across all speeds. Again, with the largest difference occurring at the highest speed.

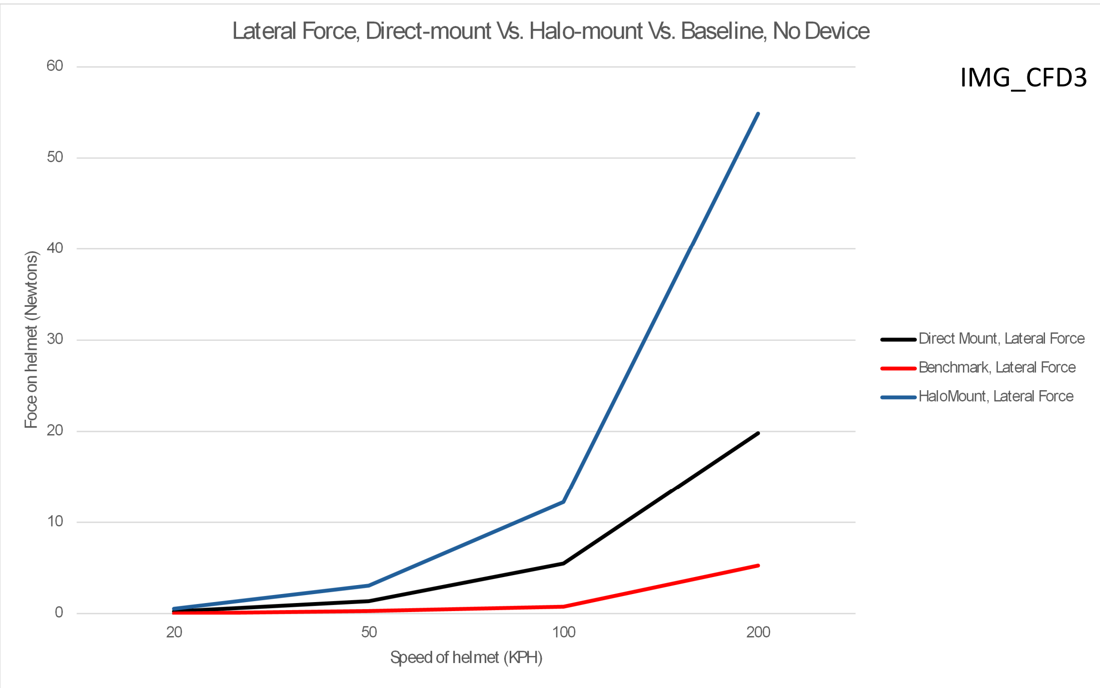
It should be noted that downforce isn't necessarily bad, so while it could appear that the Halo-Mount has achieved a better result that the bench mark, the goal was to match, as closely as possible the benchmark model which we understand works well, and the direct mount did this better.

The direct mount on average was within 6% of the benchmark helmets downforce, and 139% closer to the benchmark than the Halo-Mount.



Section 1.3. Lateral force analysis
The plot for Lateral force shows the biggest difference in force between mount designs. The direct mount, while 24% closer than the Halo mount to the benchmark, still increased the lateral force on average by 133% across all speeds.

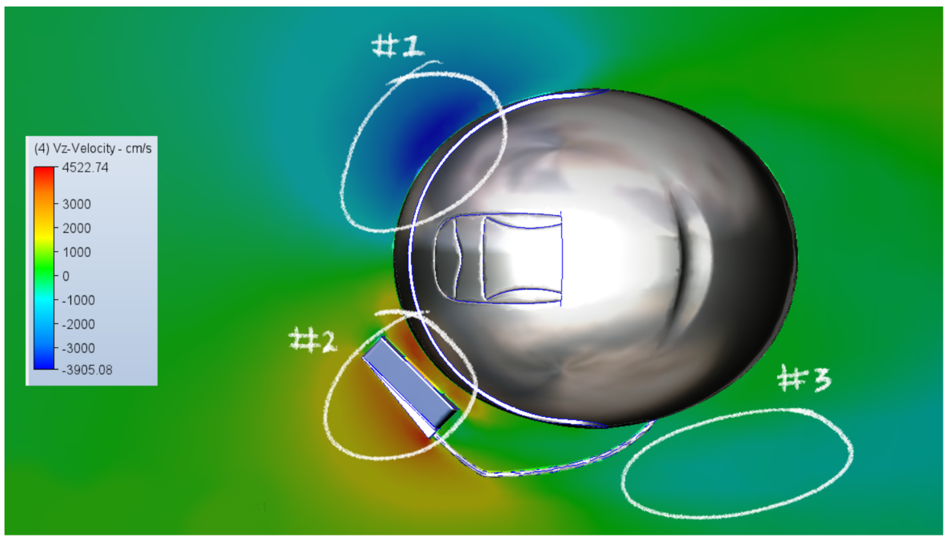
A higher lateral force results in the model being pushed towards the direction the device is mounted on.



