An integrated bicycle computer mount for aerodynamic handlebars

Daan Kemme

Integrated Product Design
Faculty of Industrial Design Engineering
Delft University of Technology

TU Delft

An integrated bicycle computer mount for aerodynamic handlebars

Development of a lightweight and aerodynamic solution for integration of bike computers into aerodynamic handlebars of professional road cycling bicycles.

January 2024

Daan Kemme
4400488

Integrated Product Design
Faculty of Industrial Design Engineering
Delft University of Technology

Supervisory Team

Chair: Dr. Ir. Arjen Jansen
Mentor: Dr. Ir. Erik Tempelman

TU Delft

Acknowledgements

I would like to express my gratitude to the following people,

My supervisory team, Arjen Janssen and Erik Tempelman, for their support and guidance during this project. Through your perspectives, valuable insights and input I was able to complete this project.

The client for proposing the assignments and providing me with the opportunity to work on this project, their insightful feedback along the way, as well as their encouragement, patience and support.

My girlfriend Annabel for always being there for me, mental support and patience. Her belief in me has always helped me to get back on track.

My parents, brother and sister for their unconditional love, encouragement and presence. Their stability and support has been my foundation for studying Industrial Design Engineering these past 7 years, and gave me the opportunity to go abroad.

To my friends who have been a source of inspiration and camaraderie throughout this academic endeavour. Their friendship has made this journey memorable and enjoyable. Specific thanks to Olivier and Alejandro, who have helped me with design input and CFD analysis.

Lastly, to my peers and all the participants for volunteering their time and giving their honest opinion.

This project would not have been possible without the collective support of these people. Thank you.

Summary

The goal of this graduation thesis is to design a bicycle computer mount (BCM) that connects bike computers with road cycling handlebars in a visually appealing, and aerodynamic way. Initiated between Delft University of Technology and a leading sports equipment company, the project addresses the evolving needs of cyclists regarding maximum integration and aerodynamic optimisation of their material.

Through context research, user research and aerodynamic research, ideas were generated and formed into concepts. From those concepts the most promising was selected to further develop into a detailed design. This design was then validated with performance test. The final weight of the BCM is 38 grams including hardware

The final design is a one-piece thermoplastic BCM is injection moulded shown on the right in figure 1. It is produced from carbon-reinforced nylon (CF/PA12) to optimise weight and structural performance. A physical prototype was made for validation with different computers and vibration testing.

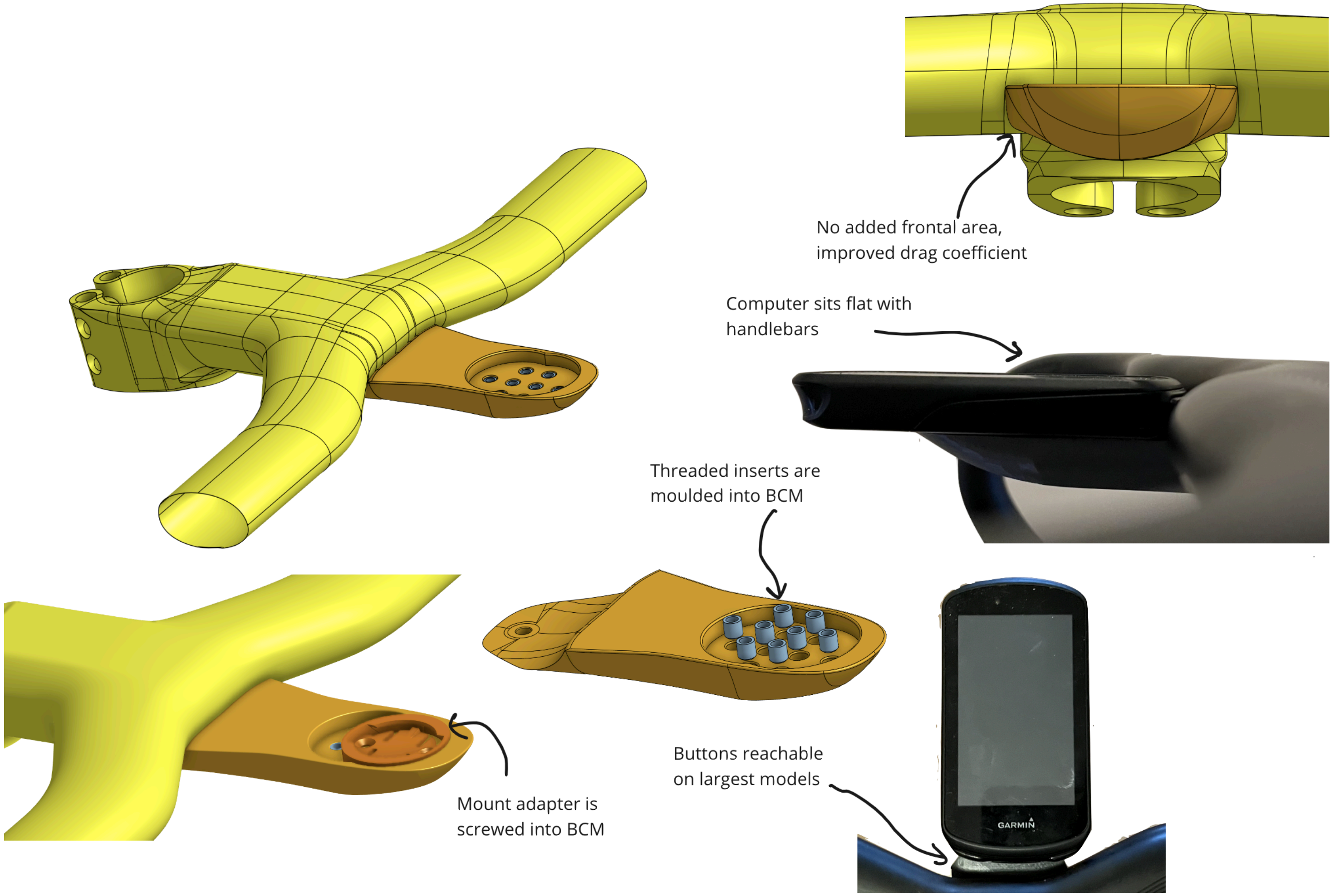


Figure 1: The final design as an outcome of the project.

1. Introduction

This graduation project was initiated as a collaboration between IPD graduation student Daan Kemme at the Delft University of Technology (DUT) and a company which will remain confidential. In this report the company will be referred to as either the client or the company.

The first part of the report introduces the assignment and provides context for the project. Thereafter an analysis is provided looking into technical, historical and design engineering perspectives. The result of this is a design vision that is used for the ideation phase, of which concepts are generated. The expected outcome of this project will be a or multiple product proposition(s) for the company.

1.1 Client introduction

The company is a developer and producer of high-end performance sporting equipment and sportswear that are distributed all over the world. They are known for being highly innovative within the sports industry. The company is now looking to further innovate in the cycling industry by optimising aerodynamics for performance road bicycles that are being used by both professionals and amateurs.
The focus of this collaboration is the redesign of their existing bicycle computer mount (BCM), specifically tailored for professional road bikes. A mentor of the client was involved in the project through meetings and feedback sessions.

1.2 Assignment

In sports there is a constant tension toward continuous improvement and breaking world records (Haake, 2009) . This is also the case in road bicycle racing, where performance has increased by more than 6% between 1990 and 2010 (Helou et al 2010). One of the contributing factors to this performance enhancement is technology, such as material advancement and aerodynamics optimization.

Professional cyclists and amateurs alike often use a cycling computer that tracks and shows a variety of data to the rider and provides them with navigation among other features. These computers are typically mounted to the handlebars of a bicycle by using clamps, screws or other fixation methods, as shown in Figure 1. The current mount offered by the client is specifically made for their own handlebars. Nowadays, handlebars on professional road bicycles are foil-wing shaped instead of round tubes, see figure 2. This is done to reduce aerodynamic drag on the cockpit of the bicycle.

Over the last years bicycle brands have put many resources and development time into improving bicycle aerodynamics. Yet, the integration of the bike computer has been left untouched. This project will focus on integration of the bike computer into the bicycle system as a whole, focussing on aerodynamics and design. Therefore the assignment is as followed:

The goal is to design a product to mount cycling computers on an integrated road cycling handlebar, while reducing its weight and improving its aerodynamic performance. This/these product(s) will be designed for the handlebar from the company.

The current BCM offered by the company is produced is shown in Figure 3, it is produced of CNC-machined alloy and offers a 1-design-fits-all approach. The company's wish is to move to a thermoplastic material for this product with a less bulky design that fits the portfolio. The focus of the product is on road- and gravel cycling handlebars which all use the two-hole mounting position. Therefore, the product should be tested using a worst-case scenario to ensure it's durability. Furthermore, the product that will result from this project will not be for sale in any conventional cycling stores, but will be a direct to consumer online sale. This requires the product to be easy to install.

Figure 1: A bicycle computer mounted to handlebars.

Figure 3: Current BCM offered by the company.

Figure 2: Flat and foil-wing shaped handlebars..

1.3 Problem definition

In summary, the problem revolves around the lack of integration and optimisation of bike computer mount for the evolving aerodynamic designs of professional road bikes. This project seeks to bridge this gap by designing a thermoplastic BCM that not only aligns with the company's product portfolio but also optimises weight and aerodynamics. For this the following questions are researched in this thesis:

Technical considerations:

1. What bike computer models and sizes are on the market, and how does the variation in design, dimensions, and features impact the requirements for universal compatible BCM?

2. How does the design of the current handlebars impact the integration and compatibility of BCM's? And what features affect the seamless mounting of bike computers?

Material Selection and Design:

3. What are the key criteria for selecting a thermoplastic material for the BCM considering the design requirements?

4. How do different thermoplastics compare to each other in terms of mechanical properties relevant to the intended function of the BCM?

Aerodynamics and Performance:

5. How does the redesign of a bicycle computer mount impact the overall aerodynamic performance of a road bike?

6. What aerodynamic design features are crucial for minimising drag and optimising the performance of the bicycle computer mount?

7. Can the mechanical performance and durability of the thermoplastics be tested?

Consumer Interaction and Installation:

8. How do users interact with their bike computers and their mounts?

9. What are key factors influencing the choice of a bike computer mount and how does this impact the design requirements?

10. Are there any additional features that users would like to see?

Testing and Durability:

11. What constitutes a worst-case scenario for testing the durability of the bicycle computer mount, considering road and gravel cycling conditions?

12. How can the product be tested for strength, stiffness, and durability to meet the demands of high-performance cycling?

13. What methodologies and tools are effective in evaluating the product's performance under real-world cycling conditions?

Market Impact and Innovation:

14. How do existing BCM's in the market address the challenges of integrating with various handlebars? And what features set them apart?

1.4 Project approach

A modified version of the double diamond approach, see figure 2, will be used in the design process. Since the design assignment is already highly specified, the discover and define phase are relatively short and small, in order to start designing as soon as possible. This way more time will be spent on optimising and testing the proposed design.

In the discover and define phase the goal is to analyse and understand the context of the product system. The method starts with a scope definition and will lead to a design requirements used for concept generation. This is done using desk research, literature research, market research, field work, surveys and interviews.

In the develop phase the project will shift towards finding a solution. This is done with ideation methods and concept generation. Once a concept has been chosen, methods such as rapid prototyping, design testing and design validation will be applied. Multiple product iterations will be made to reach the final product proposition. The product will be tested on strength, stiffness and vibration durability.

For reporting the 'NSFD - reporting made easy' format by Erik Tempelman has been used as an example (Tempelman, 2019).

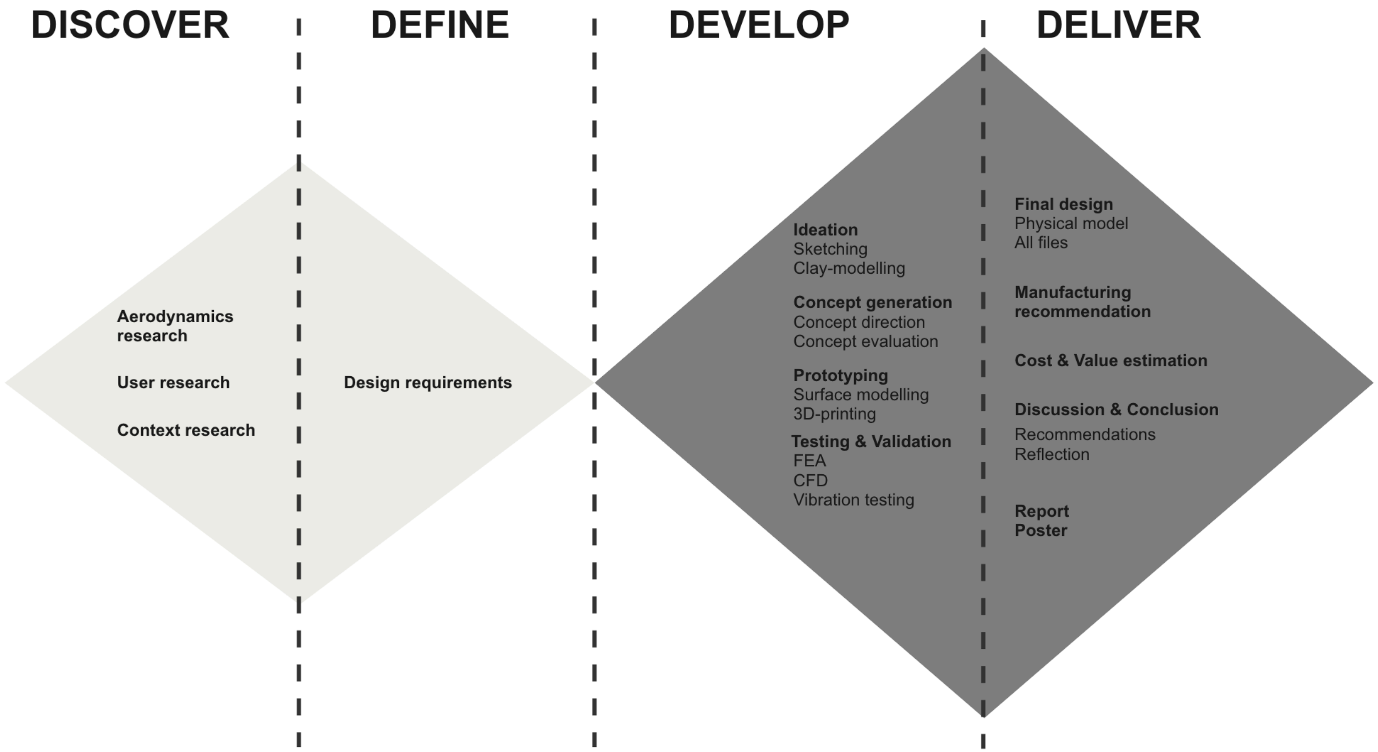


Figure 2: A modified version of the Double Diamond approach.

2. Analysis

The chapter covers the analysis phase of the project. This is used to create design requirements and a design vision. This is done with desktop research, literature research, a user questionnaire and interviews. Each chapter will start with research questions and end with design requirements as a result of the research.

2.1 Context research

In this phase the aim is to understand the context of BCM's, focussing on the handlebars and the bike computers. These two components are the focal points of the BCM and will define technical design requirements. The following research questions are covered in this chapter:

1. How does the design of the client's handlebars impact the integration and compatibility of BCM's? And what features affect the seamless mounting of bike computers?

2. What bike computer models and sizes are on the market, and how does the variation in design, dimensions, and features impact the requirements for universal compatible BCM?

3. How do existing BCM's in the market address the challenges of integrating with various handlebars? And what features set them apart?

2.1.1 Design of context: Handlebars

The steering system as shown in figure 3 of a road bicycle is commonly referred to as the "stem" (number 1 in figure 3) and "handlebar" (number 2 in figure 3) combination. The handlebar is the part of the bicycle that you hold onto while riding, and it's typically connected to the bike's fork via the stem. The stem can also come in different lengths and angles, affecting the reach and height of the handlebar for a customised fit. These parts are also made from carbon. In recent years these two components have been integrated, shown in figure 4. This result in a lighter and more aerodynamic handlebar. However, this integration comes at the cost of adjustability compared to the traditional system where you can swap to a different stem.

Furthermore, the handlebars' foil-shaped profile should be considered in the design to reach a streamlined integration that improves airflow around the bicycle computer mount and handlebars.

The current handlebar products offered by the company use two fixation holes on the bottom side of the handlebars. These holes have a nut fixated inside them, and a mount can be connected to the handlebars by using two bolts, shown in figure 4. Making design changes to the handlebars is out of scope, however if an innovative idea is generated the company would be open for suggestions to design changes for fixation.

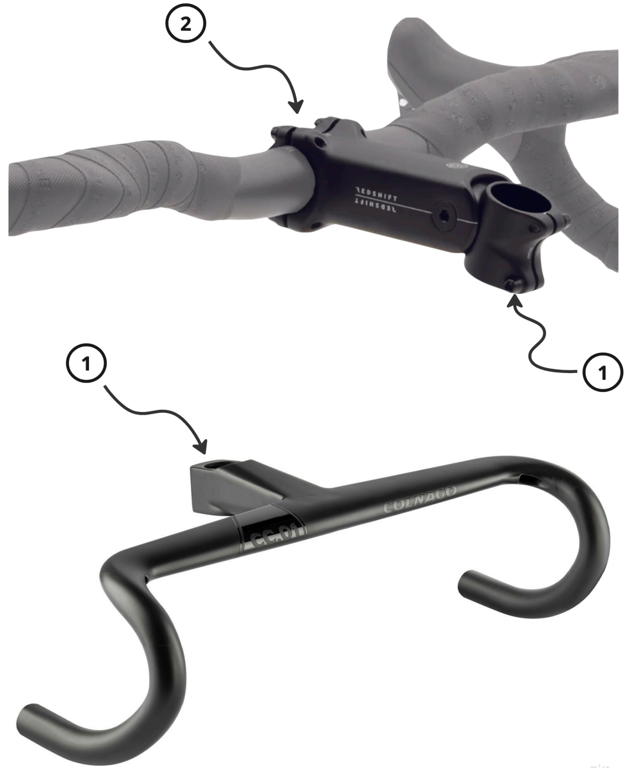


Figure 3: Top configuration shows a traditional system with a separate stem connected to the handlebars. Bottom configuration shows a one-piece integrated system.
Number 1 in both pictures shows where the handlebars connect to the fork's tube. Number 2 shows the connection between a separate stem and handlebar.

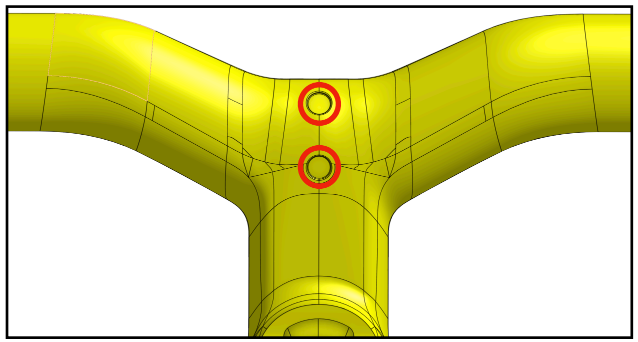


Figure 4: The two screw holes shown in red on the handlebars. These are located on the bottom of the handlebars.

2.1.2 Design of context: Bike computers

Currently the cycling computer market is dominated by Garmin and Wahoo, with 95% of UCI World Teams running one of either brand (Norman, 2023). Both brands offer their own range of products. The models that are considered in this project are: Garmin Edge 1030 plus, Garmin Edge 1040 (solar), Garmin Edge 540/840 (solar), Garmin Edge 530/830, Wahoo ELEMNT Roam V1&V2 and Wahoo ELEMNT Bolt V2. These are all performance oriented computers. The models that are out of scope are the Garmin 130 Plus and Garmin Edge Explore models, as they are listed as entry-level computers on the Garmin website (https://www.garmin.com/en-US/blog/fitness/which-garmin-bike-computer-is-right-for-me/). The selection is made in consultation with the client.

Figure 6 on page 7 shows an overview of the computer models in scope. This visual includes the following parameters:

1. **Computer dimensions**: These parameters impact the **BCM dimensions** to ensure **compatibility** with all models.

2. **Weight**: The weight of the computers impacts the **vibration** of the system, and the **structural strength** needed from the BCM.

3. **Button orientation**: The BCM should allow **easy access** to these buttons for user convenience.

4. **Mounting distance**: The distance between the centre of the mounting point and the computer edge, as displayed in figure 5. This parameter how far away from the handlebar the mounting point should be.

The dimensions and weight of these models varies, there are however similarities between models. For example the 1040, 840 and 540 models are only slightly wider and longer than the previous generation 1030, 830 and 530 models. An schematic overlay of the models is displayed in figure 8.

The length, width and thickness of the computer models will be used to determine the dimensions of the BCM. The computer length influences the position of the mounting point on the BCM. The computer width determines the width of the BCM, as it should not extend past the computer for aesthetic and aerodynamic reasons. The computer thickness affects the height of the mounting position, since the computer should be flat with the handlebar top. This contributes to the visual appeal of the bike and minimises aerodynamic drag.

Wahoo has two distinct design features that need to be accounted for. The first is that the buttons are oriented on the topside of the computer, flat with the screen. On Garmin computers the buttons are oriented on the down side of the computers, as shown in figure 6. Furthermore, Wahoo's computers have a distinctive design feature that possibly impacts the design of the BCM. A portion of the backside of the computer extends beyond the flat surface of the backside, shown in figure 7.

Furthermore, both Garmin and Wahoo use a brand specific mounting system to attach the computer on the mount. Making changes to this system is therefore out of scope.

Figure 5: Distance between edge of computer and mounting centre, a parameter used to design the BCM.