Following the wall calculations I wanted to understand how I could change the different mount designs to minimize the difference in drag, lift and lateral force between them and the benchmark helmet. To do this I used planes and isoVolumes to verify and further understand the potential limitations and faults of my current design.

Section 2. Pressure and Air-flow Analysis

IMG_VZ_top

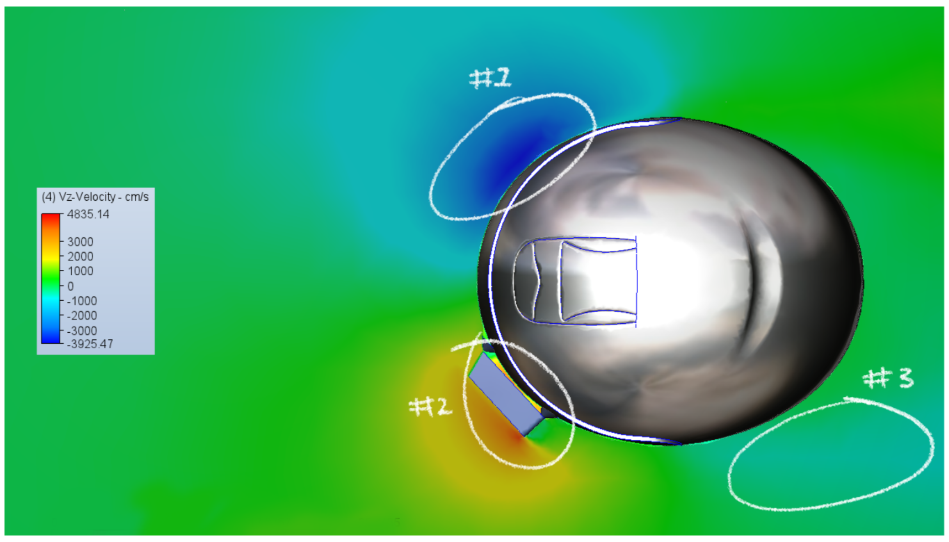


Section 2.1 Velocity planes

This velocity plane shows the lateral speed (VZ) created by a wind load of 200KPH on the HaloMount. The colours in the different zones of the plane back up the Lateral force results from the wall calculations.

In the lateral force graph, we can understand why the HaloMount generates substantially more lateral force than the direct mount. The fastest air (zone #2) is pushing the mount outwards, away from the center, creating a high lateral force. Ideal airflow can be observed on the opposite side of the helmet in zone #1.

I thought it was interesting that the sudden disruption of airflow in zone #1 caused a decrease in speed behind the helmet on the same side where the user mounted the device (zone #3). This has the potential to create turbulence for the user.



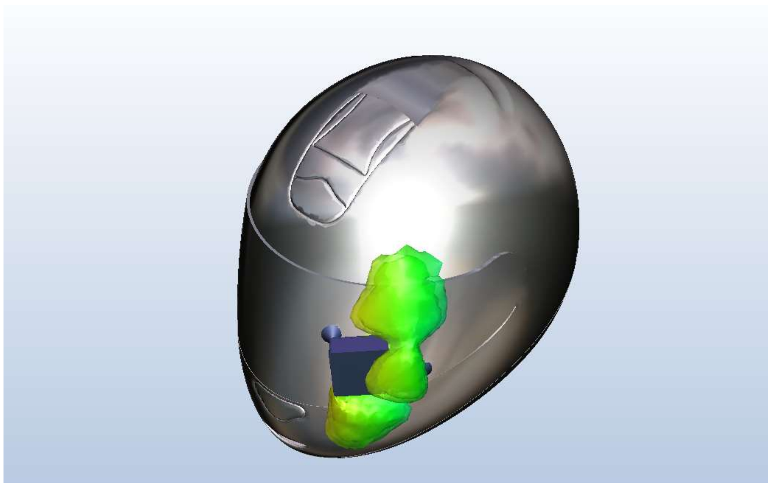
Section 2.1 Continued

This velocity plane shows the lateral speed (VZ) created by a wind load of 200KPH on the direct mount. Zone #2 has less high-speed air moving past it, therefore a lower lateral force. This results in a smaller difference in speed between zone #3 and the un-distributed air around it.

Thus, Zones #1 and #3 for the direct mount design are both substantially 'better' (Closer to benchmark design) than the HaloMount. This agrees with the wall calculation results covered earlier.

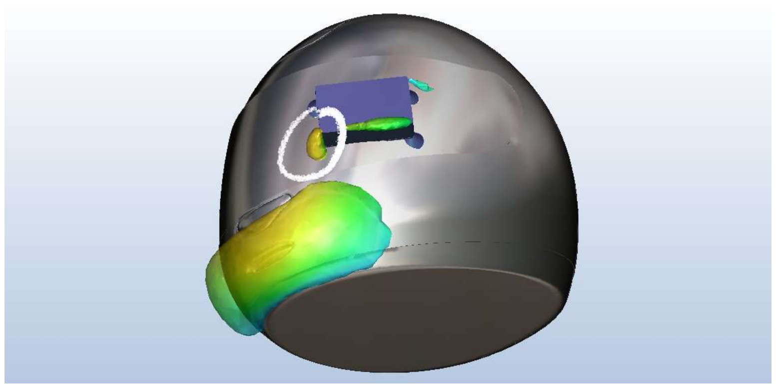
Section 2.2 ISOvolumes with lateral force

In both the HaloMount and direct mount, when an isoVolume built from static pressure is mapped with lateral force, a large high-pressure 'bubble' is revealed on the device-mounted side of the helmet. This 'bubble' indicates that the model experiences significant lateral push due to asymmetrical flow distribution and pressure imbalance around the unsymmetric section. This agrees with the result from the wall calculations, therefore this is likely why there is a high lateral force on both the HaloMount and direct mount.



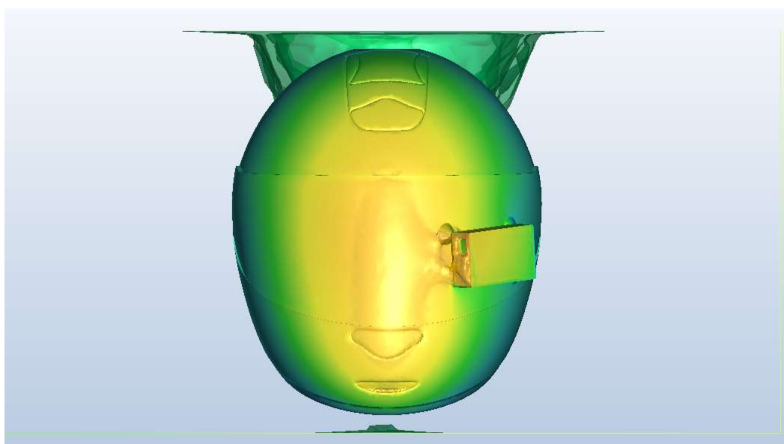
Section 2.3 ISOvolumes with turbulence

In both the HaloMount and direct mount, when an isoVolume built from static pressure is mapped with lift force, a **small** high-pressure 'bubble' is revealed. These sorts of 'bubbles' on sharp edges are often attributed to flow separation. This flow separation has the potential to create turbulence as it detaches the air flowing from the surface quickly, creating a high-frequency change in force. It should be noted that I was unable to determine whether this had a large impact on drag or lift.



Section 2.4 ISOsurface with drag.

When mapping VX (drag) with static pressure onto an ISOvolume, for both the HaloMount and direct mount, the area with the highest horizontal speed is the most-front-facing edge. This agrees with the drag, wall calculations which showed a much higher drag compared to the benchmark model.



Safety Analysis Summary

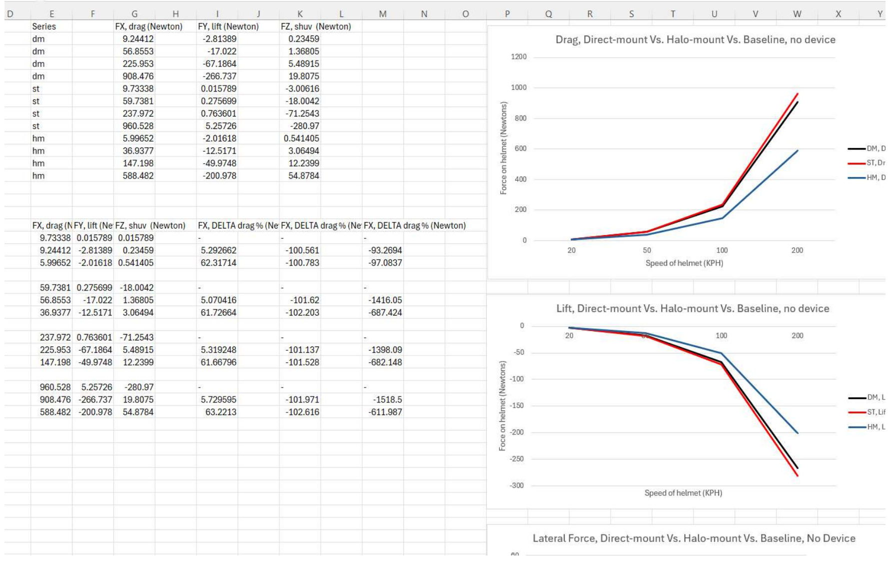
As mentioned in the beginning, this type of analysis was chosen because of my interest and curiosity towards fluid dynamics; And because of my lack of experience, these results were not used to come to a concrete conclusion on whether either mount is safe or not.