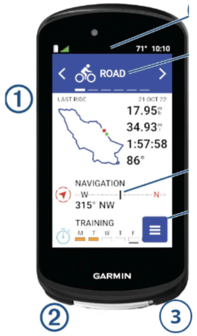
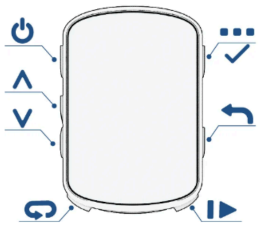
Model name	Garmin Edge 1030 Plus	Garmin Edge 1040 (Solar)	Garmin Edge 540/840 (Solar)	Garmin Edge 530/830	Wahoo ELEMNT Roam V2/V1	Wahoo ELEMNT Bolt V2
Dimensions	58 x 114 x 19 mm	59,3 x 117,6 x 20,0 mm	57.8 x 85.1 x 19.6 mm	50 x 82 x 20 mm	90.5 x 59.5 x 20.5 mm	77.5 x 47.2 x 21.3 mm
Weight	Weight: 124 g	133 g	85 g	79 g	93 g	60 g
Button orientation	2 Down side 1 Left side 	2 Down side 1 Left side 	2 Down side 2 Right side 3 Left side 	2 Down side 1 Left side 	1 Left side 2 Right side 3 Front side 	1 Left side 2 Right side 3 Front side 
Mounting distance	55 mm	55 mm	42 mm	41 mm	45 mm	37 mm
Product link	https://www.garmin.com/nl-NL/p/704417#specs	https://www.garmin.com/nl-NL/p/731136#specs	https://www.garmin.com/nl-NL/p/798925	https://www.garmin.com/nl-NL/p/621232	https://eu.wahoofitness.com/devices/bike-computers/elemnt-roam-buy	https://eu.wahoofitness.com/devices/bike-computers/elemnt-bolt-buy

Figure 6: Computer model names, dimensions, weight, and button orientation for all computers considered. This information is from 24-09-2023.

Figure 7: Wahoo's distinctive arc design feature, shown on the Bolt and Roam from sideview and back view.

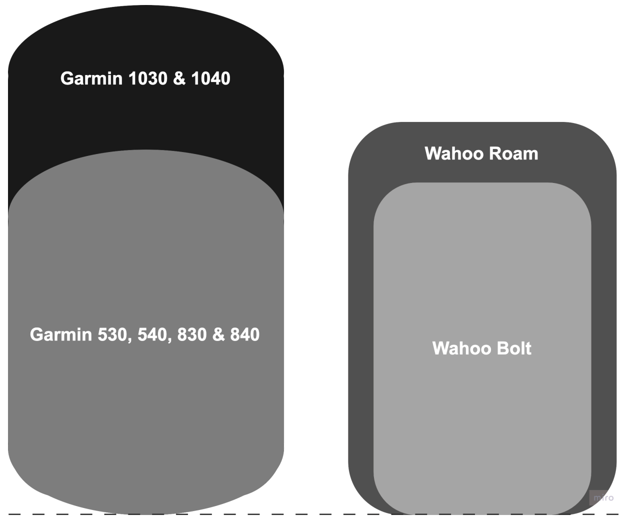


Figure 8: Overlayed models of Garmin and Wahoo.

2.1.3 Competitor benchmarking analysis

To identify opportunities for improvement of the BCM, four competitor products are evaluated in figure 9 on page 9. These four products have been selected as they are designed for similar handlebars, and are mounted to the underside of the handlebars using screws. The strengths and weaknesses of each product are shown in green and red in figure 9.

The Hinloopen BCM aesthetically blends the handlebar and computer together, but offers no adjustability and has a model-specific design. K-edge and Closethegap however offer adjustability, but no visually pleasing integration of the computer into the handlebar. The BCM serves more as a ‘bridge’ between handlebars and computer in this case. The canyon design has a more aerodynamic design, yet offers no Wahoo-compatibility as the mounting insert is printed in the design and can not be swapped. It does not offer adjustability in mounting position either.

This analysis presents opportunities that combine strengths from different products: the BCM should offers adjustability in mounting distance, and use a streamlined shape that creates an aerodynamic look and performance. The BCM should also blend the computer and handlebars together.

Design requirements

As a result from the analysis on the research questions at the beginning of this chapter, the following design requirements have been formulated

1. The BCM design should seamlessly integrate with the foil-shaped handlebar. It should have an streamlined look and enhance aerodynamic performance of the handlebars.

2. The BCM should be compatible with the following range of Garmin and Wahoo computers: Edge 1030, 1040, 540, 840, 530, 830, and ELEMNT roam and bolt versions.

3. The BCM should offer adjustable mounting positions to ensure a seamless fit for the models in scope.

				
Brand	K-edge	Hinloopen	Canyon	Closethegap
Price	€59,95	€149,-	€49,95	€62,-
Material	CNC alloy	PA12	PA11 CF	UD carbon composite
Weight	42g	42g-76g (depending on model)	20g	37g
Computer compatibility	All computers	Model-specific products	All Garmin computers	All computers
Additional features	Option to mount accessoires	-	-	Mounting option for a bell
Mounting distance adjustability	Adjustable mount position	Non-existent	Non-existent	Non-existent
Strengths	Compatibility and adjustability	Aerodynamic design, integration in handlebars	Affordable, aerodynamic design, light	Bell mount option, affordability
Weaknesses	No aesthetic integration with handlebars or computer, no aerodynamic design	Expensive, product fits only 1 model computer, bulky/heavy	No adjustability, bulky design	No aesthetic integration with handlebars or computer, no aerodynamic design
Product link	https://k-edge.com/shop/computer-mounts/garmin-mounts/garmin-ihs-mount/	https://hinloopen.bike/products/rocket-mount-for-bmc-ics-carbon-aero	https://www.canyon.com/en-de/gear/accessories/bike-tech/cockpit-and-handlebar-mounts/forward-am-i-canyon-3d-print-mount/9102036.html	https://www.closethegap.cc/nl/product/hidemybell-raceday-ss-syncros/

Figure 9: Competitive benchmarking of products on the market. Data collected on 04-01-2024.

2.2 User Research

To get an understanding of how people use and interact a BCM, user research is required. This was done using a questionnaire as a quantitive method, and interviews as a qualitative method. The research questions are:

1. How do users interact with their bike computers and their mounts?

2. What are key factors influencing the choice of a bike computer mount and how does this impact the design requirements?

3. Are there any additional features that users would like to see?

Questionnaire

A questionnaire was send out to a variety of cyclists (n=17). The first goal of this research how and when cyclists use their BCM. The second goal is to select respondents for a subsequent qualitative interview by inquiring whether or not the respondents own a cycling computer, what type of bike is used, total financial investment, and types of handlebars used. Any respondents that did not use a cycling computer were excluded from the questionnaire results.

Furthermore, the respondents were asked about how often they take their cycling computer on a ride, how they mount it to their handlebars and if they ever take the mount of the handlebars. Results showed that the target group rarely interacted with the BCM once it was installed on the handlebars, but exceptions were present.

The results of the questionnaire can be found in appendix 1. Cyclists within the target group were found to almost never take off their BCM. Exceptions to this were as follow:

1. Transportation of bike in bike bag or bike case.
2. When BCM was in the way of attaching a handlebar bag.
3. When user switched computer model or brand, a new mount was required to fit that model to the handlebars.

These results indicate that moments of direct interaction with the BCM happen very rarely. This can be used to explore permanent integration of a mounting option in the handlebars, instead of designing a separate product to mount the computer. This option will be explored in the ideation phase. For a separate BCM, the interaction exceptions above indicate that an easy installing and removing process of the BCM would be beneficial.

Interviews

Qualitative interviews were conducted with five respondents of the questionnaire that frequently use their bike computer. They range from amateurs to semi-professionals. The interviews were semi-structured with a predetermined set of open questions. The goal was to gain an understanding in what factors influence the choice of a bike computer mount, as well as if cyclist have a need for additional features on a BCM. Interviewees were also shown the competitors products, to start a conversation about differences between products.

Table 1 shows the relevant key factors that were mentioned by the cyclists during the interviews. Price and aesthetics were key factors for all the cyclists. An interesting finding is that 2 cyclists preferred aerodynamics over additional features, and 2 cyclists preferred additional features of aerodynamics.

Key factor	# of cyclist mentioned
Price	5
Aesthetics	5
Weight	3
Compatibility with different computers	2
Aerodynamics	2
Additional features (e.g. bell, light, GoPro)	2
Brand loyalty	1

Table 1: Key factors mentioned by cyclists influencing their BCM choice.

All interviewees indicated that the price of the BCM to be an important factor in the decision making process, with the upper limit around the €90-110,- mark. Besides price, aesthetics were the most important factor. Three of them indicated that the BCM has to look 'cool' and 'fast', with two of them using the quote '*if it looks fast, it must be fast*'. This indicates that cyclists care just as much, if not more, about looks as about performance. This can be kept in mind during the design process of the project.

Design requirements

The questionnaire and interviews led to the following design requirements:

1. Aesthetically pleasing appearance that complements the bike's visual appeal, addressing users' desire for a 'fast' and 'cool' look.

2. Intuitive adjustment for different bike computer models.

3. Provide mount dimensions that fit different device sizes.

4. A quick and intuitive installation process that allows users to securely attach, adjust and remove the BCM without the need for specialized tools.

5. Ensure that cyclists can easily access and use the controls on their bike computers while mounted, allowing for a seamless and distraction-free riding experience.

2.3 Aerodynamics research

In this chapter the relevance of optimising aerodynamics is explored. This is done by the following research questions:

1. How does the redesign of a bicycle computer mount impact the overall aerodynamic performance of a road bike?

2. What aerodynamic design features are crucial for minimising drag and optimising the performance of the bicycle computer mount?

Aerodynamics of bicycle system

A large portion of a cyclist's power is meant to overcome drag. It is responsible for between 70% and 80% of the total resistance at a speed of 30 km/h, and 90% of the total resistance at speeds larger than 40 km/h, both on flat terrain (Grappe et al., Kyle and Burke, 1984).

Drag in cycling is often quantified by the drag area C_dA (m^2), which is the product of the drag coefficient (C_d) of the system (cyclist and bike) and its frontal area (A). C_dA can be used to optimise the power input by reducing the C_dA value. C_dA values have significant variations between cyclists and their positions. A generic rule of thumb is that every reduction in C_dA by 0.01 means that nearly 10 watts less power is needed to cycle 40 km/h on flat terrain.

The bicycle accounts for about 18-36% of the combined cyclist-bicycle system air resistance, depending on the cyclist position and speed (Barry et al., 2012; Defray et al., 2010; Kyle and Burke, 1984). The main components of influence are the frame, wheels and handlebar. Typically the frontal area of a cyclist-bicycle system has a range from 0.330 m^2 to 0.460 m^2 (Blocken et al., 2019).

Reducing aerodynamic drag

Based on the formula in the previous paragraph, we can reduce the aerodynamic drag by reducing C_dA. C_dA depends on the size, shape and surface texture of the object. It can be by either reducing frontal area A or drag coefficient C_d.

C_d is determined by the shape and surface texture of an object. One way of reducing C_d is to make the body as streamlined as possible. This will be explored in the concept detailing phase of the project. Since the drag coefficient can only be determined through CFD or wind tunnel tests, a CFD analysis is performed in the design validation phase to assess the impact of the drag coefficient of the BCM on the overall system.

No scientific publications were found on the influence of different bicycle computer mounts on reducing this aerodynamic drag. Perhaps because it is off too little influence on the total system. To get an idea of the influence of the BCM and computer on the entire system, the frontal area is analysed in figure 10.

To ensure minimal frontal area addition, the topside of the bike computer, shown in blue in figure 10, has to sit flat with the handlebars. The design space where the BCM will be positioned is shown in red. When the BCM is designed within this frontal area, no area extends beyond the existing frontal area of the bicycle.

Design requirements

Resulting from the aerodynamics research are the following design requirements:

1. The added frontal area of the BCM & computer system to handlebars should be kept to a minimum.

2. The BCM should have a streamlined design that minimises the aerodynamic drag.

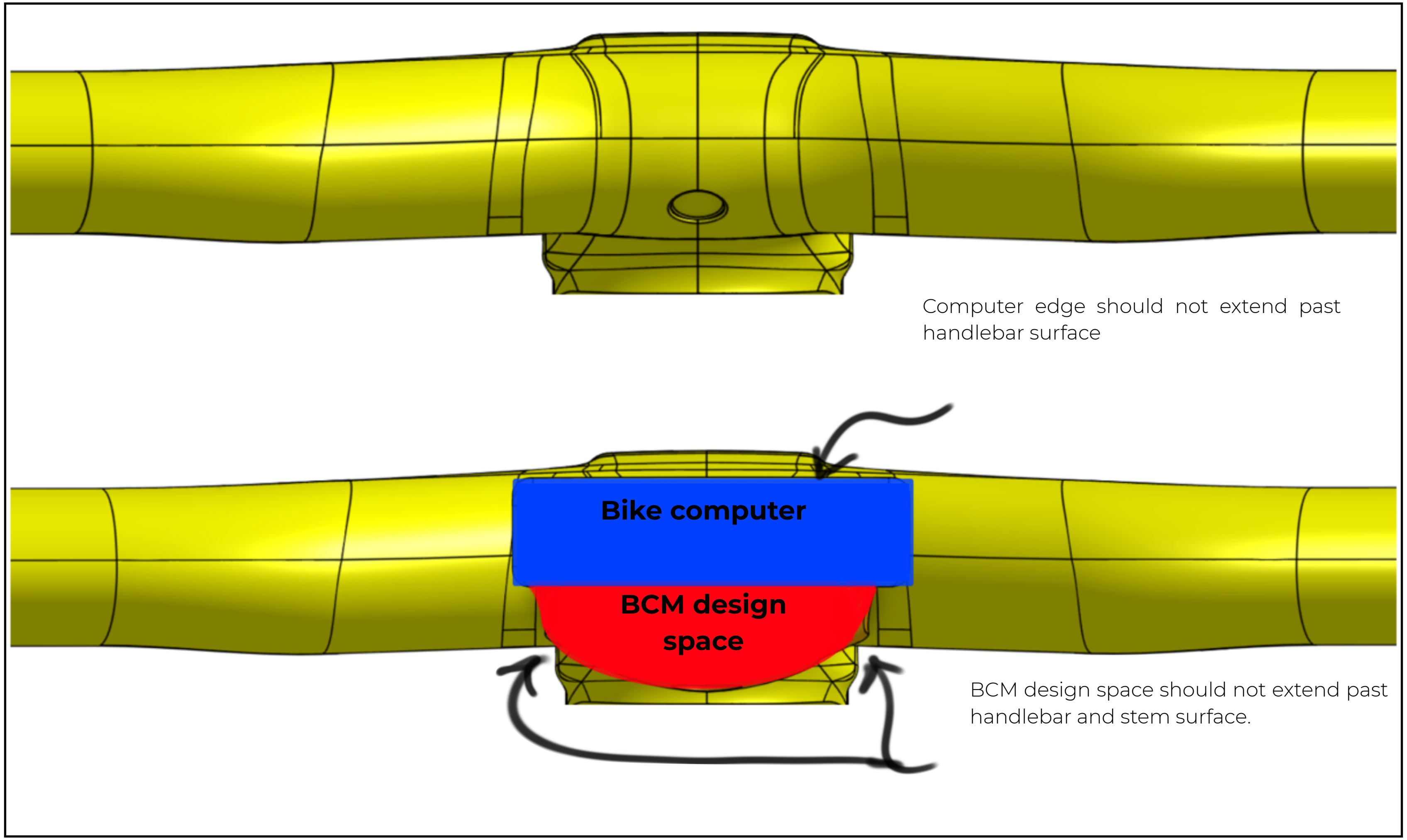


Figure 10: Frontal areas of the handlebars. Top: handlebars without bike computer and BCM. Bottom: handlebars with schematic visualisation of bike computer and BCM.

3. Design requirements

From the project assignment and the analysis phase a list of requirements is derived which is shown in table 2. The requirements are sorted into six categories, which is used as a checklist for the concept generation.

Category	Tag	Design requirement
Technology	A1	The product must be compatibly with the following bike computers: Garmin Edge 530, 540, 1030, 1040, including solar models. Wahoo ELEMENT BOLT and ROAM.
Performance	B1	The product must have a streamlined design to minimise aerodynamic drag.
	B2	The product must be resistant to impact and vibrations during cycling.
	B3	The product must be durable enough to withstand various environmental conditions (e.g., weather, temperature changes, UV exposure, moisture).
Use	C1	The product must ensure that the buttons and screen are not obstructed for use.
	C2	The product must have quick and easy installation.
	C3	The product must have intuitive adjustment for different bike computer models.
Material and production	D1	The product must have a final sales price of under €100,-.
	D2	The product must be made from a material that has low-production costs.
	D3	The product must have minimal post-processing operations.
	D4	The product's environmental footprint should be as low as possible.
Safety	E1	The product must be UCI-compliant.
	E2	The product must should prevent accidental detachment.
Aesthetics	F1	The product must have an aesthetically pleasing appearance for all computers that complements the bike's visual appeal.
	F2	The product must have an aerodynamic look.

Table 2: List of design requirements

4. Design

This design phase begins with the ideation process, using brain sketching, clay modelling, 3D-modelling and 3D-printing to generate and explore concept directions.

4.1 Ideation process

Sketching

To start of the ideation phase with hand sketching is used to explore shapes, handlebar integration and mounting options. From this ideation, critical areas of the design are identified to explore further. These also serve as a starting point for concepts.

Firstly, the design space that was defined in chapter 2.3 is shown in 2D in figure 11. The ideation in figure 12 explores different solutions for the shape of the mount, mounting options, and streamlining the design. The results from the ideation will be used to further explore concepts.

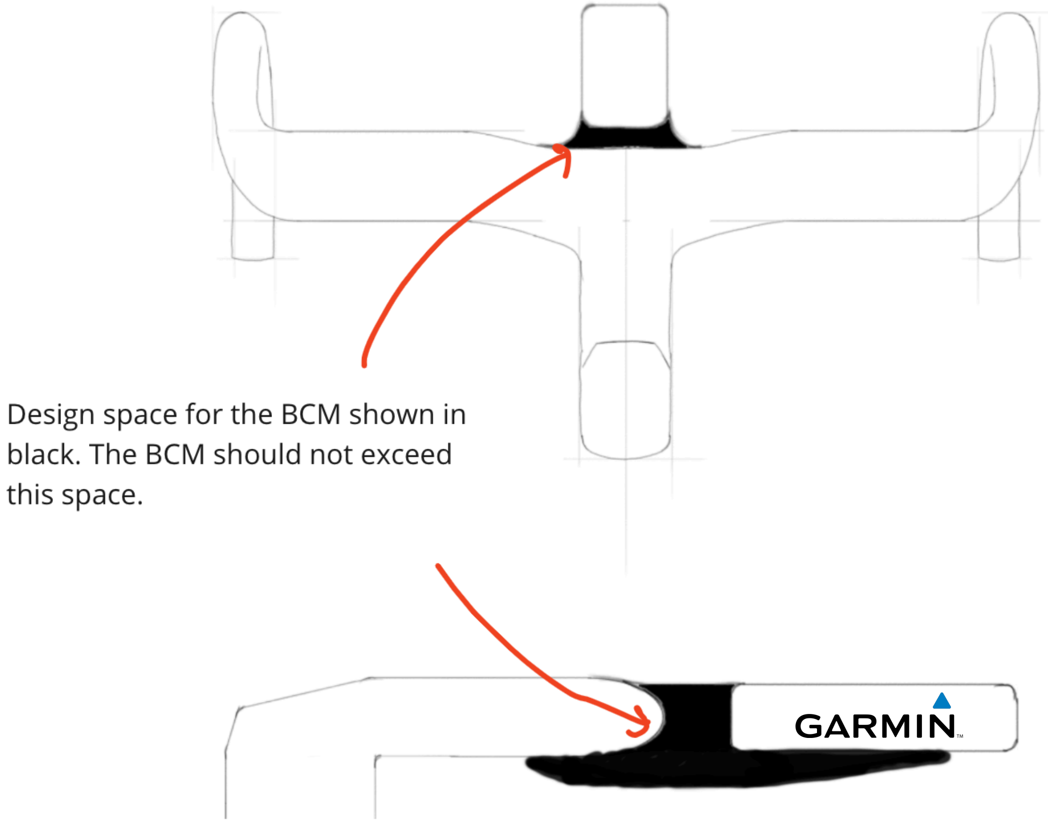


Figure 11: The 2D design space definition of the BCM shown in the top view (top) and side view (bottom) of the handlebars with computer attached.

Clay Modelling

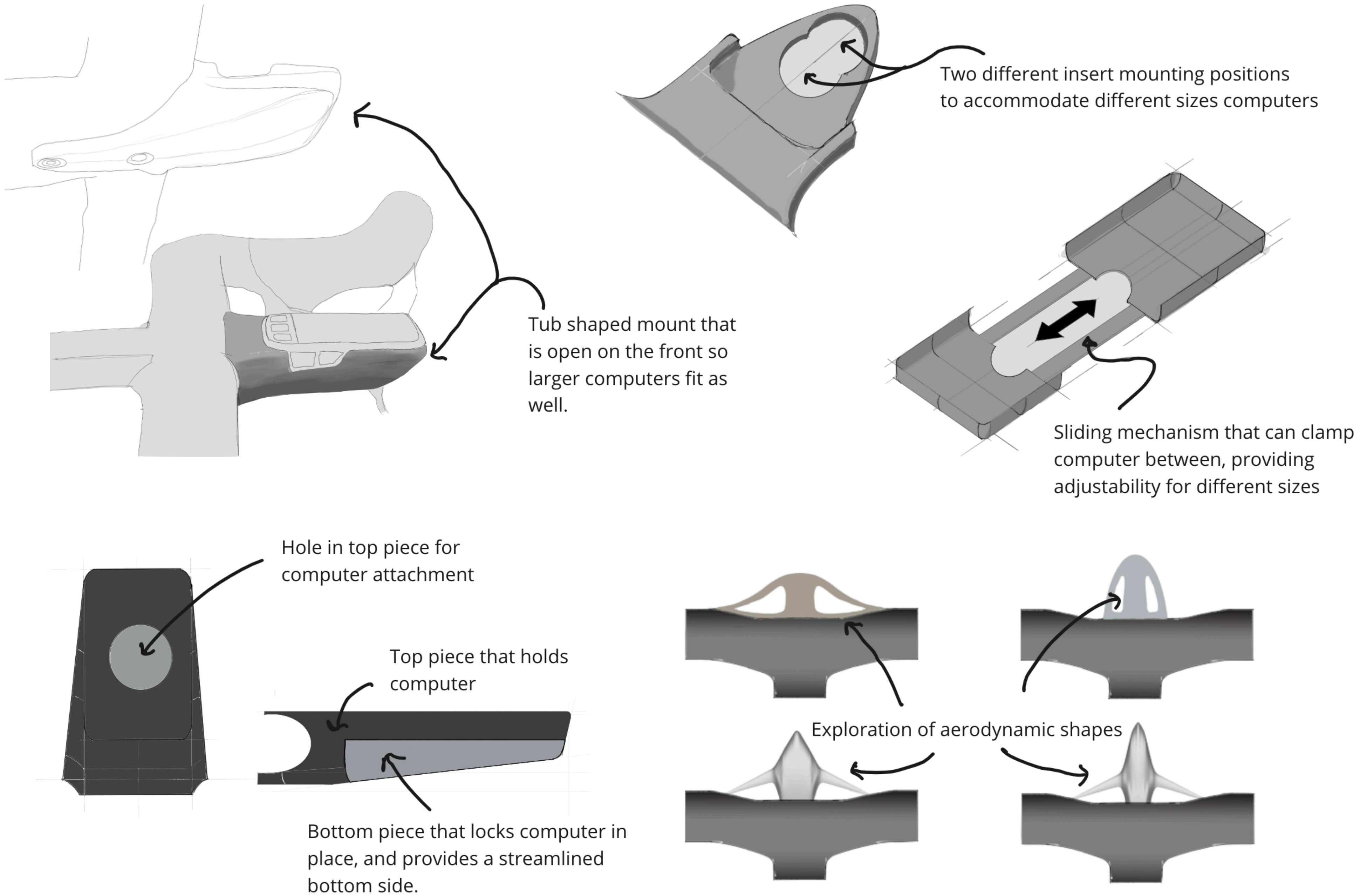


Figure 12: Results of the ideation hand sketching session.