Having said that, the wall calculations done in section 1 showed that the Halo-Mount across the drag, lift and lateral force tests, was on average, 110% worse (further from the benchmark) than the direct mount.

The largest difference and potentially what would create the biggest hazard for the user was highlighted in the lateral forces section of the wall calculations.

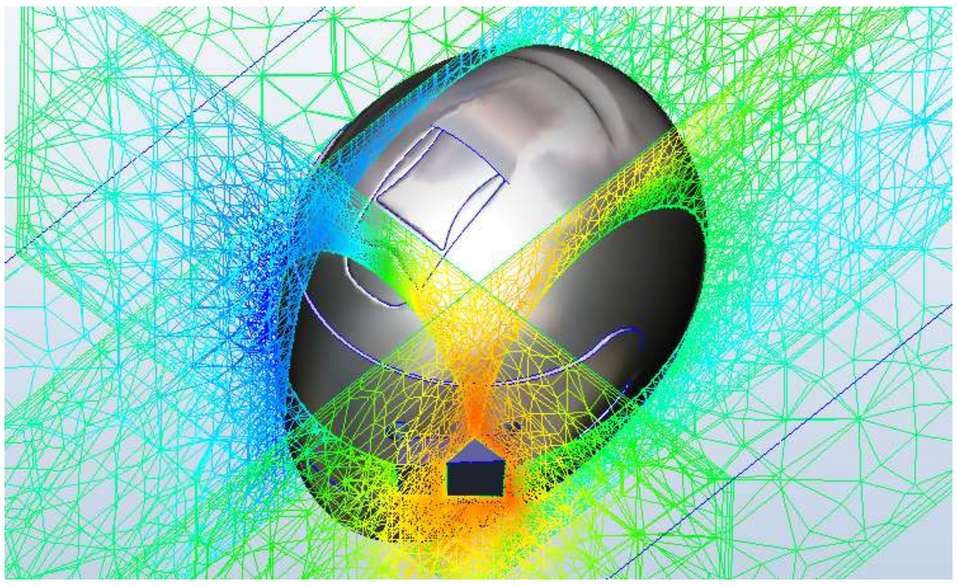
Throughout all speeds, across all mounts, there was substantially more lateral force on the helmet in the direction the mount was placed on. This would result in uneven strain to the motorcyclist's neck; over a long period this at best could result in an agitated neck, at worse could result in an accident.

The plane and isoVolume results related to lateral force could be used to answer questions generated from the wall calculations (I.e. Why was there substantially more lateral force on the halo mount as opposed to the direct mount). This could be used to make the mount designs better (closer to the benchmark).



Series	FX, drag (Newton)	FY, lift (Newton)	FZ, shuv (Newton)
dm	9.24412	-2.81389	0.23459
dm	56.8553	-17.022	1.36805
dm	225.953	-67.1864	5.48915
dm	908.476	-266.737	19.8075
st	9.73338	0.015789	-3.00616
st	59.7381	0.275699	-18.0042
st	237.972	0.763601	-71.2543
st	960.528	5.25726	-280.97
hm	5.99652	-2.01618	0.541405
hm	36.9377	-12.5171	3.06494
hm	147.198	-49.9748	12.2399
hm	588.482	-200.978	54.8784

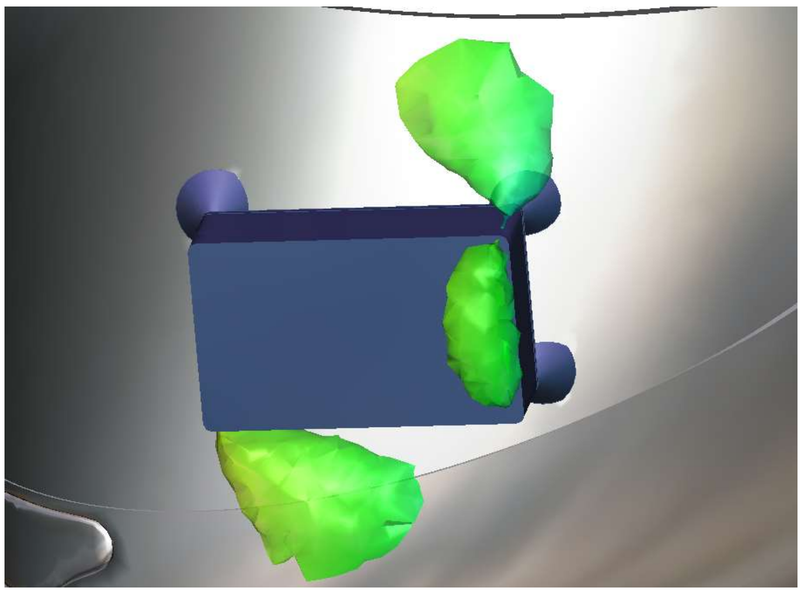
FX, drag (N	FY, lift (Ne	FZ, shuv (Newton)	FX, DELTA drag % (Ne	FX, DELTA drag % (Ne	FX, DELTA drag % (Newton)
9.73338	0.015789	0.015789	-	-	-
9.24412	-2.81389	0.23459	5.292662	-100.561	-93.2694
5.99652	-2.01618	0.541405	62.31714	-100.783	-97.0837
59.7381	0.275699	-18.0042	-	-	-
56.8553	-17.022	1.36805	5.070416	-101.62	-1416.05
36.9377	-12.5171	3.06494	61.72664	-102.203	-687.424
237.972	0.763601	-71.2543	-	-	-
225.953	-67.1864	5.48915	5.319248	-101.137	-1398.09
147.198	-49.9748	12.2399	61.66796	-101.528	-682.148
960.528	5.25726	-280.97	-	-	-
908.476	-266.737	19.8075	5.729595	-101.971	-1518.5
588.482	-200.978	54.8784	63.2213	-102.616	-611.987



It should be noted that it proved very difficult to interoperate plane and isoVolume results covered in section 2 related to lift force and drag in such a way that they agreed with the wall calculations done in section 1. Therefore I would feel confident making any changes to the designs to change drag or lift.

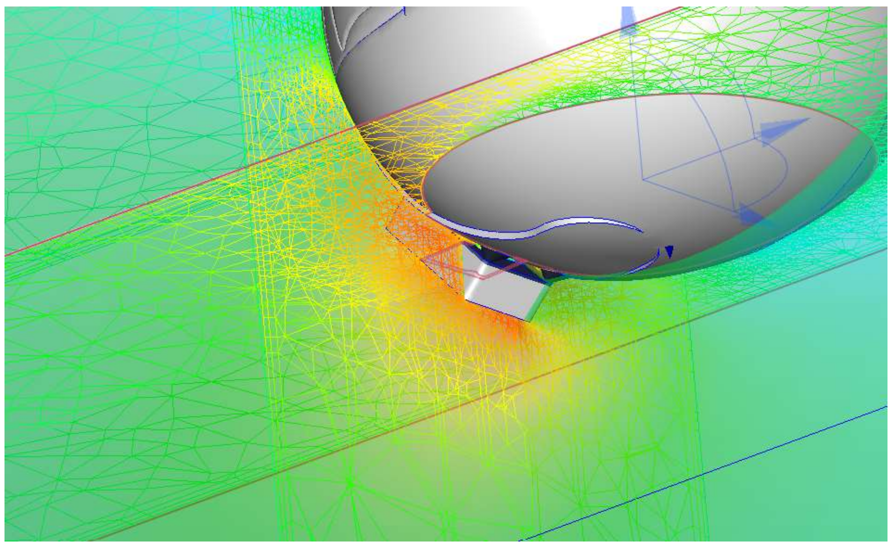
The CFD test results do not agree with my hypothesis. The Halo Mount did create substantially more drag, lift and lateral force compared to the benchmark, with 162%, 145%, and 169% differences respectively. This disagreed with requirement 1.

However, the direct mount results did partially agree with my hypothesis. The direct mount only created a small amount of extra drag, and lift (an average of ~6% difference overall speeds). However this trend did not continue with lateral force, this had an average 133% difference from the benchmark.