Following the sketches, a physical exploration of form was conducted using clay. Having both the handlebar and bike computer (Garmin edge 1030 plus) available, this was done to create a feeling for dimensions and proportions.

Three areas of interest were identified to explore with the clay study. To visualize these a basic 3D-CAD model was created, shown in figure 13. Figure 14 shows these areas in red:

1. The frontal shape of the BCM, this area needs to be within the design space and needs to have a minimal but aerodynamic profile.

2. The plateau of the BCM that supports the computer. This should not extend past the sides of the computer, yet offer enough strength and stiffness to support all computers.

3. The gap that is created between the BCM, the handlebars and the computer. This gap needs to be minimal, but big enough in order to reach control buttons on the computer. It will be explored if adding a lip helps to enhance the transition between mount and handlebars.

The process of the clay modelling is shown in figures 15 and 16, with the results shown in figure 17. From this study it showed that adding a lip is as shown in figure 14 in area 3 will only cause increased difficulty to reach control buttons. Therefore this will not be implemented in the concept directions. The results of the clay study are taken into considerations when designing the concepts.

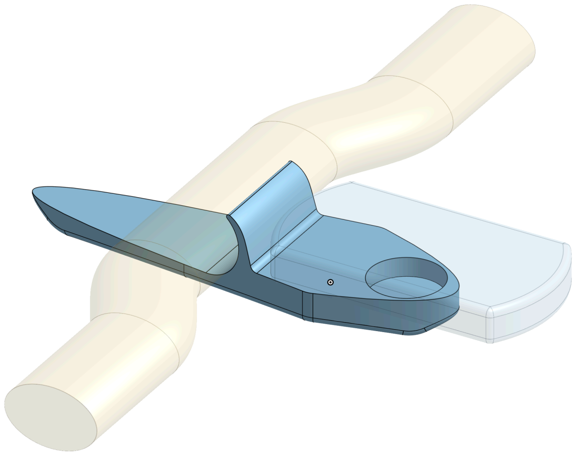


Figure 13: A basic 3D CAD model (shown in blue) of a BCM used to illustrate the three areas of interest.

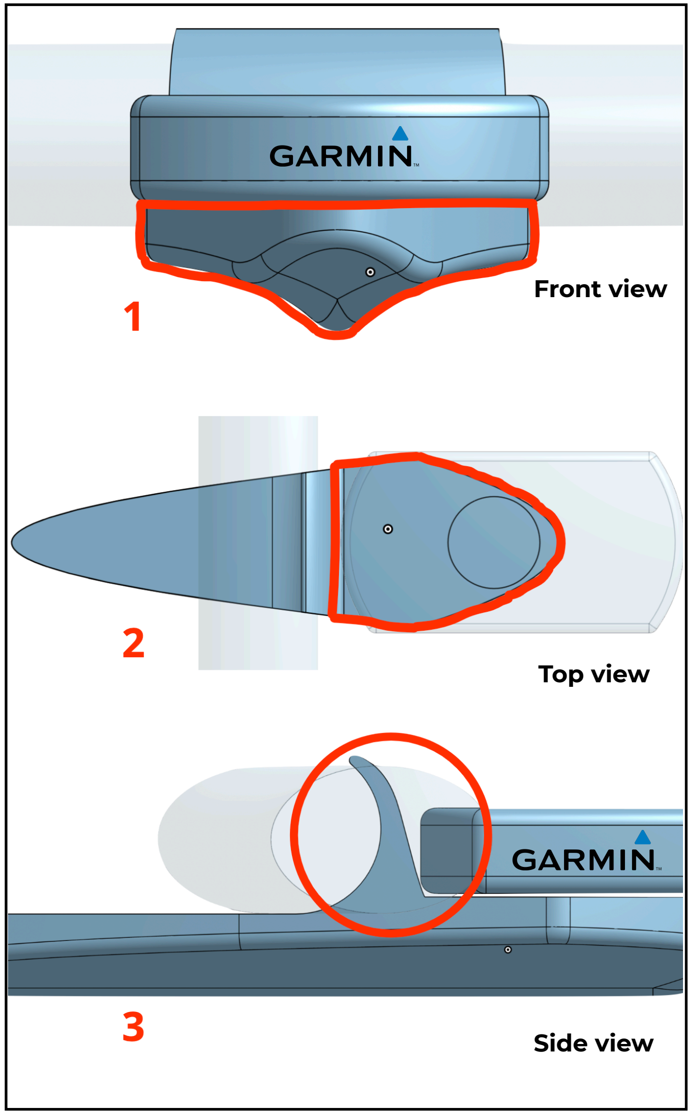


Figure 14: Three areas of interest identified for the clay study shown in red.

Figure 15: Exploring the plateau shape (area of interest #2)

Figure 16: Clay model to copy handlebar curvature and transition

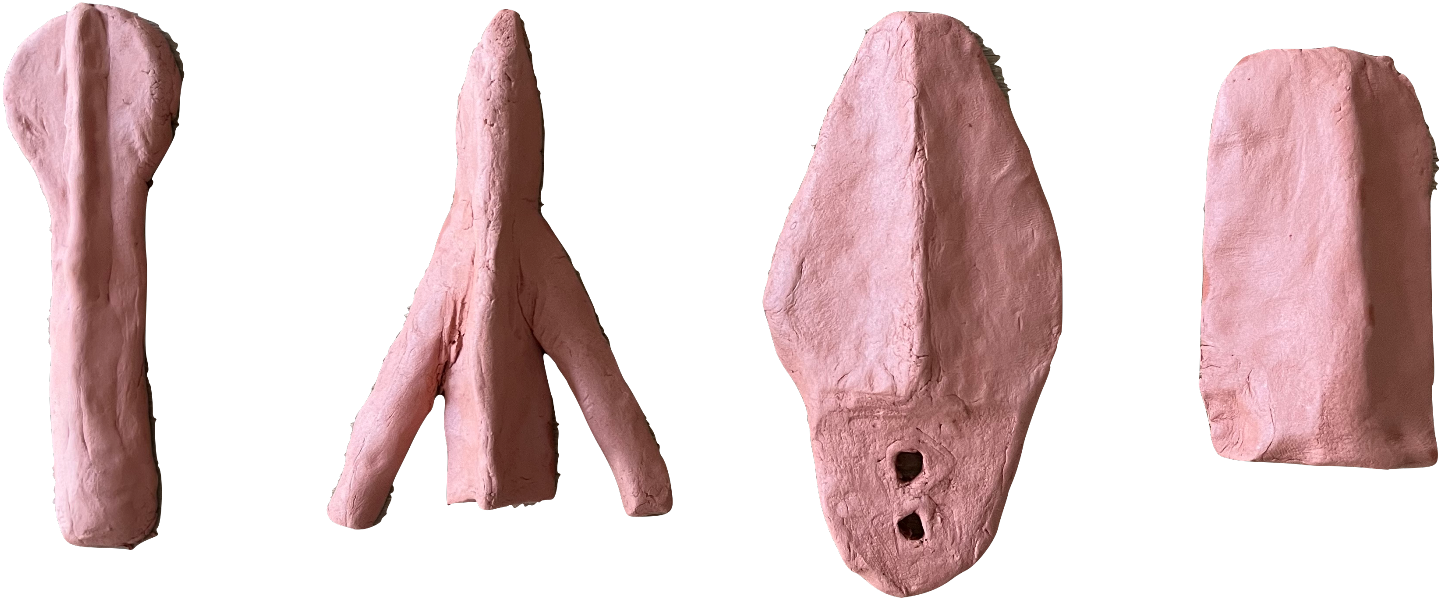


Figure 17: Bottom view of dried clay models, exploring plateau- and aerodynamic shapes.

4.2 Mounting mechanism ideation

Based on the main driver of compatibility, this chapter seeks to explore ways to change the existing mounting mechanism to accommodate both Garmin and Wahoo computers.

Wahoo and Garmin computers use their own respective systems to mount their computers. This complicates the design requirement to make the mount universal, but the system used by both companies is similar. They are essentially the same design but 90 degrees rotated from each other, as shown on the left in figure 18. The backside of the computers has a design that fits their respective insert.

This ideation explores whether it's possible to design a universal insert that accepts both Garmin and Wahoo computers. When the inserts of both brands are rotated 45 degrees in opposite directions an identical orientation is found, as shown on the right side in figure 18.

To make sure the computers are oriented vertically, the locations of the pins should remain in the original position. Due to the scope of not changing the computers and thus their mounting mechanism, this has to be solved in the insert design. Figure 19 shows a universal design ideation.

Figure 18: Showing the mounting systems for Garmin and Wahoo. From left to right: the backside of the computers, the inserts found in the mounts itself, the insert with a 45 degree twist, and a simplified sketch to illustrate the similarity.

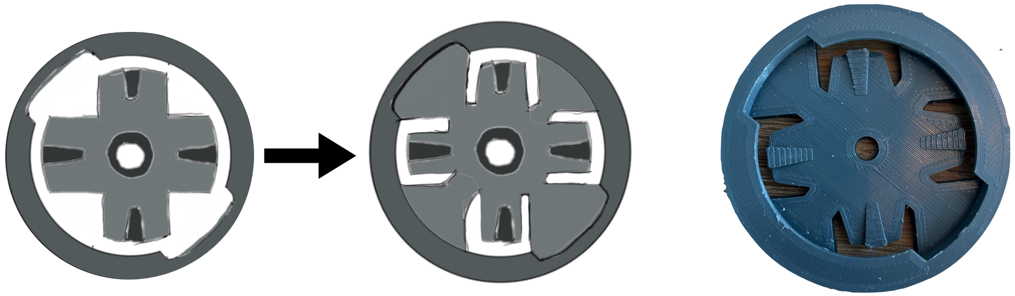


Figure 19: Translating the simplified sketch above into a printed universal design concept.

4.3 Adjustable mount ideation

In this ideation the possibility of a BCM with an adjustable mounting position is explored. The length of the gap between the computer and handlebars varies when using a mount with only one mounting position. Integrating an adjustable mounting position to facilitate an equal gap between handlebar and bike computer for each model is explored.

The result of a brainstorm session is shown in figure 20. The bottom part of the mount can not extend beyond the smallest computer option for aesthetic and aerodynamic reasons. Simplified models of computers have been used as white blocks in figure 20 to display this.

It consists of two parts: the body (dark grey) and the clamp (light grey). The body is fixated to the handlebars using the existing screw holes. The mounting system is integrated into the clamp part. The insert (shown in red) can be moved within this clamp using a rail system where the insert can snap in place. The insert needs to be placed into the position that matches the computers mounting system. As shown in figure 20, this shifts away from the handlebar once the computer gets larger.

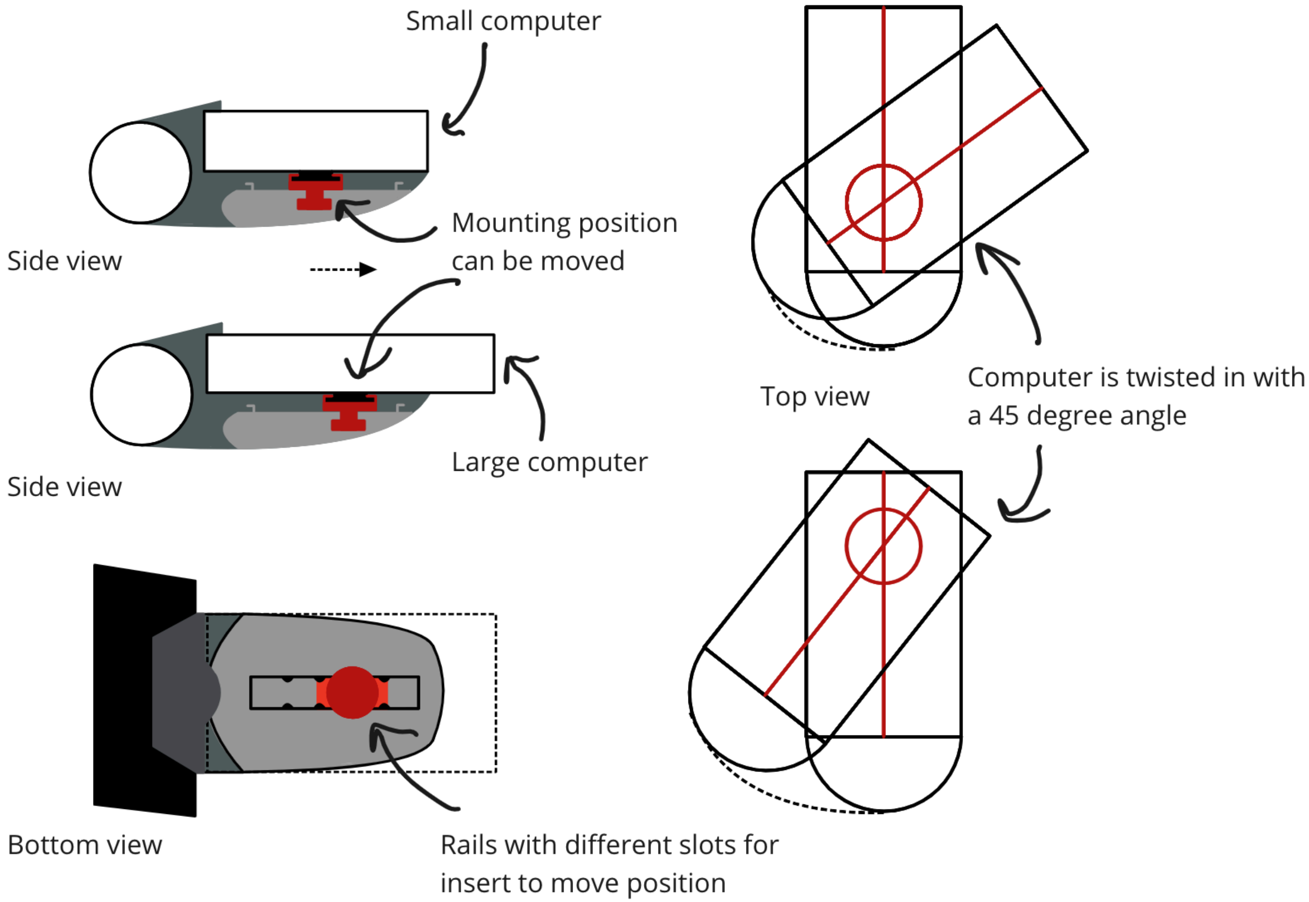


Figure 20: Concept for an adjustable mounting system.

4.4 Design exploration integrated mount

The user research indicated that the BCM is very rarely removed from the handlebars. This ideation explores including it into the carbon handlebars, instead of making a separate BCM. This is done by sweeping the handlebar slightly backwards towards the user. This will simultaneously result in a more inward and aerodynamic position of the elbows in the flat top riding position

Figure 21 explores how this can be integrated in the handlebars by sketching designs of this integration. A first prototype was created to test if the largest of the computers would fit on this handlebar, shown in figure 22. Essential to the design is that design of the handlebars should not interfere with the user interface of the bike computer, such as buttons and touchscreen.

The plateau that extends from the handlebar makes use of conventional inserts that screw into the round placeholder. This ensures computers of any brand can be attached. This concept would eliminate the need for a separate BCM.

The results of the ideation phase are used to create three concept directions in the next chapter.

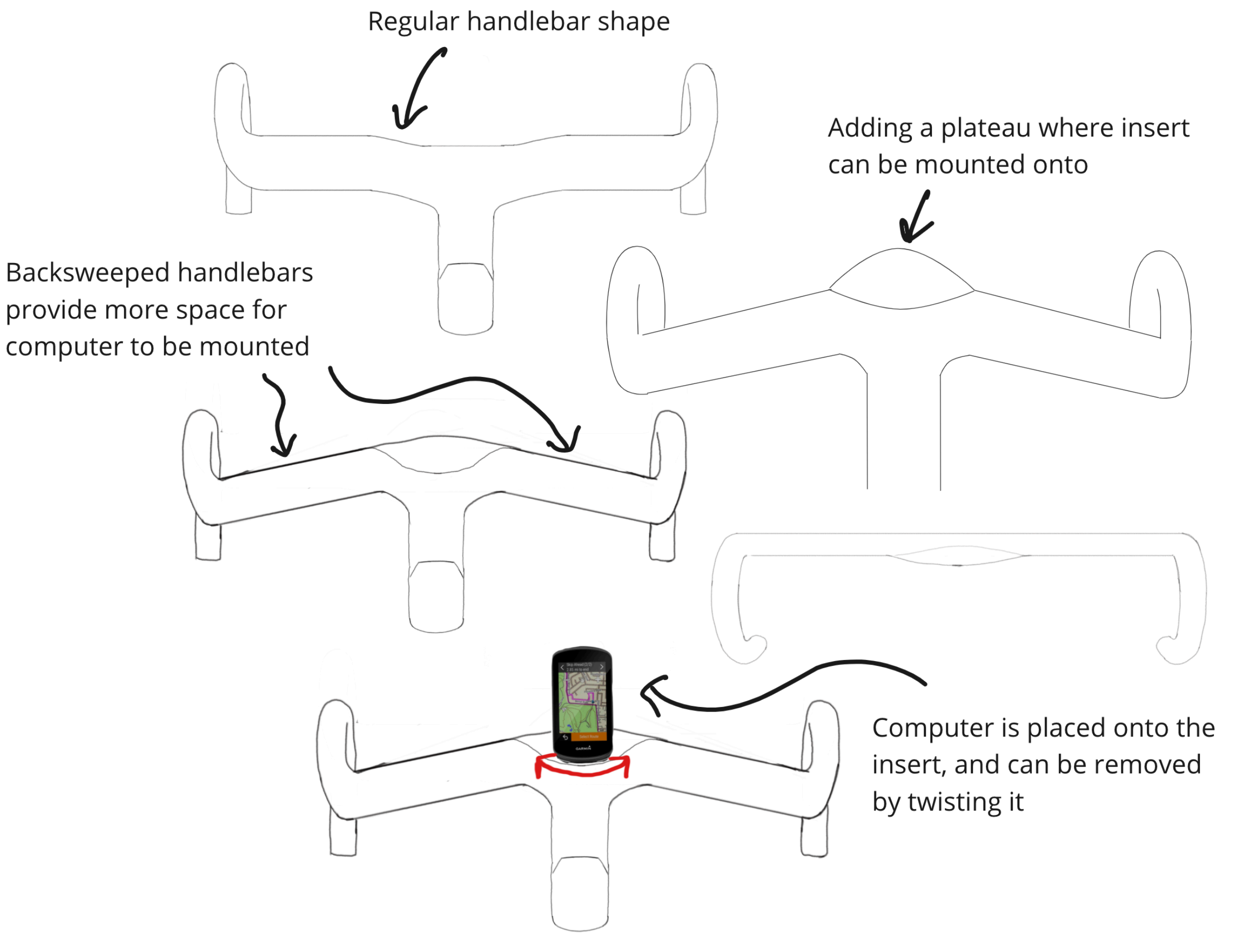


Figure 21: Sketches exploring the possibility of directly integrating the computer into the handlebars, so no separate BCM is needed.

Figure 22: Test print of integrated mount concept in handlebars

5. Concepts directions

5.1 Concept 1: One-piece Thermoplastic BCM

The first concept is a single piece thermoplastic BCM that is focussed on simplicity. This concept provides compatibility with all computer models, while still being produced of a single part. This avoids complexity in production and assembly. The BCM provides two insert mounting positions. Based on the computer model owned, the user has to fixate the insert in the corresponding position. When the user switches computer model, the insert can be adjusted to the other position when needed.

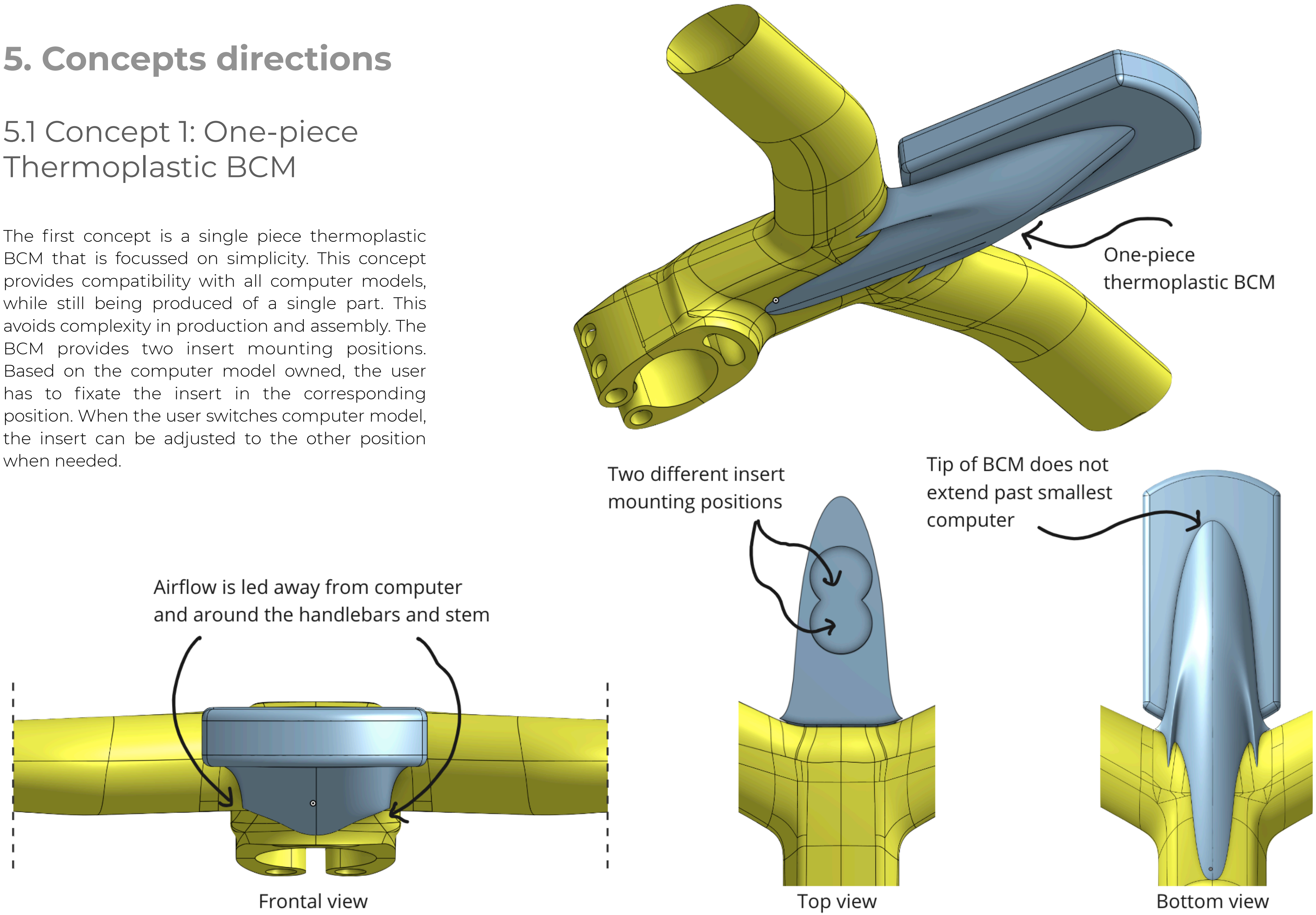
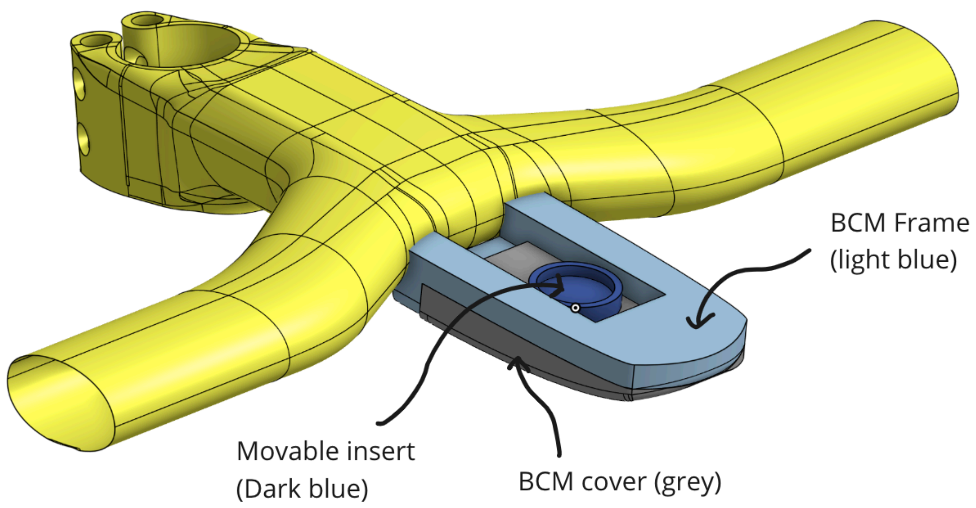


Figure 23: Concept direction 1: one-piece thermoplastic BCM

5.2 Concept 2: The Adjustable BCM

The second concept has a specific mounting point for each of the computers in scope, and is based on the ideation in 4.3. It consists of a frame, cover, and an insert that can slide within the cover. The mounting process is shown below: The frame is mounted to the handlebars, and the insert needs to be put into the position that corresponds with the computer length. The computer can then be placed onto the frame, and twisting the cover back in straight position locks the computer in place.



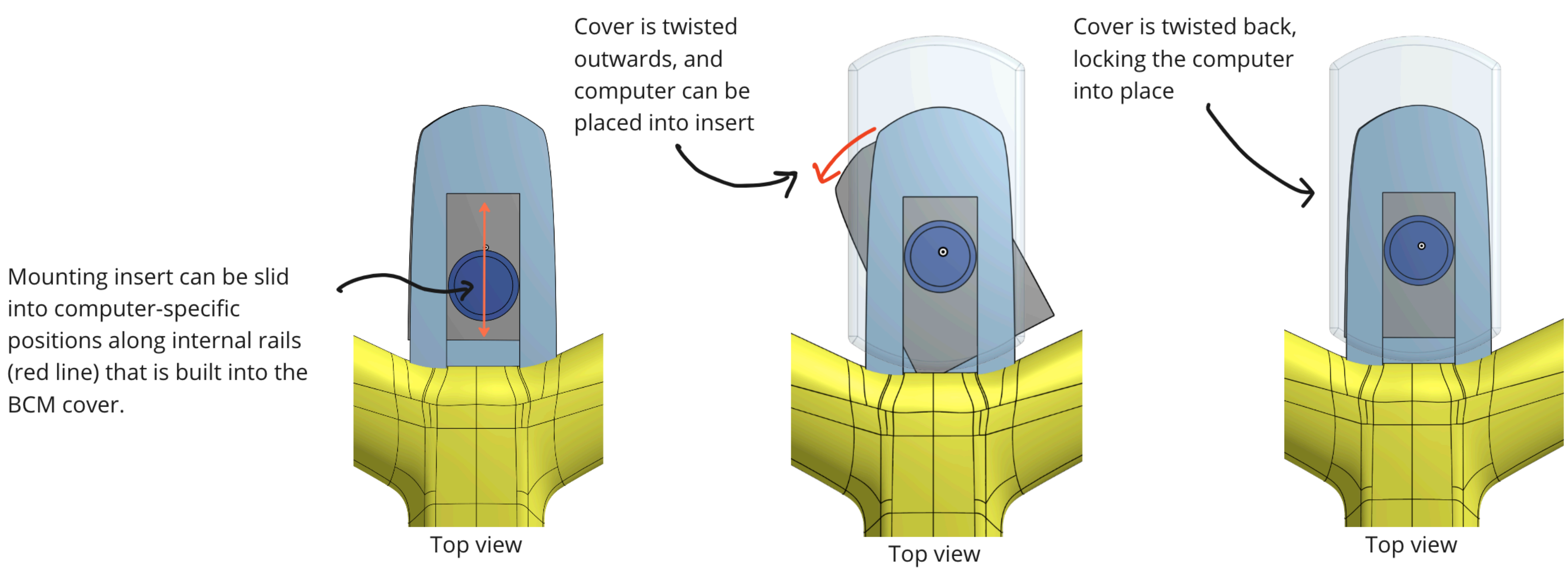
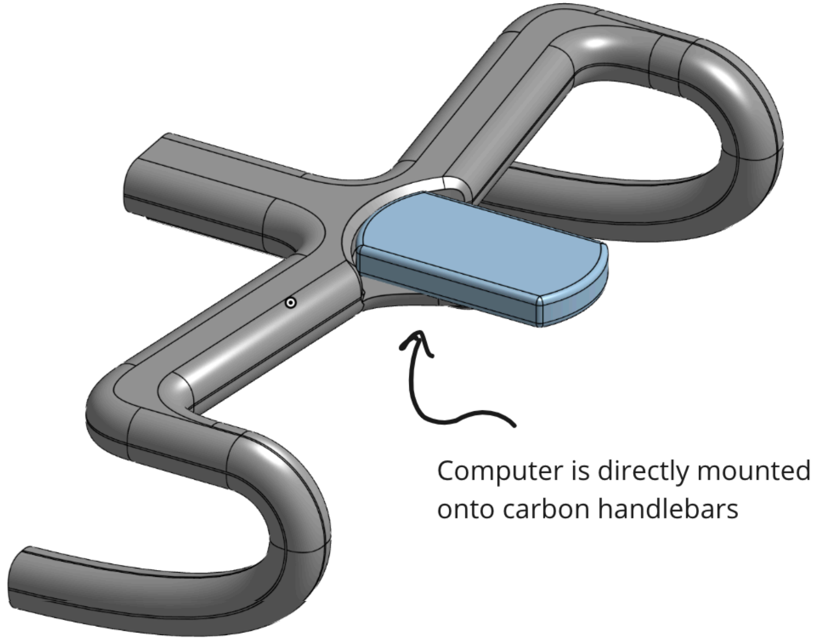
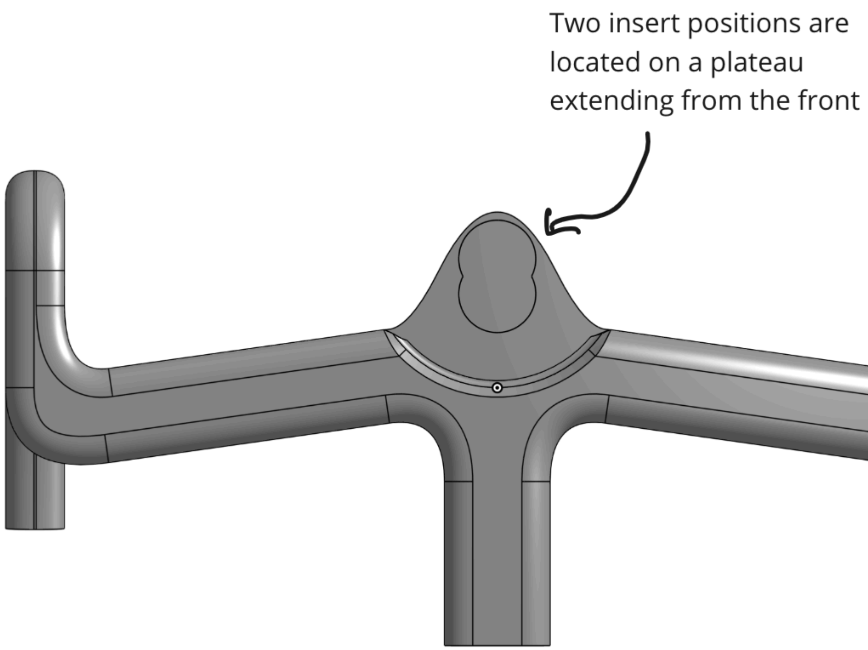


Figure 24: Concept direction 2: The adjustable BCM

5.3 Concept 3: The future handlebars

The last concept is based on the ideation in chapter 4.4. It is a futuristic concept, in which the computer is directly mounted on the handlebars, without the need of a separate BCM. A plateau is added to the front of the handlebars, providing two slots were inserts can be placed to mount the bike computer onto. This concept also leaves space under the handlebar to either add aerodynamic design features to improve the drag coefficient of the handlebars.





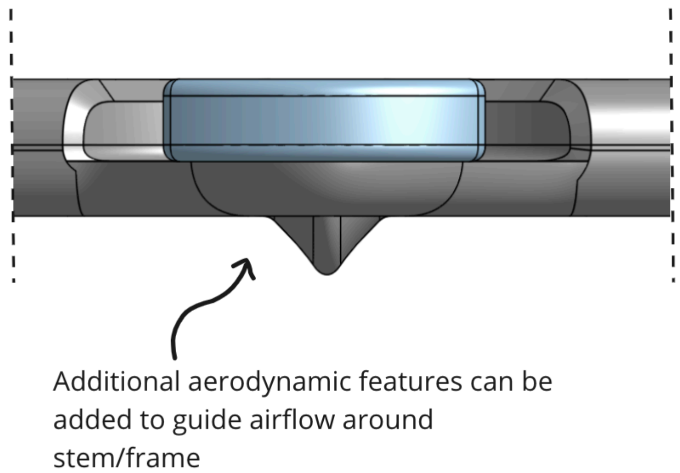


Figure 25: Concept direction 3: The future handlebars

5.4 Concept choice

To evaluate the three concepts directions the weighted objectives method from the Delft Design Guide (Van Boeijen et al., 2020) is used. From the design requirements formulated in chapter 3, four criteria are derived that are the fundamental for the project, and each received a weight based on their importance:

Aesthetics 35

The user interviews indicated that all users value the look of the BCM. The BCM should have an a 'fast' look and complement the visual appeal of the handlebars.

Cost & Price 30

The product should require minimal investment and have a retail price of under €100,-. An estimation of cost is made based on product complexity. User research also indicated that price was an important factor in the decision making process of buying a BCM, and should therefore be kept to a minimum.

Compatibility 20

The product should accommodate all computers within scope, ideally with minimal adjustments required by the user.

Feasibility 15

The product should be ready for the market as soon as possible. Therefore it should require minimal additional time investment from the client.

Conclusion

As a result of the weighted objectives method, the thermoplastic BCM concept has the highest score and will be further developed and tested on performance hereafter. This is primarily due to the relative low costs of a single injection moulded part, versus having multiple parts and integrated mechanisms in the adjustable BCM, or integrating a mounting option into the carbon handlebars. Furthermore, it offers an aesthetically pleasing look that blends well in the handlebars, whereas the adjustable BCM has a more bulky look.

		One-piece thermoplastic BCM		**Adjustable BCM**		**Future Handlebars**	
	Weight	Score	Total	Score	Total	Score	Total
Cost & Price	35	5	175	3	105	2	70
Aesthetics	30	4	120	3	90	4	120
Compatibility	20	4	80	5	100	4	80
Feasibility	15	4	60	2	30	1	15
Total	100	435		325		250	

Table 3: Weight objected method for the three concepts

6. Embodiment and detail design

This chapter focusses on the design embodiment and detailing of the chosen concept. This is done be evaluating the design using a form relationship study. The design features that result from this are then implemented in the CAD-model. This chapter also focusses on the material selection and production method. To ensure that the resulting design is strong and stiff enough, it is tested using FEA.

6.1 Form relationship study

To ensure an aesthetically pleasing BCM, a form relationship study is conducted. Since the chosen concept has a pointy and aggressive look, this study aims to change that. The goal is to have a BCM that has a similar design style to that of the computer. This helps to indicate that the BCM is intended for the bike computer, and makes sure it blends in with the overall design. For this study, a Garmin 1030 Plus is analyzed, and design features and curves are highlighted to be implemented into the design. The results can be seen in figure 26, and are implemented in the detailed CAD-model.

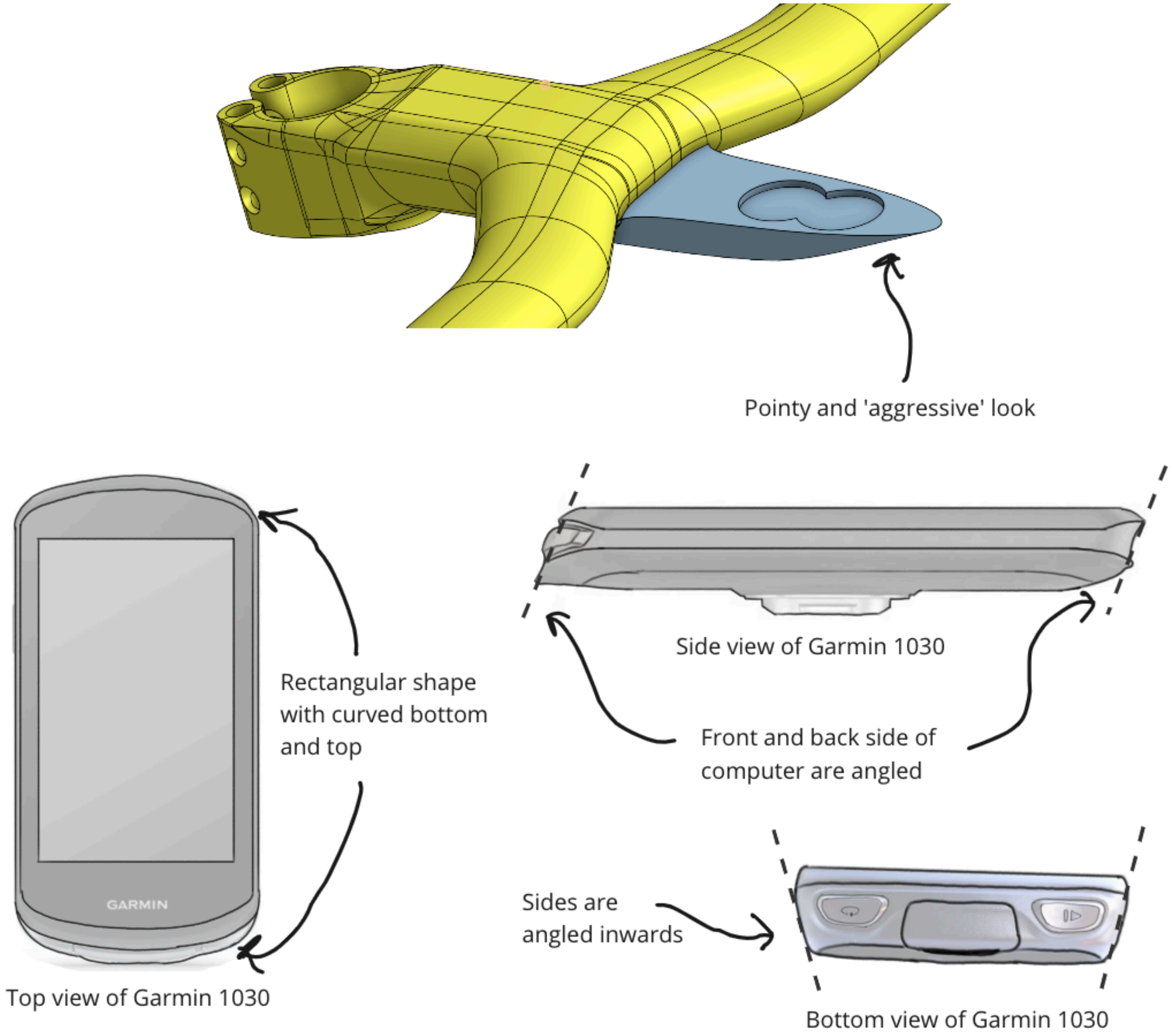


Figure 26: Form relationship study, with highlighted design features that are implemented in the CAD-model.

6.2 Design development

To transition the design concept into a 3d-model, Onshape computer-aided design (CAD) software is used. Within CAD there are 3 main types of modelling: Solid, surface and mesh. Although solid modelling is widely used, surface modelling is the next step up in complexity. Surface modelling involves defining the outer boundaries of an object using curves and surfaces as shown in figure 27, which is useful for design with complex shapes and contours. It is often used by automotive and aerospace industries for aerodynamic designs. A 30-hour course from Onshape's learning platform was followed to get acquainted with this technique. This was then applied to translate the concept into digital 3d-models, with a goal of modelling the BCM in such a way that changes can be made to the overall shapes and curvatures of the BCM, without having to remodel te entire BCM.

From here, design iterations were made and printed to test the computer compatibility and the fit on the handlebars. The results of this are shown in figure 28.

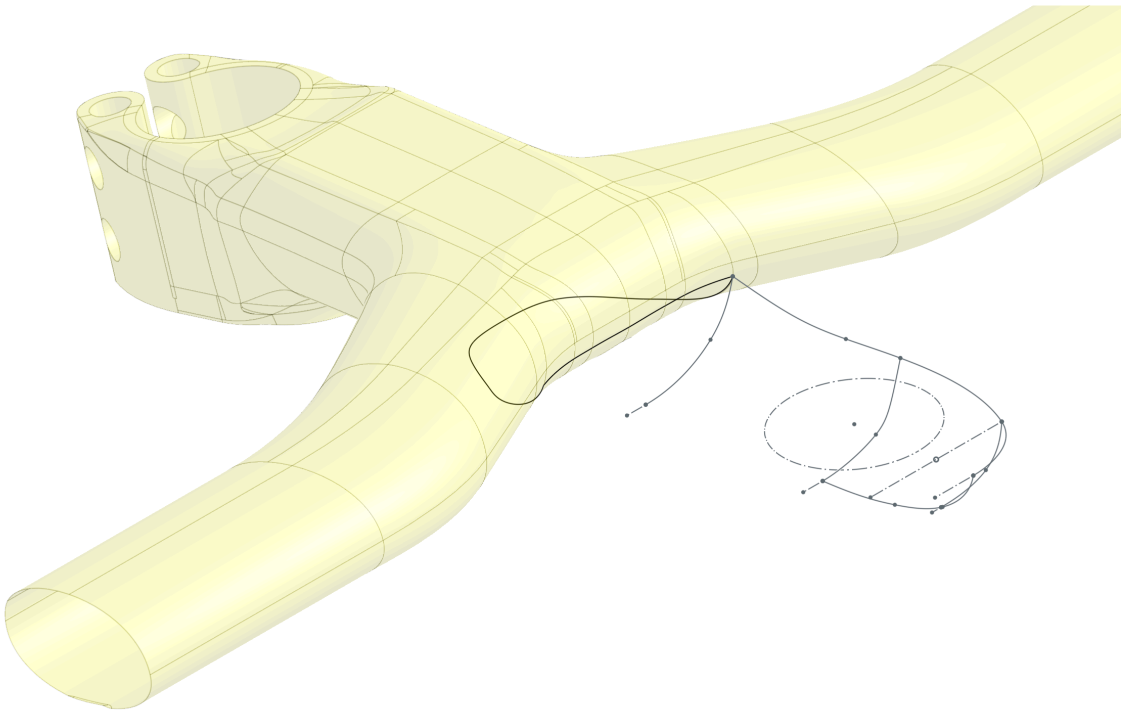


Figure 27: The shaping of curves in a 3-d space, the curves form the outer boundaries of the BCM.