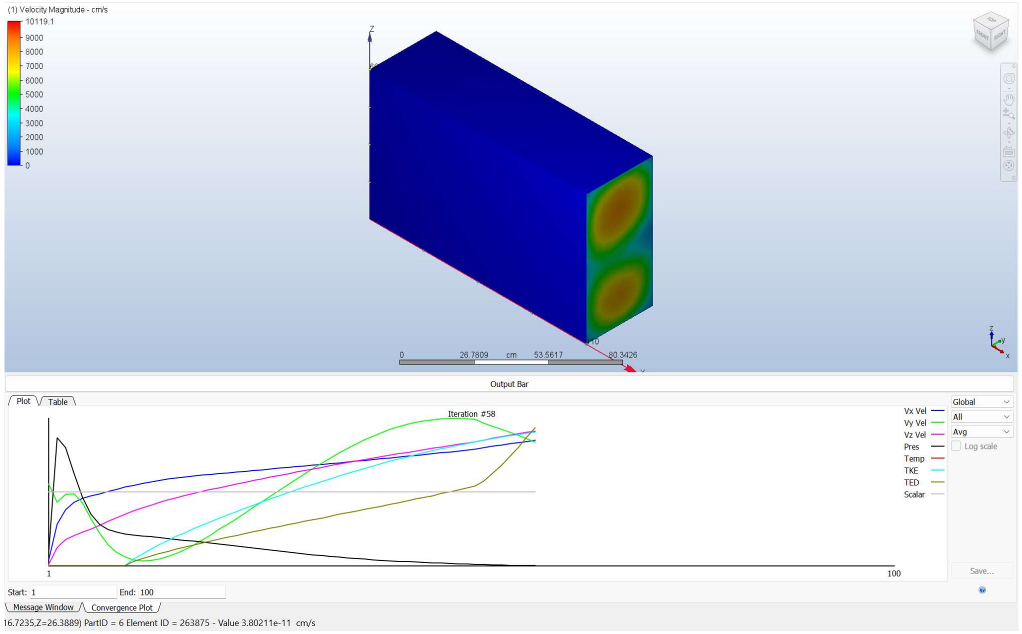
Looking at the ISOvolumes generated 'early' on both mount designs, there was a high pressure 'bubble' on a sharp edge, these are common occurrences at an area with a high-frequency change in pressure, often causing a force which rapidly changes direction (turbulence). This disagreed with requirement 2.

ISOvolumes related to VX wind velocity (drag), proved to be difficult to interoperate, however, the idea that a higher VX velocity around the mount creates more drag agreed with the wall calculations done in section 1, this further disagreed with my initial hypothesis.



To summarize, according to this simulation neither mount design would be particularly safe, and unfortunately, as I covered earlier, if these tests were to go by, I wouldn't feel confident making changes that would affect the drag or lift force generated by the addition of the device.

However, if these tests were to go by, I would feel confident making changes to decrease lateral force experienced by the user.



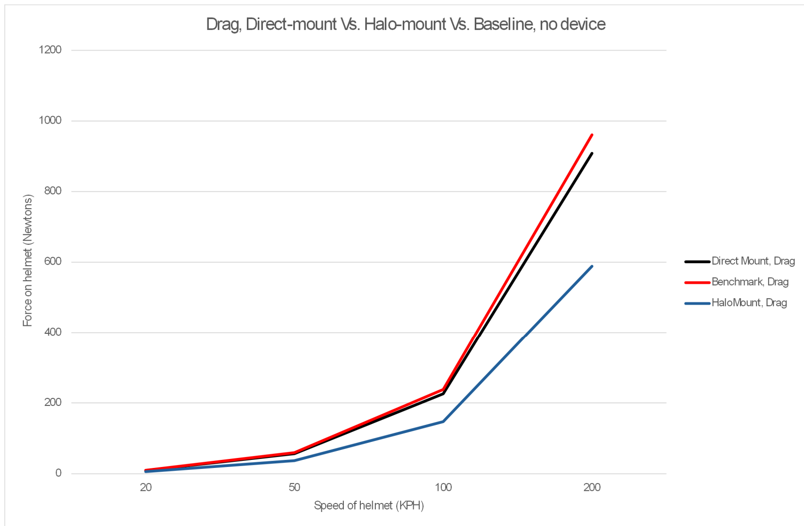
Simulation settings

- **Simulation quantity:**
  - 100 at each different speed
- **Mesh:**
  - SO tolerance: 0.012
  - No. Wall layers: 3
  - Layer factor: 0.45
  - Later gradation: Auto
- **Domain size:**
  - Y-LEN: 37.2, Z-LEN: 72.6, X-LEN: 121
- **Material:**
  - The main device, Helmet, ABS, molded plastic
  - Mount arm, Aluminum, 6061

What changes would I make to the simulation?

Next time I run a simulation I will do more careful planning about setting up the simulation.