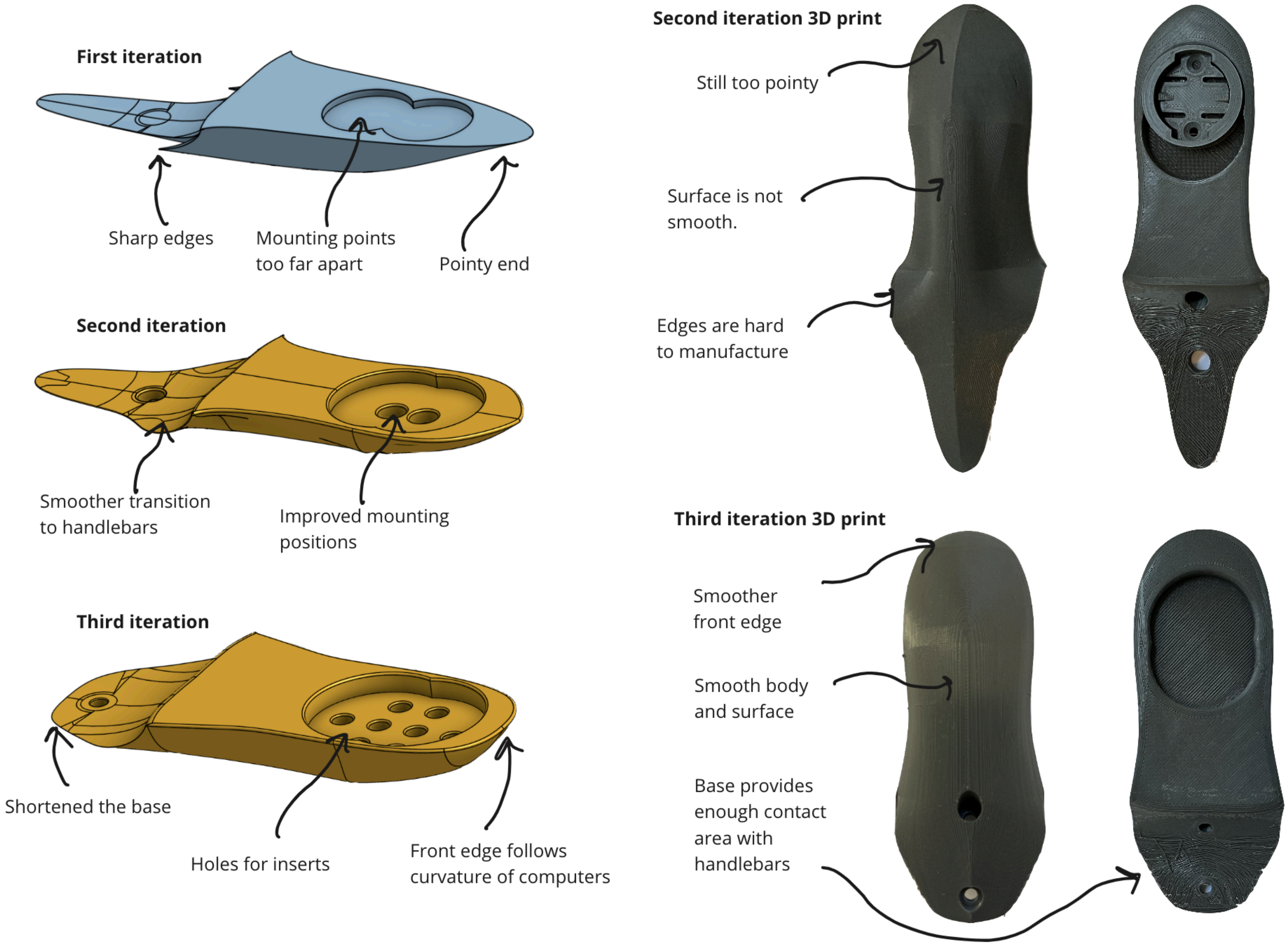


Figure 28: Design iteration made using CAD-models and physical 3D-printed prototypes.

6.3 Material and production selection

One of the main criteria for successful introduction of a new product is production costs. This chapter focusses on the material selection and production methods for thermoplastic parts by desk research and field research. A visit to a dutch company called 'WeFabricate' was done to observe the production process in person. To help select a material for the design, three important questions were formulated:

1. What are the key criteria for selecting a thermoplastic material for the BCM considering the design requirements?
2. How do different thermoplastics compare to each other in terms of mechanical properties relevant to the intended function of the BCM?
3. Can the mechanical performance and durability of the thermoplastics be tested?

Material criteria

To ensure choosing a material that aligns with the project's goals and requirements, various criteria have to be considered. Biron (2015) describes the main requirements concerning plastic solution, which are displayed in figure 29. The focus for this project lays on the requirements circled in red.

For this project the mechanical performance is relevant in order to ensure structural integrity, durability and weight reduction. Other key criteria include raw material costs, aesthetics such as colour, and production efficiency costs.

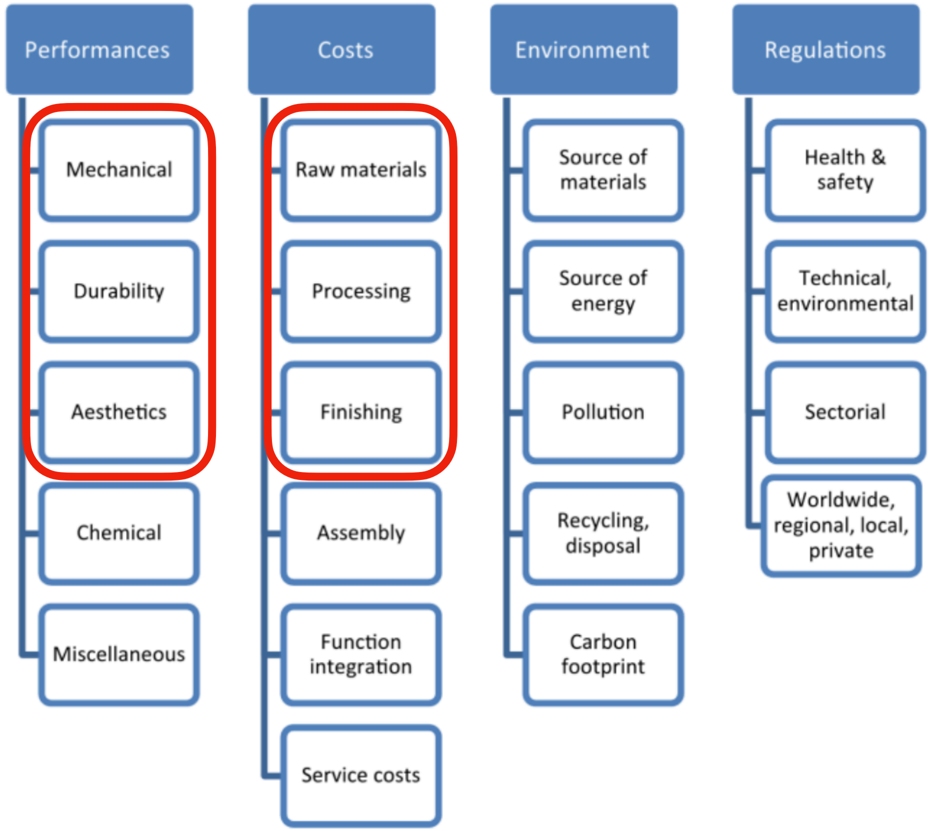


Figure 29: Main requirements concerning plastic solutions. The focus for this project is put on the requirements circled in red.

Material selection and evaluation

To make an initial selection of materials desk research is performed, and Granta EduPack level 2 is used to select materials. Granta EduPack is a material database of information about materials: their properties, their character, what they are used for, where they come from, their environmental attributes and more. Level 2 contains general material families.

In order to reach high strength-to-weight ratio and stiffness, thermoplastic materials can be reinforced with fibres. One way of doing that is adding discontinuous carbon fibres (CF) to a polymer matrix. CFRTPs are widely used in sporting goods and are gaining popularity in many industrial sectors (S. Yao et al., 2018).

To select potential materials for the BCM, criteria were set to compare them in Granta level 2. The materials were plotted on a graph with specific strength (strength-to-weight ratio) on the x-axis and Young's modulus on the y-axis. Other criteria set were: compatible with injection moulding, price (<15 kg/m3), and transparency (product should not be transparent). The graphs can be found in appendix 2. This shortlist based on Granta level 2 will be used to further investigate in level 3: Polyamide (PA, Nylon), Polypropylene (PP), Acrylonitrile Butadiene Styrene (ABS), Polyethylene (PE), Polyoxymethylene (Acetal, POM)

These materials are compared to assess which has the best material properties for the application of a BCM. The chosen material properties include impact resistance, mechanical strength, temperature sensitivity, chemical resistance, moisture absorption and ease of processing. The data is retrieved from Granta and the results are shown in table 4.

From this Nylon appears to have the best material properties. It is also widely used for injection moulding, making it suitable for complex shapes. Granta EduPack level 3 polymer was used to for further investigation on specific materials. Level 3 contains specific polymer materials with its material properties. The shortlisted materials were plotted using the same criteria in Level 2, the graph can be found in appendix 2. Adding carbon fibre to the polymer matrix results in a higher young's modulus and specific strength. This further increases with the total percentage of carbon fibre added. However, adding more fibres or longer fibres will result in poor formability. Therefore the material that has the best properties while still being able to be injection moulded, will be selected. Furthermore, it is worth noting not all CFRTP are added in Granta, and based on this research other nylons can be reinforced with CF too.

Based on this analysis with Granta, a PA composite with CF reinforcement has the best material properties for this application. Common carbon reinforced nylons include CF/PA6, CF/PA12, CF/PA46 and CF/PA66. Of these, CF/PA12 is most suitable due to its low water absorption and superior wear properties over the other CF/PA composites (Kurokawa et al., 2003). Its wear property is superior to other PA/CF composites. Furthermore, PA12/CF has the lowest water absorption among PA/CFs, and should results in the best dimensional stability in the practical use

Material	Impact resistance	Mechanical strength	Temperature stability	Chemical resistance	Moisture absorption	Ease of processing
ABS	Good	Moderate	High	Moderate	Low	Good
PP	Moderate	Limited	Moderate	Good	Low	Good
PE	Limited	Limited	Low	Good	Low	Good
POM	Moderate	Good	Moderate	Good	Low	Moderate
PA	Good	Good	Moderate	Moderate	Moderate	Good

Table 4: The five selected materials are compared to each other using different material properties.

Production visit

Based on the material research and its production compatibility, a visit to the production company WeFabricate was made. WeFabricate is a new company innovating the production industry by automation of the manufacturing flows with standardisation and optimisation in both software- and hardware level.

They have their own production machines, such as injection moulding machines, CNC-machines, and can design and produce moulds in house. Generally, tooling design is one of the most expensive and time-consuming parts of the injection moulding process. It determines the quality of the injection moulding process and the parts produced. The tooling design impacts tolerances and this in turn affects the quality control of the product. Complexity of the design puts tolerances at risk because of factors such as cooling or number of cavities in the mould. Tooling design and mould production can usually take several weeks up to several months.

WeFabricate are able to translate a design into a product within days, by having manufacturing design, production and assembly all under one roof. For thermoplastics this means they can provide the pre-processing of the designed part, tooling design, mould production and part production within a week. This highly improves cost-effectiveness. Therefore having the product produced by them is included in the recommendations.

Lastly, to attach the Garmin/Wahoo mounting adapters there need to be threads in the BCM. Ideally this is done without too much post-processing. There are several ways to achieve this without post-processing, by using separate threaded insert parts as shown in figure 31. These can be fixated in the thermoplastic part by using heat or ultrasonic to melt a border zone and place the insert. However, this requires time and effort in post-processing. A more effective way of doing this is directly moulding the inserts into the thermoplastic part, as shown in figure 31.

Figure 30: Production hall from WeFabricate (source: https://www.werkenindekempen.nl/werken-bij/wefabricate-b-v)

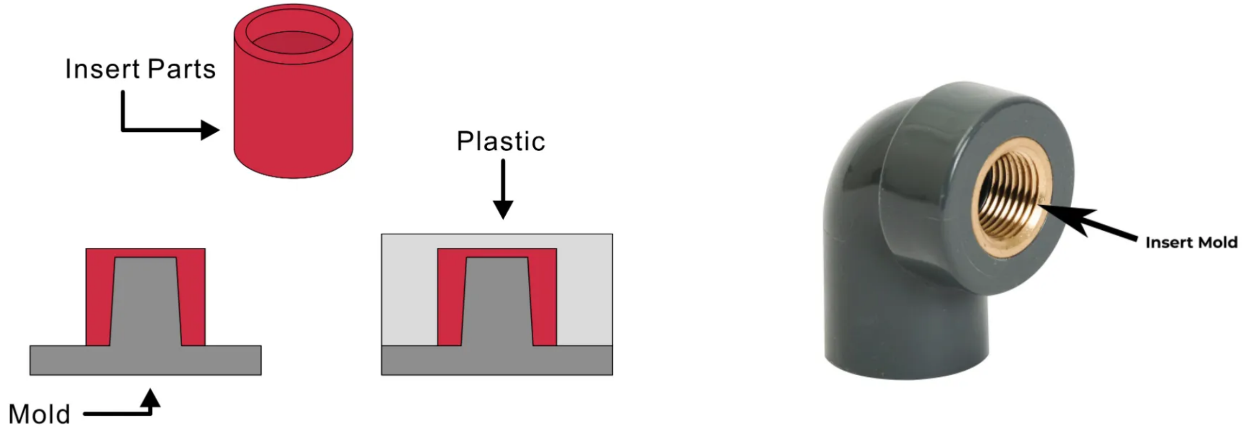


Figure 31: Inserts can be directly moulded into the plastic part by placing inserts onto pins in the mould. (Source: https://tymagnets.com/insert-molding/)

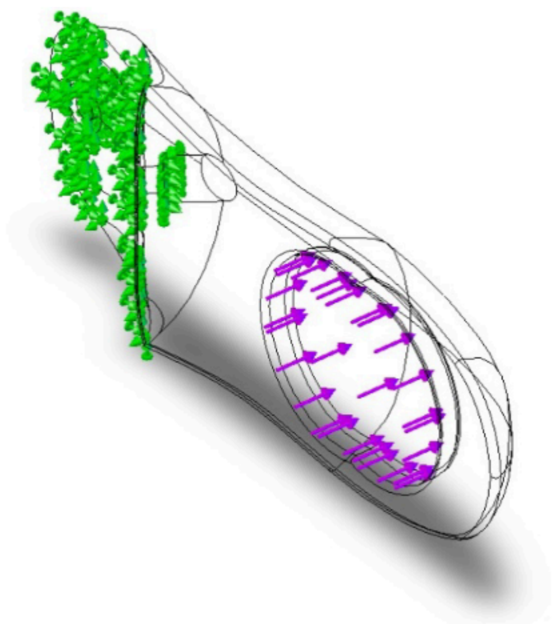
6.4 Impact analysis

Finite Element Analysis (FEA) was employed to explore structural integrity and mechanical behaviour under various loads. While high-force impacts directly on the BCM are not common in cycling, impact testing can simulate worst-case scenarios, providing insights into how well the BCM responds under extreme conditions such as falls or collisions.

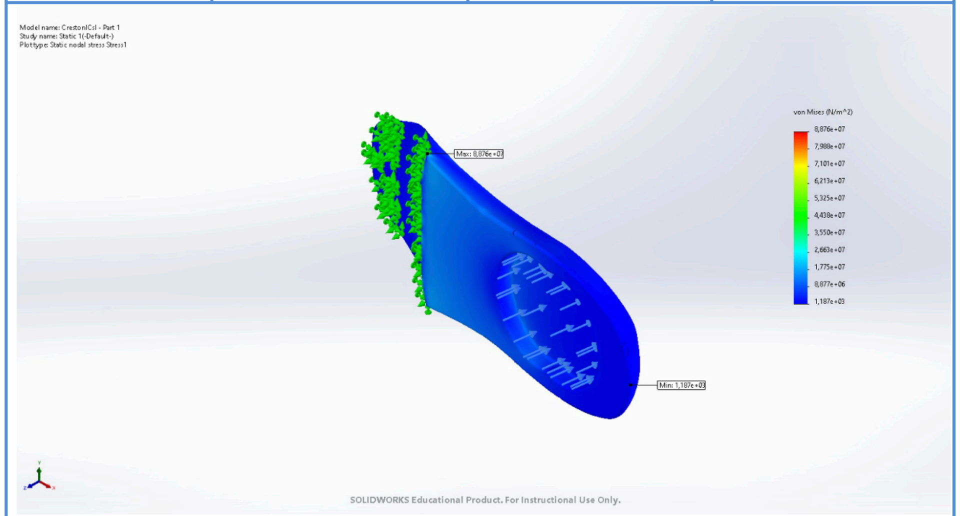
Impact simulation

To make a relevant impact simulation, several assumptions have to be made. First of all, the BCM is fixated to the handlebars by use of the two screws. Then a worst case scenario is defined. In this case a relevant worst case is the accidental dropping of a heavy object onto the BCM, for this a static force of 500N is used which impacts the mount perpendicularly.

The results are shown in figure 32 and indicate that the maximum stress under this load stay below the yield strength of CF/PA12. Therefore there is no concern about the structural integrity and the BCM can easily withstand the forces that are encountered during everyday use.



Name	Type	Min	Max
Stress1	VON: von Mises Stress	1,187e+03N/m^2 Node: 22218	8,876e+07N/m^2 Node: 67

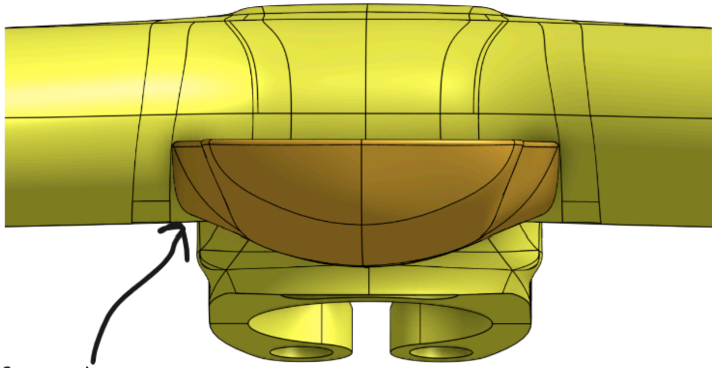


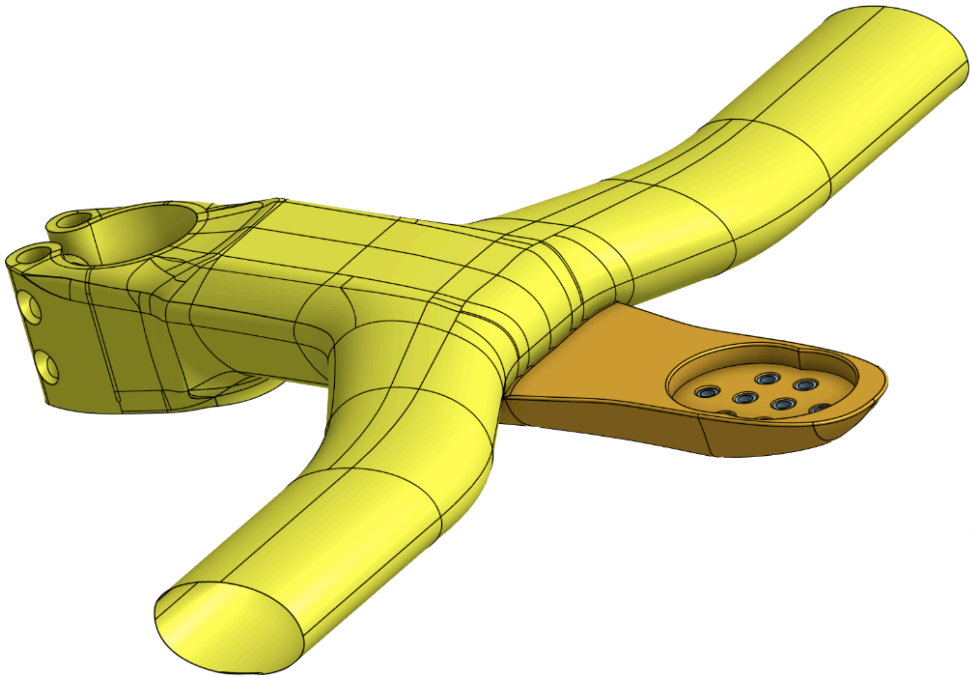
CrestonICsl - Part 1-Static 1-Stress-Stress1

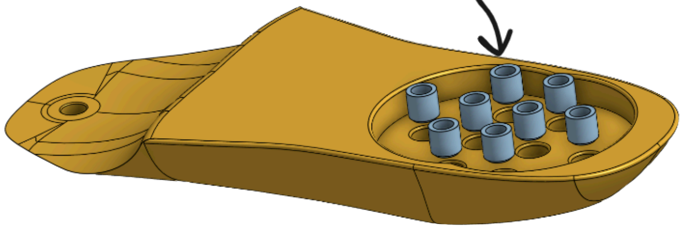
Figure 32: The fixations (green) and loads (purple) set for the FEA test (top), and the results of the stress test (bottom).

7. Final Design

The final design is shown here with its key features.







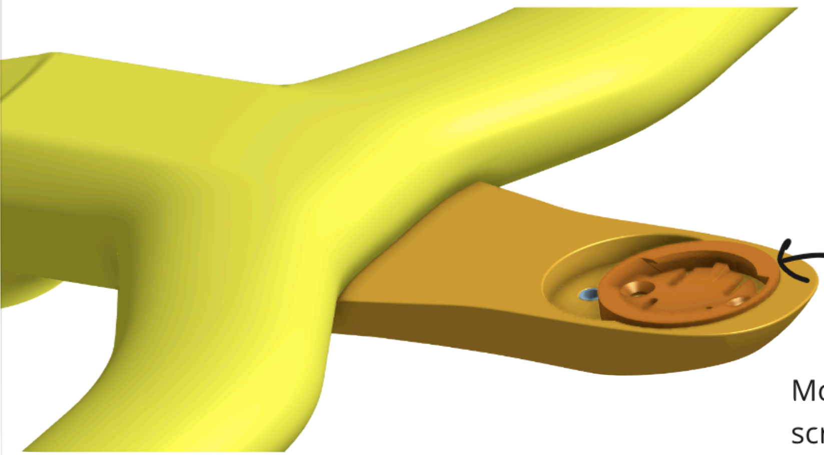


Figure 33: The final design.

8. Design validation

The final design and development results in the phase of design validation. In this chapter, the design concept undergoes testing and evaluation to ensure it meets the expectations set during the define phase. This is done with performance testing on vibrations and aerodynamics using CFD.

8.1 Vibration testing

Cycling exposes equipment to various stresses, including vibrations. This section evaluates the BCM's resilience through vibration testing. Understanding how the mount absorbs shocks and dampens vibrations is crucial for ensuring its durability and stability during real-world cycling scenarios. Cyclists often encounter various surfaces and terrains, leading to different vibration profiles. Vibrations from the BCM can be transmitted to the bike computer, impacting the cyclist's ability to read data accurately. The natural frequency directly addresses how well the BCM adapts to and dissipates these vibrations.

Unlike impact testing, which simulates sudden forces, vibrations during cycling are continuous. Over time, vibrations at or near the natural frequency can induce resonance, potentially leading to material fatigue. By identifying and optimising the natural frequency, the BCM can be designed to operate away from resonance conditions, mitigating the risk of material fatigue.

Natural frequency

The eigenfrequency, or natural frequency, of an object is determined by its physical characteristics and material properties. The eigenfrequency is the frequency at which a system oscillates when disturbed from its natural (equilibrium) position. The material of a product can significantly affect its eigenfrequency due to factors such as density, elasticity, and stiffness. The shape and geometry of a product also play a role in determining its natural frequency. The distribution of mass and stiffness throughout the object can influence how it responds to vibrations.

Definition of worst case range

To initiate the vibration testing process, an analysis of Power Spectral Density (PSD) data provided by the client was conducted. The goal was to identify a worst-case frequency range that the BCM should avoid. Based on the data provided by the client, shown in figure 34, it was determined that the critical frequency range falls between 10 Hz and 40Hz. This range corresponds to the typical vibrational frequencies experienced during cycling, making it imperative for the mount's natural frequency to be outside this spectrum so it will not resonate during riding.

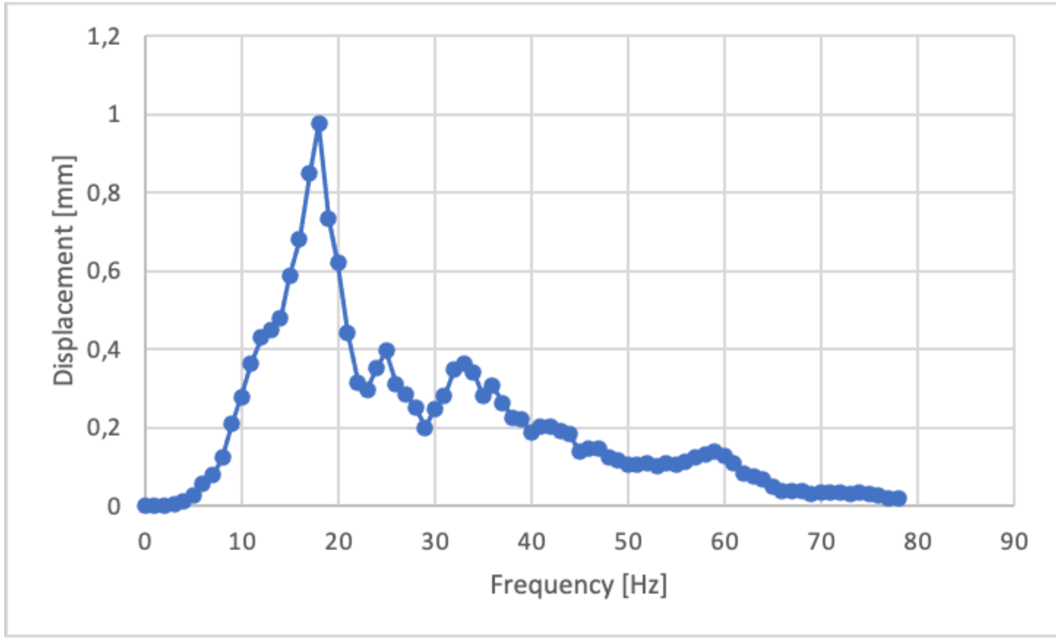


Figure 34: The displacement caused by vibration at different frequencies.

Theoretical calculation of natural frequency

The natural frequency of the bike computer is a key parameter influencing its response to external vibrations. To ensure stability and avoid resonance within the defined frequency range, the natural frequency (fn) is calculated to test if it is outside the 10 Hz to 40 Hz range. Ideally it has a natural frequency that is much higher (>80 Hz). This calculation is done by simplifying the system of the BCM and the computer. The BCM is considered as a cantilever beam with length L fixated to the handlebars, and with the computer as a separate mass located at the end of the BCM, as illustrated in figure 35.

We then use the basic formulas shown in figure 36 to determine the natural frequency of the system. The geometric values taken for the calculations are derived from the final design, and the for the concentrated mass the weight of a Garmin 1030 Plus is considered.

The calculated natural frequency of the system is between 95-130 Hz, depending on the how many fibres are in the CF/PA12. However, for the test a PLA prototype is used. The expected natural frequency for this is 80 Hz.

When the computer is not mounted, and there is no concentrated mass at the end of the BCM, the system will have a much higher natural frequency, and will therefore not resonate in riding conditions.

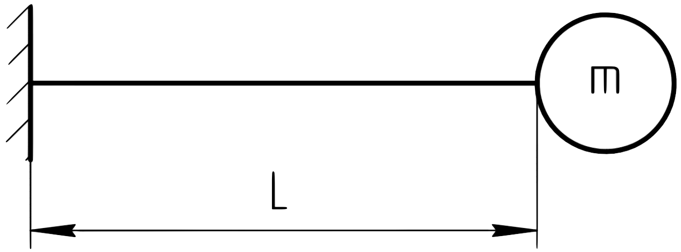


Figure 35: The simplified system of the BCM and computer. (Source: https://calcdevice.com/vibration-frequency-of-cantilever-beam-id191.html)

Natural frequency of mass M, acting alone:

$$f_M = (1 / 2\pi)*(48EI_x / M)^{0.5};$$

Natural frequency of the unloaded beam, acting alone:

$$f_{beam} = (0.56 / L^2)*(EI_xL / m)^{0.5};$$

Total natural frequency of beam of the first mode:

$$1 / f^2 = (1 / f_{beam}^2) + (1 / f_M^2)$$

Figure 36: Basic formulas for calculating the natural frequency of the system. (Source: https://calcdevice.com/vibration-frequency-of-cantilever-beam-id191.html)

Schematic visualisation of test setup

To validate whether the natural frequency of the BCM is indeed outside of this range, a test set-up is prepared. A schematic overview of the test set-up is displayed below in figure 37. The goal of the test was to find the natural frequency of the designed BCM.

The setup was made by using a 12V electromagnet motor linked to an Arduino board, that was controlled by the code that is in appendix 3. A small magnet was glued into the mount, positioned right below the centre of the mounting position of the computer. The physical test setup can be seen on the next page in figure 38, 39, and 40.

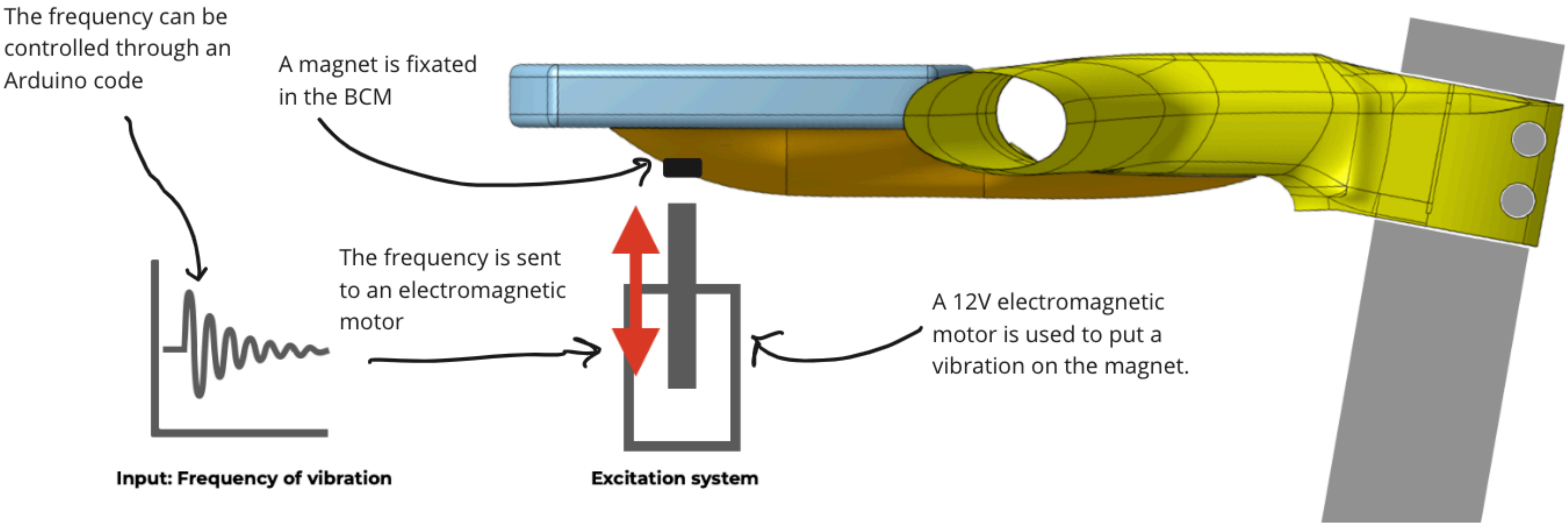


Figure 37: Schematic overview of the test setup that will be used for vibration testing.

Testing approach

To find the natural frequency of the designed mount, the output frequency was applied with intermediate steps of 10 Hz. When an increase in vibration was visually and tangibly noticeable, this was an indication for getting closer to the natural frequency of the BCM. If this was the case, the output frequency was narrowed down to a 5 Hz range to get a more accurate natural frequency range.

Results and discussion

The results indicate that the natural frequency of the BCM is in the 60-65 Hz range. Although this is lower than the calculated natural frequency of 80 Hz, it is higher than the worst-case range. This can be due to the fact that the mount uses an infill pattern inside the prototype rather than being solid.

Since the test indicate that the natural frequency is above the defined worst-case, there is no reason to change the design. It is expected that the final product has a higher natural frequency than tested, as the Young's modulus of CF/PA12 is higher than that of PLA, and the final product will be solid instead of hollow.

Figure 38: The magnet embedded in the BCM.

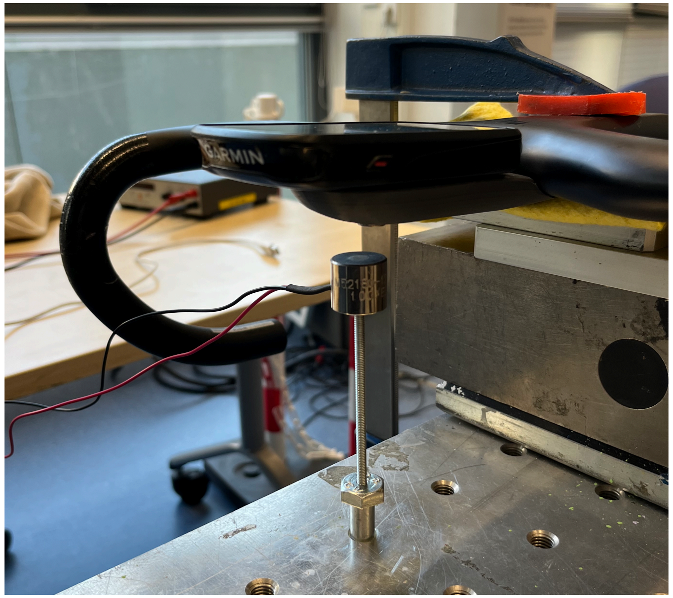


Figure 39: The electromagnetic motor is directly placed under the magnet.

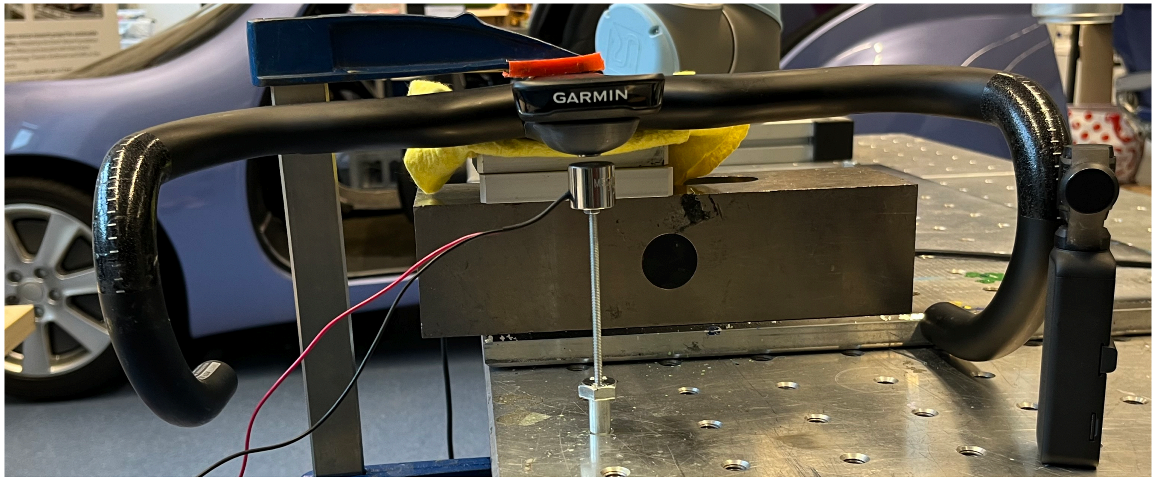


Figure 40: The handlebar is held in place by a clamp, and is ensured it can not resonate by itself.

8.2 Aerodynamic performance using CFD

Lastly the design is tested on aerodynamic performances. Here it is tested if the BCM impacts the drag coefficient.

Since there is nog model available of the entire system of a cyclist plus a bike, the test will be done using just the handlebars, BCM and computer models. Three test have been performed to make a comparison between them. All tests are performed with a wind speed of 30 km/h. The test environment is shown in figure 41.

The first CFD analysis is done with the handlebars, without any BCM or computer attached. Secondly, an analysis is done with the mount attached, and lastly one is performed with both the computer and mount attached. The full results of the 3 CFD test can be found in appendix 6. The drag coefficient for the three tests are:

No BCM, no computer: 0.618404

With BCM, no computer: 0.637387

With BCM, with computer: 0.713581

A lower drag coefficient number indicates better aerodynamic performance. The difference between having no BCM and the designed BCM attached is very minimal. This indicates that the airflow around the BCM itself does not hinder the overall aerodynamic performance much. When a computer is added, the drag coefficient increases. Since the computer is a boundary condition, this can not be changed.

However, the results of this analysis only offer information about localised aerodynamic effects, and not of the entire system. Based on the frontal area it is expected that the drag coefficient of the BCM alone does only present ±1% of the system's total aerodynamic efficiency. It is advised to run the simulations again with the entire system, while only changing the BCM and computer placement between simulations to get a better representation of the impact.

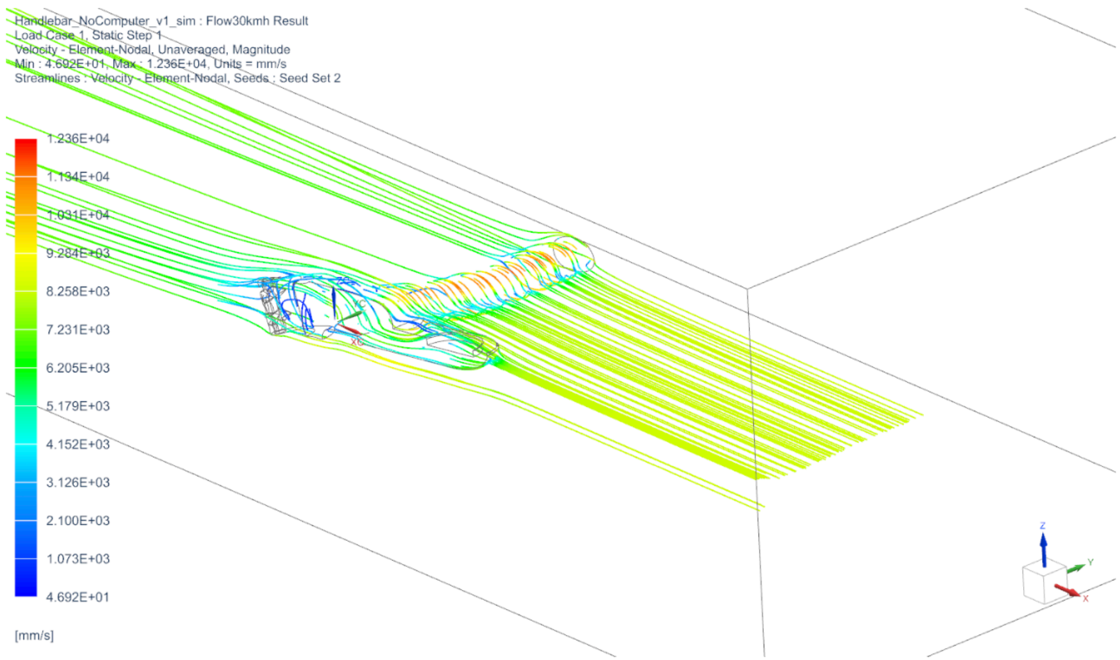


Figure 41: Test environment of the CFD analysis.

9. Conclusions and recommendations

Conclusion

The objective of this project was to design a product to mount cycling computers on an integrated road cycling handlebar while keeping its weight to a minimum, and improving its aerodynamic performance. It should also fit the aesthetic of a high performance aerodynamic bicycle, and mainly the aerodynamic handlebars. The outcome is product made of carbon reinforced PA12 with a total weight of 38 grams including hardware.

During the project it was discovered that the influence of the BCM on the aerodynamic performance of the entire bike-cyclist system was of very minimal impact. However, an unexpected discovery was that the users were more interested in the 'fast' look of the mount than the actual performance, as this was deemed marginal.

The ideation phase made clear that the BCM does not need an overly fancy solution, and should not be over-engineered. Therefore the concept needed to be simple and elegant. This and the ability of a clean look with the variation in computer dimensions needed to be combined in the BCM.

Finally, a prototype was 3d-printed to showcase the BCM mounted onto the handlebars. This was also used to validate the compatibility, aesthetics and performance.

Aesthetics

The final design blends the bike computer brands and models from the scope into the handlebars in a visually appealing way. This was achieved by and avoiding sharp edges and using design features from the computer and handlebars, which resulted in a smooth surface transition between the BCM and the computer.

Aerodynamic performance

Although the BCM contributes to the overall aerodynamic drag experienced by the cyclist-bike system, he analysis indicated that the BCM has a very minimal impact on the overall aerodynamic performance. However, to try and marginally improve the performance, the final BCM design does not add any frontal area to the system and tried direct the airflow around the handlebars, which is not seen in most competitor BCMs.

Vibration testing

A worst-case scenario range of natural frequencies of 10-40 Hz was established that the BCM should avoid, as this could cause product failure. The design was theoretically calculated to have a natural frequency far above that, and testing confirmed this.

Material

The testing proved that thermoplastic materials, specifically those reinforced with carbon fibres, can be used for products that require a certain degree of structural strength. Using injection moulding with these materials leads to amore efficient production process.

Recommendations

The following recommendations are made to the client to turn the development of this project into a success, or use the results of this project for other ends.

Aerodynamic performance

Due to a lack of access to 3d-models of a bicycle and cyclist, CFD was only performed on the part of the handlebars where the BCM is mounted. Although it is expected the influence of the BCM on the overall aerodynamic performance of the system is expected to be minimal, it is advised to run a CFD study on the full system. This analysis can run a study with the designed BCM, and a study without a BCM or another model of BCM to find out the impact of the BCM on the entire system.

Vibration testing

The vibration testing in this project served as a confirmation for the durability of the BCM. This method of testing thermoplastic parts, and perhaps sports-performance parts of other materials, is interesting to explore further for products that endure any tip of vibrations or impacts (e.g. mountain biking products). Also, multiple materials can be compared to each other using this method.

Future development

The shifting of cycling becoming a more data-driven sports can cause the way computers are designed and used to shift in the upcoming years. It is recommend to keep an eye on the innovation in this field, and explore opportunities of integrating the computer entirely into the handlebars such as in concept direction 3.

Final remarks

It is recommend that for this product the client moves away from CNC-machining alloy to thermoplastic, as they have proven to be strong and light enough. It can be explored if other products that are currently made from CNC-machined aluminium can also be made from thermoplastics. The client can decide to send the finished BCM design to a manufacturer, such as WeFabricate, to set up production. If desired, the client can make modifications to the design before doing so.

Reflection

I started this project with excitement to step foot into the world of cycling products. I am glad that I got to know the client and that they allowed me to take on this project. My own passion for cycling in combination with interviewing passionate cyclists has kept me enthusiastic for this business.

During the design project I found out that the project was quite straight-forward and there was a danger of over engineering the product. This was something I struggled with since it is different from a typical IPD (graduation) project. Therefore the project shifted towards validation of a relative simple design of the BCM for performance. Therefore I had to abandon my initial planning and adjust the goals of the project.

I have also reached a goal that I set before the project started: learning new skills such as surface modelling and Computational Fluid Dynamics. Both these took a heavy time investment, and I am particularly proud of how I build my confidence with surface modelling.

I'd like to thank the client for the feedback during the project as well as the assistance with parts and prototypes. Thank you to Arjen Jansen and Erik Tempelman for guiding me through the design process and to help me find a way to finalise the project, as well as life lessons along the way.

10. References

Biron, M. (2015). Material selection for thermoplastic parts: Practical and Advanced Information. William Andrew.