I spoke to an admin of the r/CFD Reddit page about my settings, he suggested a taller vertical domain, as well as running more simulations. I also spoke to Finn McIntyre, a current PhD candidate researching fluid mechanics; Finn suggested to receive more accurate results, the mesh should be perfected, this could remove some of the stand-out values like the lower lift for the HaloMount. Note: this also could be due to vortexes I cannot locate.



What Changes Would I Make To The Design?

Looking at my initial requirements in comparison to my results, it could be fair to say that both the Halo Mount and direct mount could be unsafe for the user in their current state. This would be due to the excess forces compared to the benchmark helmet. I have comprised the key changes I could make to each design to improve the safety of the end user.

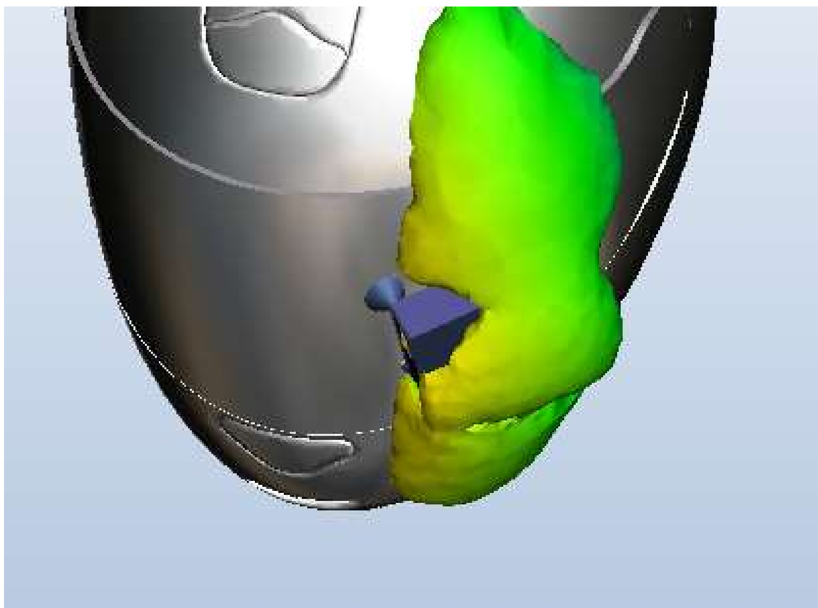
The biggest issue for the mounts was the increased lateral force compared to the benchmark. The lateral force on the better of the two designs (direct-mount) was 133% higher on average across all speeds than the benchmark.

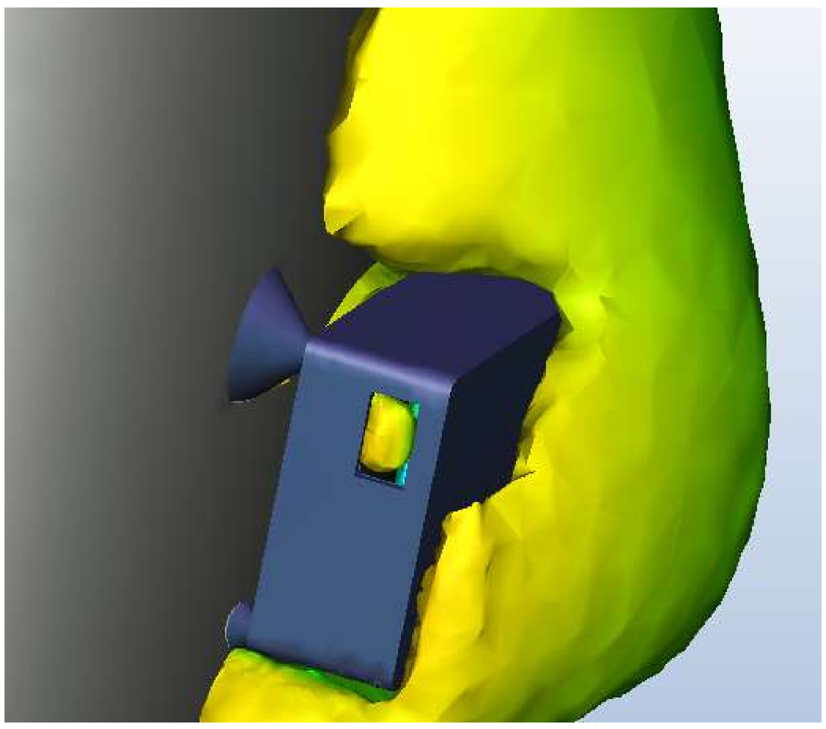
ISOvolumes mapping pressure to VZ (lateral force), showed that the region where the mounts were experienced a significant lateral push due to asymmetrical flow and pressure imbalance.