Haake, S. (2009). The impact of technology on sporting performance in Olympic sports. Journal of Sports Sciences, 27(13), 1421–1431. https://doi.org/10.1080/02640410903062019

Helou, N. E., Berthelot, G., Thibault, V., Tafflet, M., Nassif, H., Campion, F., Hermine, O., & Toussaint, J. (2010). Tour de France, Giro, Vuelta, and classic European races show a unique progression of road cycling speed in the last 20 years. Journal of Sports Sciences, 28(7), 789–796. https://doi.org/10.1080/02640411003739654

Norman, P. (2023). 2023 men's WorldTour team bikes and equipment | Who's riding what? BikeRadar. https://www.bikeradar.com/features/pro-bike/worldtour-bikes/

Mignot, J.-F. (2015). The history of Professional Road Cycling. The Economics of Professional Road Cycling, 7–31. https://doi.org/10.1007/978-3-319-22312-4_2

3D printing of plastic and titanium parts for racing bicycles. (2013). Metal Powder Report, 68(5), 30–32. https://doi.org/10.1016/s0026-0657(13)70172-3

UCI (2023). Clarification Guide of the UCI Technical Regulation. https://assets.ctfassets.net/761l7gh5x5an/6cmP3f8KY4mTfI6hAYCduP/bc302478704fbb84db10f47571a8a45c/Clarification_Guide_of_the_UCI_Technical_Regulation_-_20230126_-_ENG.pdf

Frames and Materials | Exploratorium. (2023, March 7). Exploratorium. https://www.exploratorium.edu/explore/cycling/frames#:~:text=Swiftwalkers,hit%20the%20road%20in%201817

Bicycle Market Size, Share & Trends Analysis Report By Product (Mountain, Hybrid, Road, Cargo), By Technology (Electric, Conventional), By End-user, By Distribution Channel, By Region, And Segment Forecasts, 2023 - 2030. (2020). https://www.grandviewresearch.com/industry-analysis/bicycle-market

Slane, J., Timmerman, M., Ploeg, H., & Thelen, D. G. (2011). The influence of glove and hand position on pressure over the ulnar nerve during cycling. Clinical Biomechanics, 26(6), 642–648. https://doi.org/10.1016/j.clinbiomech.2011.03.003

Elmansy, R. (2021). The Double Diamond Design Thinking Process and How to Use it. Designorate - Design Thinking, Innovation, User Experience and Healthcare Design. https://www.designorate.com/the-double-diamond-design-thinking-process-and-how-to-use-it/

Mignot, J. (2015). The history of professional road cycling. In Sports economics, management and policy (pp. 7–31). https://doi.org/10.1007/978-3-319-22312-4_2

Chan, D. S. a. K. (2020, June 14). Pandemic leads to a bicycle boom, and shortage, around world. CP24. https://www.cp24.com/news/pandemic-leads-to-a-bicycle-boom-and-shortage-around-world-1.4983751

Falcous, M. (2017). Why we ride: road cyclists, meaning, and lifestyles. Journal of Sport & Social Issues, 41(3), 239–255. https://doi.org/10.1177/0193723517696968

Blocken, B. B., Van Druenen, T., Toparlar, Y., & Andrianne, T. (2019). CFD analysis of an exceptional cyclist sprint position. *Sports Engineering*, *22*(1). https://doi.org/10.1007/s12283-019-0304-7

Van Boeijen, A., Daalhuizen, J., & Zijlstra, J. (2020). *Delft Design Guide : Perspectives - Models - Approaches - Methods*. https://research.tudelft.nl/en/publications/delft-design-guide-perspectives-models-approaches-methods

Malizia, F., & Blocken, B. B. (2021). Cyclist aerodynamics through time: Better, faster, stronger. *Journal of Wind Engineering and Industrial Aerodynamics*, *214*, 104673. https://doi.org/10.1016/j.jweia.2021.104673

Yao, S., Jin, F., Rhee, K. Y., Hui, D., & Park, S. (2018). Recent advances in carbon-fiber-reinforced thermoplastic composites: A review. *Composites Part B: Engineering*, *142*, 241–250. https://doi.org/10.1016/j.compositesb.2017.12.007

Kurokawa, M., Uchiyama, Y., Iwai, T., & Nagai, S. (2003). Performance of plastic gear made of carbon fiber reinforced polyamide 12. *Wear*, *254*(5–6), 468–473. https://doi.org/10.1016/s0043-1648(03)00020-6

11. Appendices

Appendix 1: User questionnaire responses

These include al questions and corresponding answers from respondents.

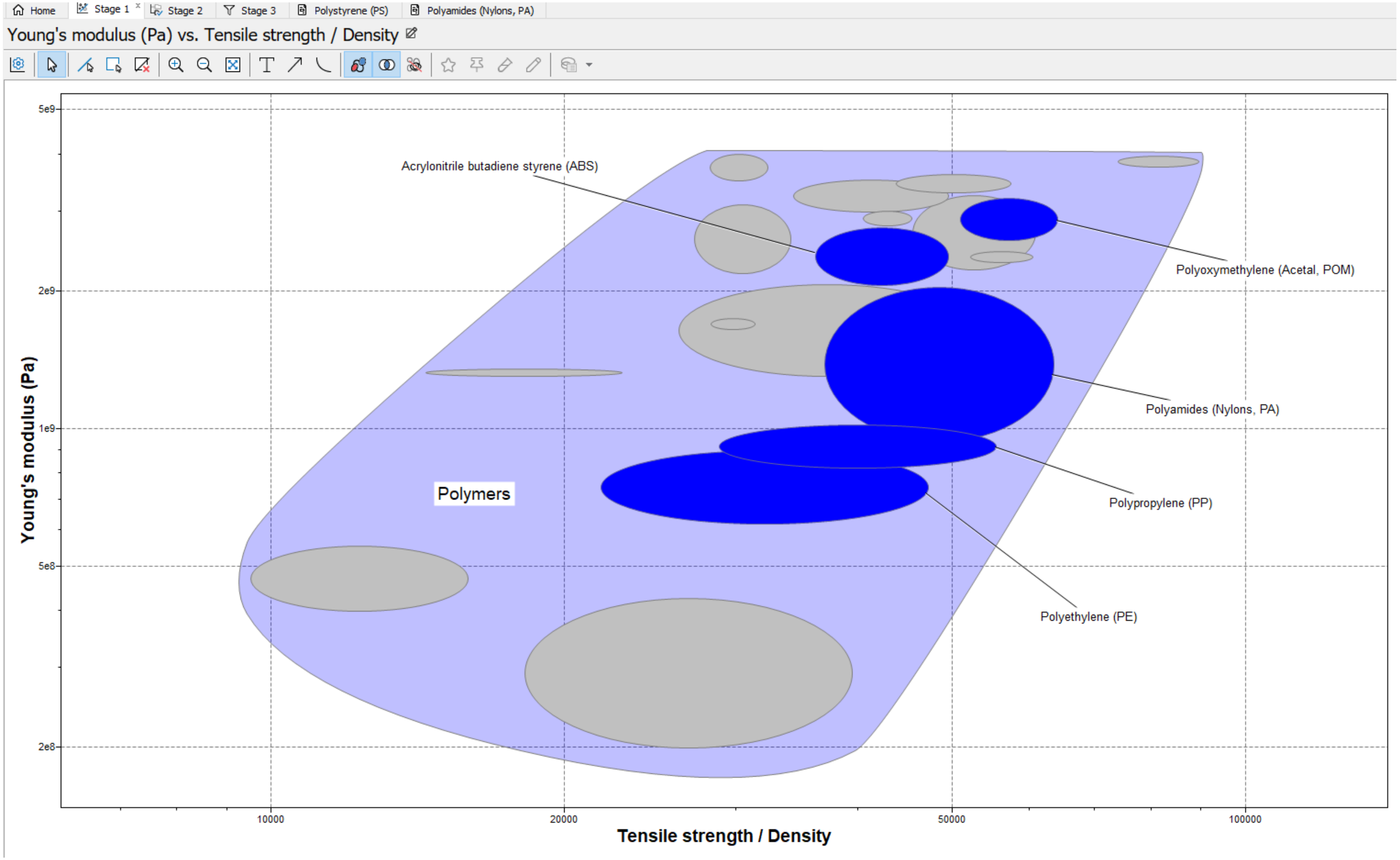
What type of cyclist do you describe yourself as?	What bike do you own? Brand, model, year	How much did you spend on gear in total? This includes your bikes, clothes and accessories.
Intermediate rider	Cannondale, Caad13, 2020	€ 1000 - 3000
Amateur	Canyon endurace	€ 1000 - 3000
Amateur	Bianchi, no idea, 2015	€ 0-1000
Intermediate rider	Ridley Noah SL	€ 5000 - 10000
Frequent/Experienced rider	Trek Madone	€ 5000 - 10000
Intermediate rider	S-Works Venge (year I don’t know, 2nd hand)	€ 1000 - 3000
Amateur	Sensa, Romagna, 2015	€ 0-1000
Intermediate rider	Trek madone 2023	€ 5000 - 10000
Amateur	Koga Roadracer	Got bike 2nd hand from family
Intermediate rider	Canyon Aeroad 2023	€ 5000 - 10000
Amateur	Specialized Allez	€ 1000 - 3000
Intermediate rider	Sensa	€ 3000 - 5000
Intermediate rider	Cervel S5 2023	€ 5000 - 10000
Amateur	specialised	€ 1000 - 3000
Beginner	cinelli	€ 0-1000
Frequent/Experienced rider	Cannondale SuperSix Evo	€ 5000 - 10000
Beginner	not sure	€ 0-1000

How often do you go cycling?	Do you own a cycling computer?	If so, which brand and model?	How often do you take your cycling computer when you go for a ride?
Every week	Yes	Wahoo Elemnt Bolt V2	Always
Few times a year	No		Sometimes
Few times a year	No		
Many times in spring/summer, almost never when raining	Yes	Wahoo Element Roam	Always
Every week	Yes	Wahoo ELEMNT Roam	Always
Few times a month	Yes	Wahoo ELEMNT bolt	Always
Few times a month	No	n.a.	n.a.
Every week	Yes	Garmin edge 1030 plus	Always
Few times a year	Take my phone		
Few times a year	Yes	Garmin Edge 1030 Plus	Always
Few times a month	Yes	Garmin Edge 530	Always
Multiple times a week	Yes	Garmin edge 540 Solar	Always
Multiple times a week	Yes	Garmin Edge 840	Always
Few times a month	Yes	Garmin edge 530	Always
Few times a year	No		
Multiple times a week	Yes	Garmin edge 1040 solar	Always
Few times a year	No		

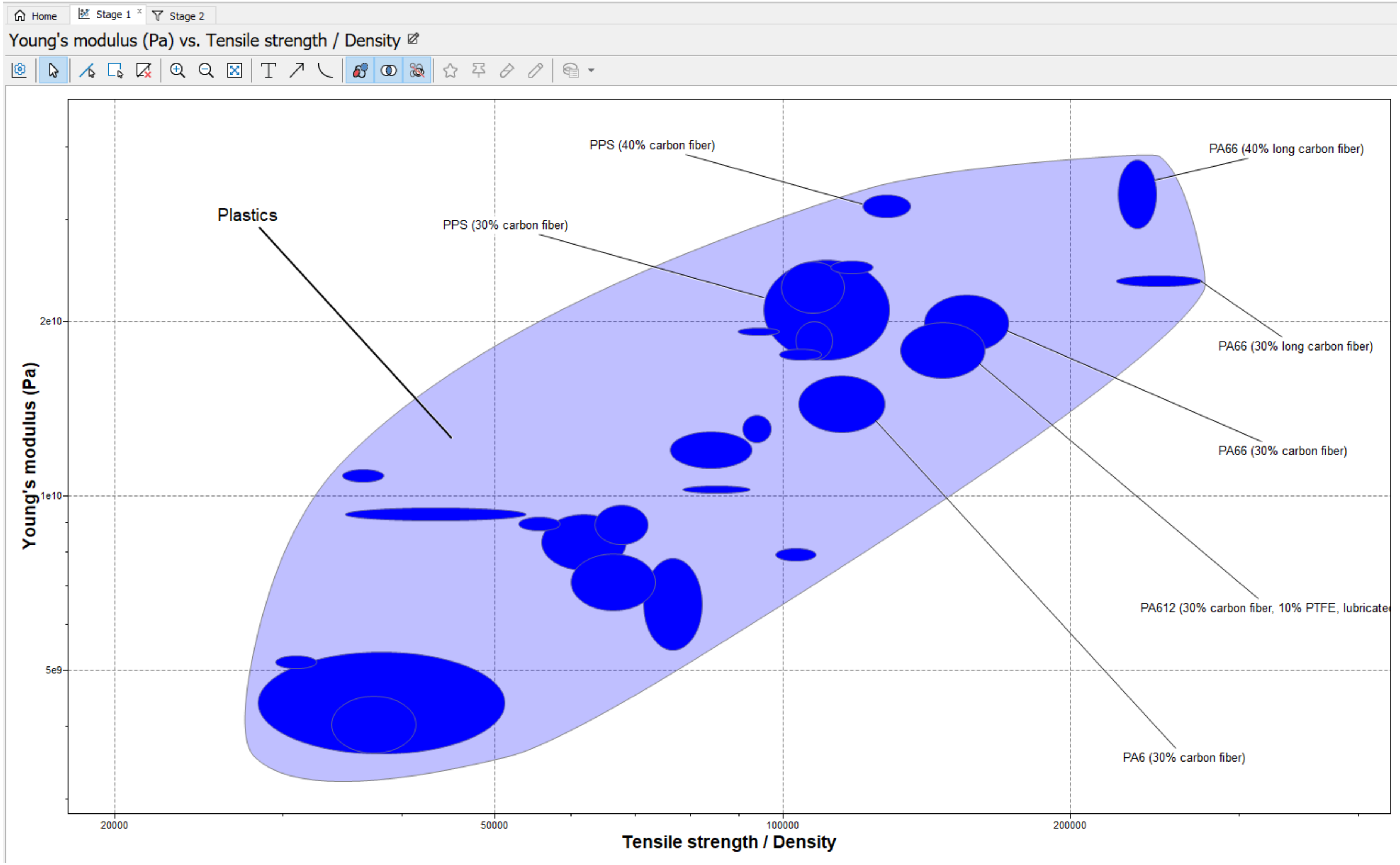
What type of handlebars do you use?	How often do you take off your computer mount of the handlebars?	Why or when do you take it off?
Classic (round shape)	Never	
Classic (round shape)	Never	Only when it needs replacing for some reason
Classic (round shape)		
Flat top (aero shape)	Rarely	When switching bikes
Flat top (aero shape)	Maybe did it once	To put on another model of mount
Classic (round shape)	Never	I don’t
Classic (round shape)	n.a.	n.a.
Flat top (aero shape)	Almost never	Transportation
Classic (round shape)		
Flat top (aero shape)	Never	N/A
Classic (round shape)	Never	N/A
Flat top (aero shape)	Never	N/A
Flat top (aero shape)	Maybe once or twice since I bought the bike	When I need it on a different bike
Classic (round shape)	Never	n/a
Classic (round shape)		
Flat top (aero shape)	Once a year	When at risk of damage
Not sure.		

Appendix 2: Granta EduPack

Granta level 2 chart showing the specific strength versus the Young's modulus for Polymer families.



Granta level 3 graph showing specific materials within the polymer families on the same axes as level 2. From this graph a selection of materials was made.



Appendix 3: Arduino code and test setup build information.

For the test a electromagnetic motor had to be placed under the magnet integrated in the BCM. This was done as following:

A M10 bolt was hollowed out, and a M4 thread was tapped in this cavity. This allowed an M4 threaded tube, on which the electromagnetic motor was mounted, to go through the M10 bolt. The M10 bolt was fixated in an aluminium plate. The handlebars were fixated so they could not vibrate on their own, influencing the results of the BCM.

naturalfreqtest.ino

```
// Pin connected to the vibration motor
const int motorPin = 3;  //

// Frequency in Hertz (Hz) that you want to test
const float targetFrequency = 90.0;  // Change this to desired testfrequency

// Calculate the period (in milliseconds) based on the testfrequency
const unsigned long periodMilliseconds = 1000 / targetFrequency;

void setup() {
  pinMode(motorPin, OUTPUT);
}

void loop() {
  // Turn on the vibration motor
  analogWrite(motorPin, 128);  // 128 is half of the maximum PWM value (255)

  // Wait for half of the period
  delay(periodMilliseconds / 2);

  // Turn off the vibration motor
  analogWrite(motorPin, 0);

  // Wait for the remaining half of the period
  delay(periodMilliseconds / 2);
}
```

Appendix 4: Ergonomics research

This study was conducted during the discover phase, but was not directly proven to be helpful for the concept, and is therefore placed in the appendix.

This study aims to explore the ergonomics of a road cycling cockpit and what types of injuries are involved. The research question is:

1. What are common injuries that occur with handlebars? And are there opportunities to resolve this with a new mounting system?

Injuries related to handlebars

Sensory and motor impairments of the hand are common among both amateur and experienced bicyclists. This phenomenon is called Cyclist's Palsy and presents as numbness and/or paresthesia in the fifth and ulnar aspect of the fourth finger, sometimes accompanied with weakness in the abductors or adductors of these fingers. Persistent ulnar nerve compression is believed to be the primary cause of Cyclist's Palsy (Slane et al, 2011).

Cyclist have three main positions to place their hands when riding. These positions are shown in figure 11 and explained below.

1. Drops
   Used when cyclist wants to be in an aerodynamic position and when descending to lower Gravitational point.

2. Tops
   Used when cyclist is not required to be close to bike control levers. Can be used in either relaxed or aerodynamic position.

3. Hoods
   Used for quick access to control levers of the bike, the breaks and shifters.

The different hand positions on the handlebars

Each of these positions place the wrists and elbows at a certain angle. When the hands are in the drops or hoods position, the wrists are in a vertical position allowing the cyclist to maintain a straight line between the elbow and the wrist, resulting in an aerodynamic position. When the hands are placed on the tops however, the cyclist is required to either bend their wrists, or force their elbows outwards. Wrist position is believed to affect the internal loading on both the ulnar and median nerves (Capitani and Beer, 2002, Mogk and Keir, 2008, Patterson et al., 2003). Figure above shows the wrist angle deviation and extension. The tops hand position, which requires the riders to place their hands on the medial portion of the handlebars shown in figure x, resulted in ulnar deviation of the wrist. Ulnar wrist postures can result in pressure on the median nerve within the carpal tunnel, and potentially contribute to median neuropathy (Keir et al., 2007).

Results

Since the wrist injuries of the ergonomics research can not be solved with the BCM, these do not result in design requirements. However, the results of the user research indicate opportunities for integrating the BCM into the carbon cockpit. This ergonomics research can be used to make improvements to the handlebar ergonomics simultaneously and will be explored in the ideation phase.

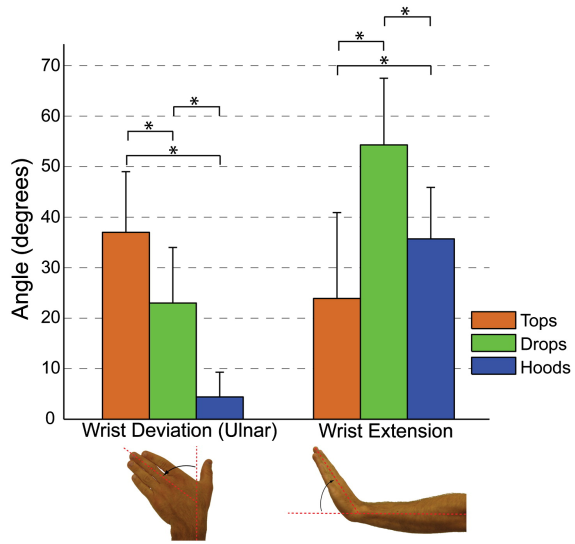


Figure x: Ulnar wrist deviation and wrist extension shown in different hand positions (https://www.sciencedirect.com/science/article/abs/pii/S0268003311000672)

Appendix 5: Design brief with all confidential info removed

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name ____

initials ____ given name ____

student number ____

street & no. ____

zipcode & city ____

country ____

phone ____

email ____

Your master programme (only select the options that apply to you):

IDE master(s): IPD / DfI / SPD

2nd non-IDE master: ____

individual programme: - - (give date of approval)

honours programme: ____

specialisation / annotation: ____

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair ____ dept. / section: ____

** mentor ____ dept. / section: ____

2nd mentor ____

organisation: ____

city: ____ country: ____

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Arjen Jansen date - - signature ____

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme ____ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name ____ date - - signature ____

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED / NOT APPROVED

Procedure: APPROVED / NOT APPROVED

comments

name ____ date - - signature ____

Initials & Name D.R.J. Kemme Student number 4400488

Title of Project Development of a lightweight and aerodynamic integrated bike computer mount

Personal Project Brief - IDE Master Graduation

TU Delft

Development of a lightweight and aerodynamic integrated bike computer mount — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 27 - 01 - 2023 — 23 - 06 - 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The client is a producer of bicycles, winter equipment, and sportswear. They are known for being highly innovative in the cycling industry. The client has released a new bike designed to meet the demands of professional cyclists. This bike therefore has to be as lightweight, comfortable and aerodynamic as possible. Although their professional team has already ridden the Tour de France on it in 2022, the bike is yet to become available for sale to consumers.

Nowadays, almost all professional cyclists and most of the amateur cyclists cycle with a cycling computer that tracks and shows different types of data to the rider, as well as providing navigation. These computers are typically mounted to the handlebars of a bike. This can be done in a variety of ways, such as clamps, screws or with elastic bands. For their latest handlebar/cockpit design, the client would like a model specific mount that has minimal weight and maximum aerodynamic efficiency to fit with their ideology.

Currently the cycling computer market is dominated by Garmin and Wahoo, who use a specific mounting system to attach the computer on the mount. The mounting system is therefore standardized (and universal). However, the size and shape of these computers differs. It would therefore be interesting to research the personalization/customization of computer mount to perfectly fit a specific bike computer. Currently mounts are produced of CNC machined alloy, and therefore offer a 1-design-fits-all approach to save costs. Thermoplastic materials and their production methods offer opportunities for changing this.

Next to the design and development of the mount, the exploration of additional features would be interesting to explore. Things suchs as a bikelight, bell, a theft retrieval system (Airtag) or even a GoPro mount.

In this industry every single gram counts, especially in this professional segment. Every possible benefit, whether weight-wise or aerodynamically, counts as a marginal gain over a competitor. Other important factors for road bikes include comfort, price, aesthetics, quality and durability. Depending on the type of rider, the importance of each of the factors may weigh differently.

space available for images / figures on next page

Personal Project Brief - IDE Master Graduation

TU Delft

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Current bike computer mount options offered by the client does not fit their ideology: They are not optimized for weight and aerodynamical purposes. The current mount is produced out of CNC machined alloy, and the new product should be from a thermoplastic material.
As described in the introduction, marginal gains are a hot topic. Bike brands put maximum effort into improving aerodynamics and integration. However, bike computer integration is left untouched. Therefore the new mount should be innovative and at least competitive with products on the market.
Through material & production research, as well as concept testing with CFD, FEA and user tests, a mount will be developed that should improve integration, aerodynamics and weight.

Subproblems I would like to explore are:
- Explore a variety of production methods to achieve this without losing performance on strength, durability and longevity.
- Use vibration test data to analyze loads, optimize material distribution and improve overall design.
- Integrating additional features be added such as a lighting/bell mount.
- Explore computer brands/models compatibility for one part.

Conflicting demands that are expected:
- Light weight vs. low price.
- Unique but allows various bike computers.
- Small series at low price.
- Aerodynamic design vs. production price.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Design a product to mount cycling computers on an integrated road cycling handlebar, while reducing its weight and improving its aerodynamic performance. This/These product(s) will be designed for the handlebar
from the client.

I expect the outcome to be a product (or multiple products). The newly designed mount(s) should fit a wide range of computer brands and models in order to achieve the best integration with the handlebars and to serve all customers.
The main pillars of the project are 1. Use vibration data to evaluate loads on the mount and create a strong/stiff enough mount from a new material, and 2. to have a cleaner looking, more aerodynamic and integrated solution.
I have made some sub research questions that I want to explore during graduation:

1. Is the current production method (injection moulding) feasible (financially/technically) for these new model specific computer mounts?
2. Is it possible to set up a customisation process for model-specific parts?
2. Could Additive Manufacturing improve the weight and aerodynamic properties of the mount over current production techniques?
3. Can Scott's current production facilities be used? Is it feasible to introduce a new production method?
4. Is there a way to make the product more sustainable?
5. Can extra functionalities be added to the computer mount, without sacrificing product performance?