As well as decreasing lateral force, decreasing flow separation in this region would help to decrease turbulence generated by the high-frequency change of pressure often associated with flow separation around asymmetric zones.

Multiple approaches could be taken to alter the designs to bring them closer to the benchmark figure (decrease lateral force and turbulence). A simple change that would decrease lateral force would be rotating either mount such that the USB port is not facing the wind load.

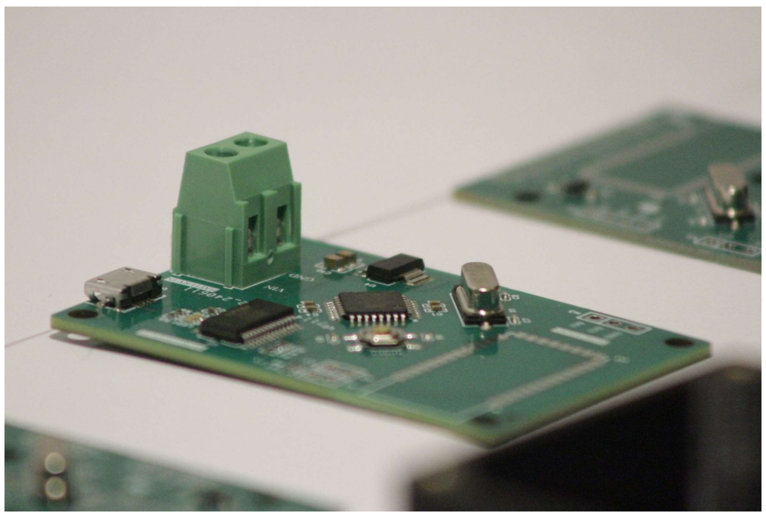
A simple design change that would help to decrease flow separation would be shaping the front-facing edges; Adding material here in the form of a slope towards the visor would increase the amount of time the air has to change direction in the disturbed region, decreasing the force on the helmet. Another simple design change that would allow performance closer to the benchmark would be altering the surface facing the helmet so that it follows the visor's shape. This would greatly reduce the air travelling between the visor and the display. A not-so-practical but interesting solution to asymmetric flow would be a secondary mounted device on the opposite side of the helmet. This could cancel out the lateral force. However, this would move the design further from the benchmark in drag and lift; therefore this will not be considered for future designs.





What I have learnt and final thoughts

Skills



Engineering 'production' skills

- KICAD, Easy-Eda (Circuit design)
- Solidworks, Fusion360 (3D printing, device modelling)
- Autodesk CFD (Safety analysis)

Engineering 'practical skills'

- **Designing with the intent of production.** It's one thing to create a product to meet specific constraints in isolation from the rest of the system, but it's another thing to consider how a manufacturer would produce it and how that piece interacts with the rest of the system. (PCB production and 3D production)

- **Communication.** I am fortunate enough to have worked with over a dozen talented people on this project, some for just a short discussion, some for the full duration of the project (I.e. App developer Joel Bannister). But no matter how talented you are, you can't read someone's mind; Thus being able to communicate effectively and efficiently is crucial to getting this project finished on time.

- **What's possible, what not?** At every stage in this project, without fail, I found myself doing, (or at least considering) something which inevitably too ambitious; If things didn't backfire immediately, I got punished further down the line, every, single, time. After probably a few too many of the same lessons being taught, I learnt to step back and try to understand what I was getting myself into.

Final thoughts.

Although the HaloMount and direct mount both produced un-admirable lateral force wall results, the direct mount performed well compared to my initial requirements, 1% outside of my requirements in both the drag and lift section of the report. The main culprit for the increased lateral force for both mounts was the asymmetric designs resulting in asymmetric airflow created, most obviously present in the sharp front-facing edges of each mount. This was discovered through the use of ISO volumes in terms of VZ and pressure.

As I previously mentioned I would feel uncomfortable suggesting any changes that would surely bring the performance closer to the benchmark of the mount in terms of drag and or lift. This is because the plane and ISO volume results I gathered surrounding these **were inconclusive**.

I would feel confident in making changes to these designs to bring the performance closer to the benchmark of the mount in terms of lateral force because the plane and ISOvolume results I gathered surrounding lateral force **were conclusive** as they agreed with the wall calculations.

To narrow the gap between the HaloMount and direct mount in terms of lateral force according to the CFD results, the design should be such that there is an airtight seal between the display side of the casing and the visor, as well as adding material in the form of a slope. Both of these changes would decrease the amount of flow separation, partially making up for the biggest flaw which is the unsymmetric design.