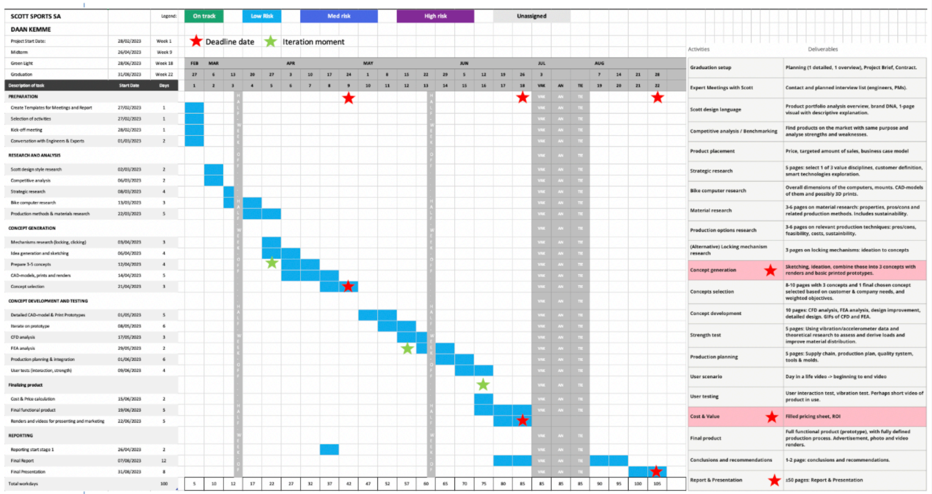
Personal Project Brief - IDE Master Graduation

TU Delft

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 27 - 01 - 2023   28 - 08 - 2023 end date



I have structured the project in activities with corresponding deliverables shown on the right. These activities are planned in the Gantt chart on the left and potential risks and progress will be tracked here. Three iterative moments/review dates have been scheduled to reflect upon activities and results, and review whether I am on the right track. This will be done in collaboration with the committee. Physical meetings will take place once a week on Tuesdays with the coaches. Once every 3 weeks we will schedule a meeting with both coaches where I present and discuss the progress. Meeting dates with Scott will vary based on where things stand in the project, and who needs to be involved.

I will add a separate image of the planning in case it is too small here.

Personal Project Brief - IDE Master Graduation

TU Delft

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

I have completed two internships abroad in the US and Switzerland, both in the medical industry, and I consider this as a field I see myself working in after graduating. However, I want to explore other industries and companies before I commit to a specific professional direction. Since two years I put myself a goal of doing either an internship or graduation project in my main passion: performance cycling.

The reason I chose this project out of the proposed projects was the fact it is a product that is planned on being released on the market, and used by both professionals and amateurs. It is also heavily focussed on performance, and therefore has to be overengineered to maximize effiency. It offers opportunity for me to do research with the usergroup, make CAD-models and test them, do basic CFD simulation, prototype and validate and think about production. Besides, this project focusses exactly on the market I am most interested in: Performance cycling.

Also sports engineering is not too far of my other interest, the medical industry. It will be interesting to see if I can apply some of my medical knowledge on this project. My electives included BioMechanics, Machine Learning and most importantly an internship in which I expanded my CAD-skills (Creo) amongst other hard- and soft skills. I also developed a feeling of Swiss work culture which could help in my communication with Scott. But I think the main competence that will help me during this project is passion. This is one of the rare times during my BSc. and MSc. I have a real passion for the company and products that I will be working on/with.

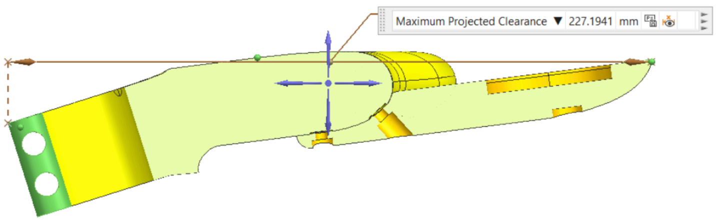
My ambition is to explore if the sports/cycling industry is a better fit for me than the medical industry. Also, I want to explore if I want to work in this industry after graduating. Whether that will be as a Design Engineer or something else is also something I can hopefully answer after this project.

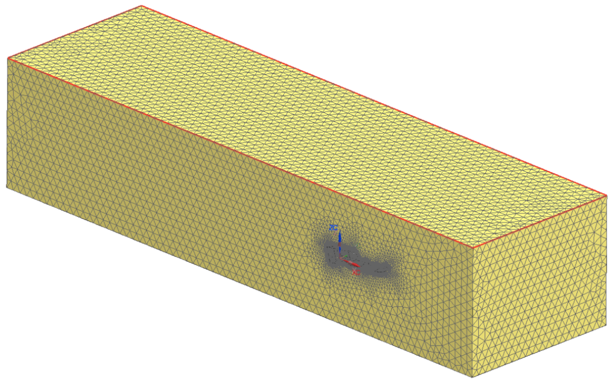
FINAL COMMENTS

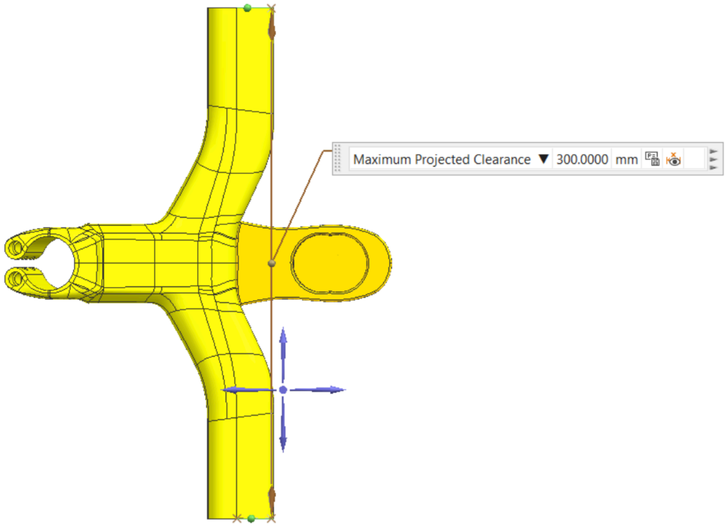
In case your project brief needs final comments, please add any information you think is relevant.

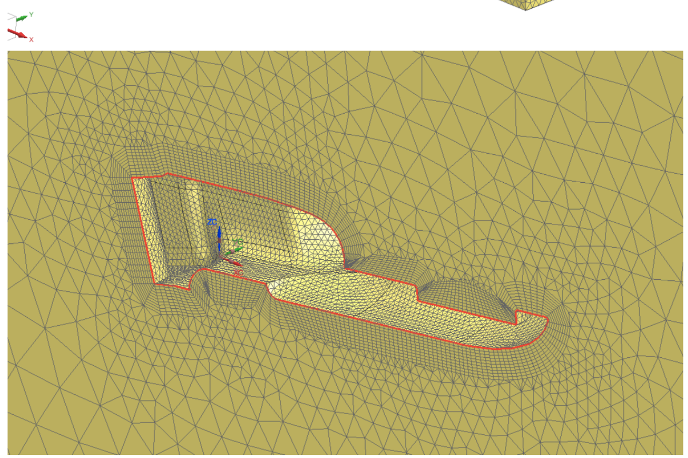
Appendix 6: CFD results

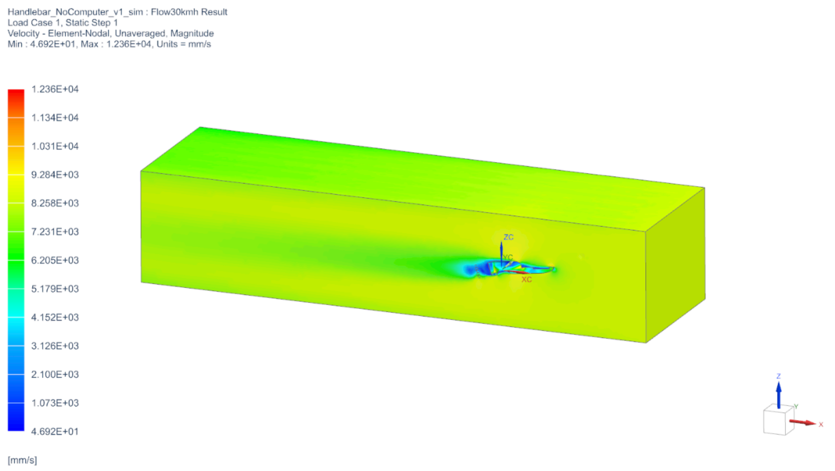
This appendix shows pictures and results from the CFD analysis.

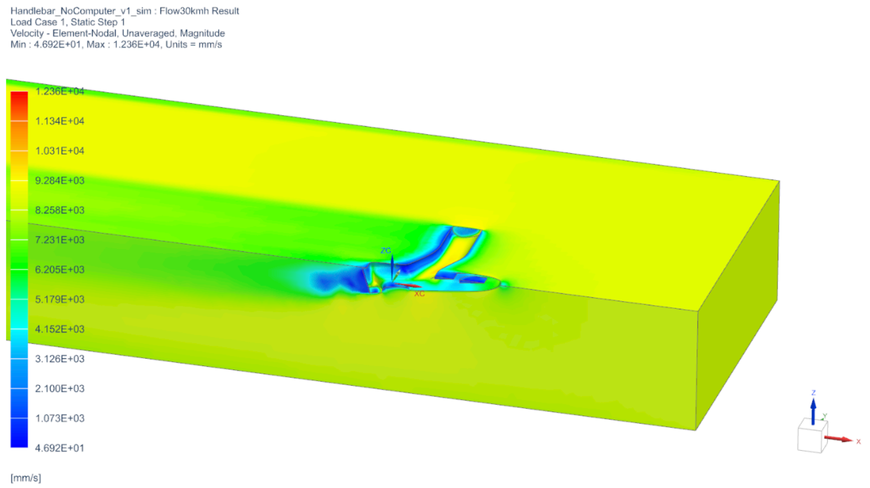


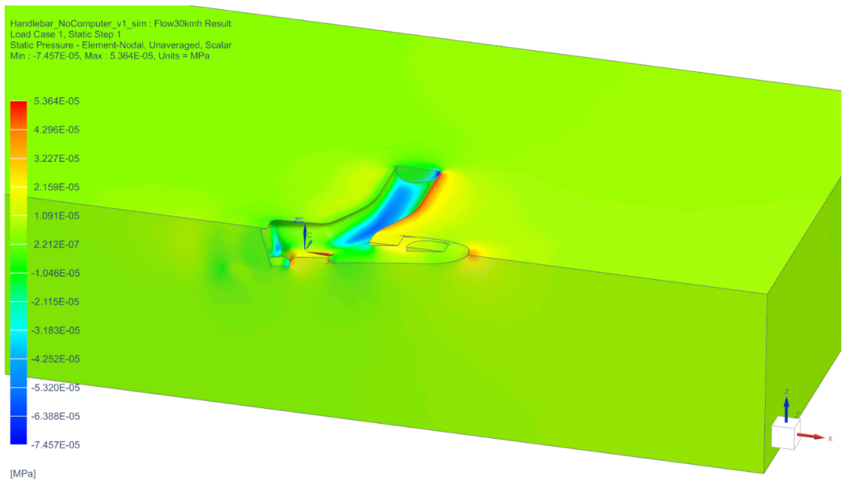


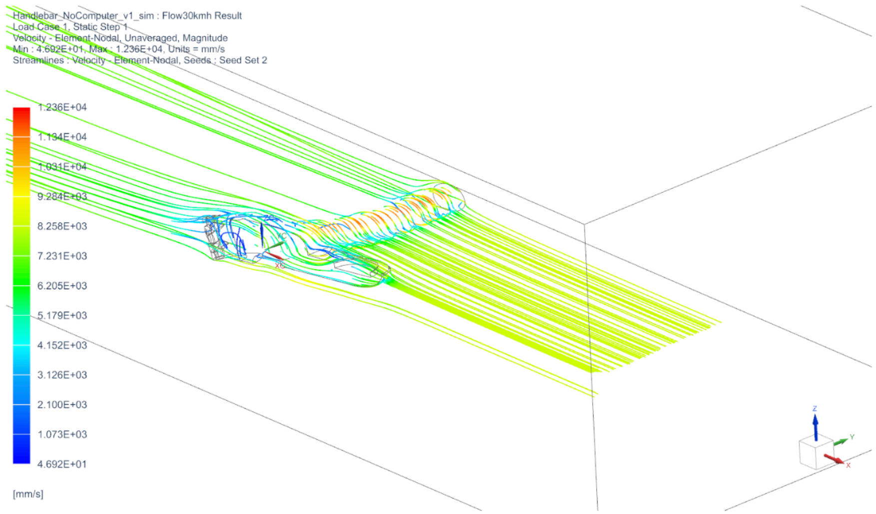


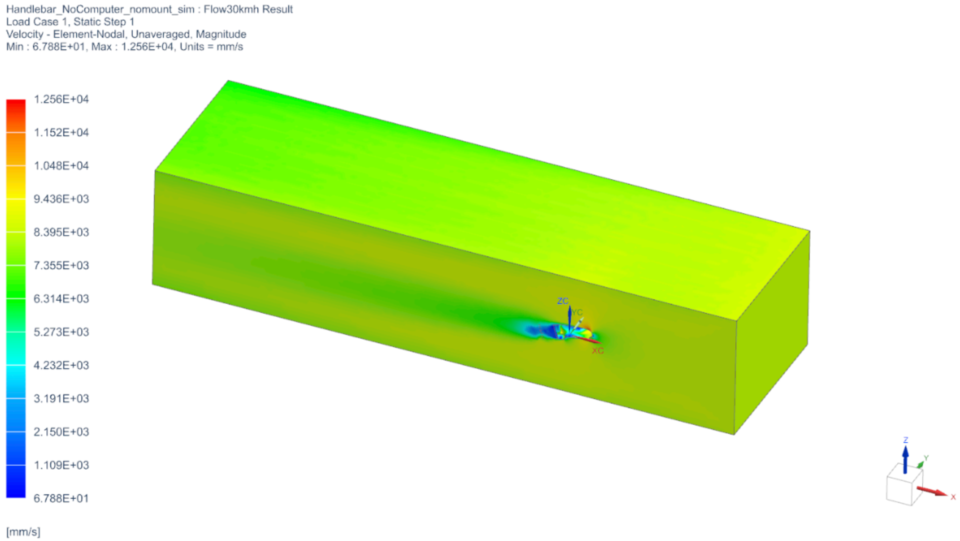


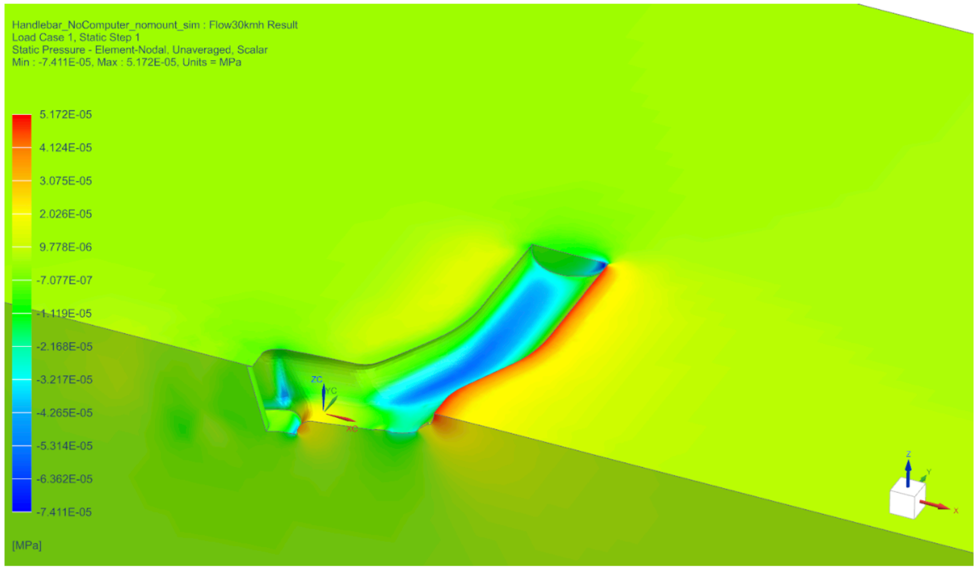

Handlebar_NoComputer_v1_sim : Flow30kmh Result
Load Case 1, Static Step 1
Velocity - Element-Nodal, Unaveraged, Magnitude
Min : 4.692E+01, Max : 1.236E+04, Units = mm/s
1.236E+04
1.134E+04
1.031E+04
9.284E+03
8.258E+03
7.231E+03
6.205E+03
5.179E+03
4.152E+03
3.126E+03
2.100E+03
1.073E+03
4.692E+01
[mm/s]

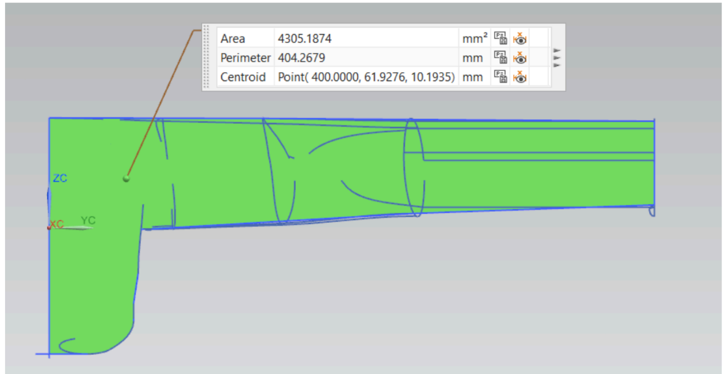

Handlebar_NoComputer_v1_sim : Flow30kmh Result
Load Case 1, Static Step 1
Velocity - Element-Nodal, Unaveraged, Magnitude
Min : 4.692E+01, Max : 1.236E+04, Units = mm/s
1.236E+04
1.134E+04
1.031E+04
9.284E+03
8.258E+03
7.231E+03
6.205E+03
5.179E+03
4.152E+03
3.126E+03
2.100E+03
1.073E+03
4.692E+01
[mm/s]


Handlebar_NoComputer_v1_sim : Flow30kmh Result
Load Case 1, Static Step 1
Static Pressure - Element-Nodal, Unaveraged, Scalar
Min : -7.457E-05, Max : 5.364E-05, Units = MPa
5.364E-05
4.296E-05
3.227E-05
2.159E-05
1.091E-05
2.212E-07
-1.046E-05
-2.115E-05
-3.183E-05
-4.252E-05
-5.320E-05
-6.388E-05
-7.457E-05
[MPa]


Handlebar_NoComputer_v1_sim : Flow30kmh Result
Load Case 1, Static Step 1
Velocity - Element-Nodal, Unaveraged, Magnitude
Min : 4.692E+01, Max : 1.236E+04, Units = mm/s
Streamlines : Velocity - Element-Nodal, Seeds : Seed Set 2
1.236E+04
1.134E+04
1.031E+04
9.284E+03
8.258E+03
7.231E+03
6.205E+03
5.179E+03
4.152E+03
3.126E+03
2.100E+03
1.073E+03
4.692E+01
[mm/s]





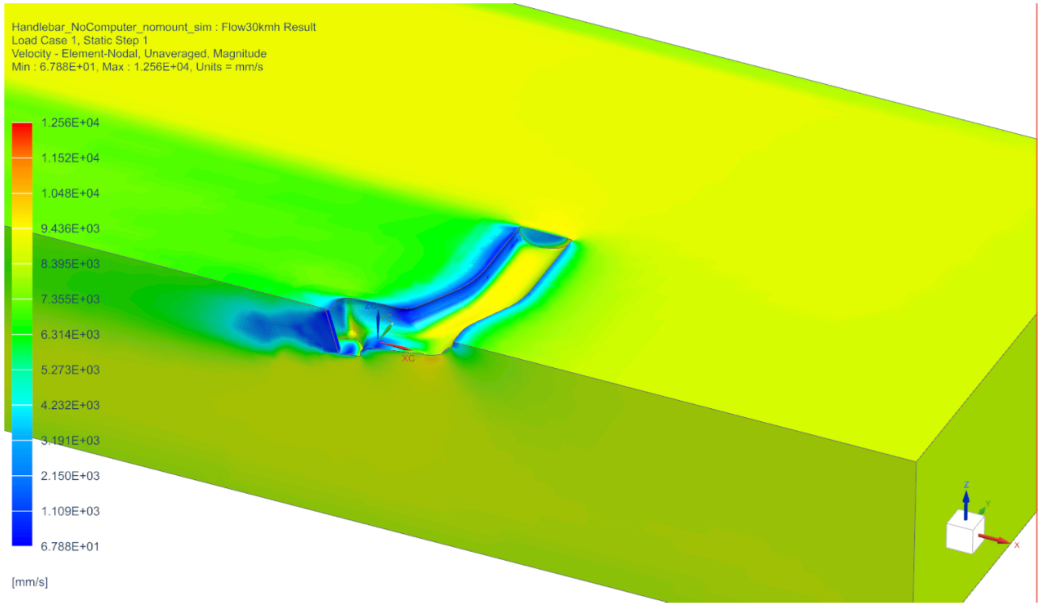


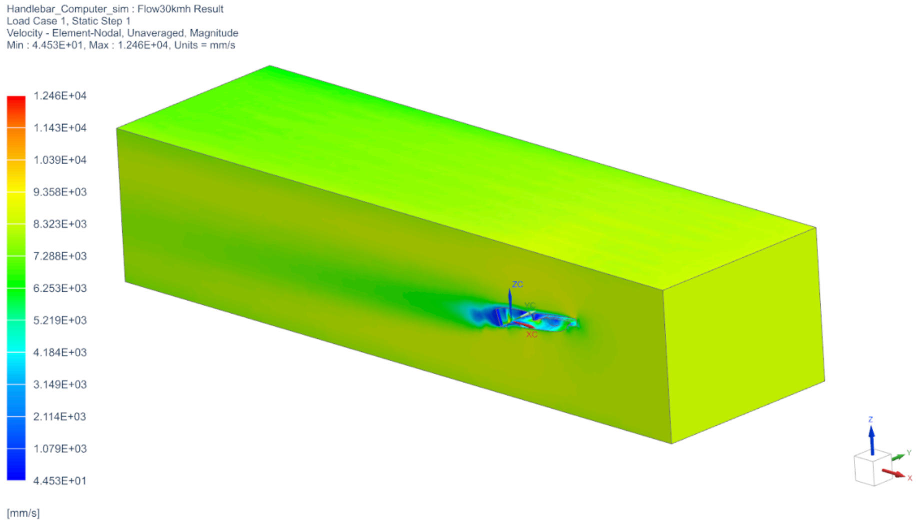
Units

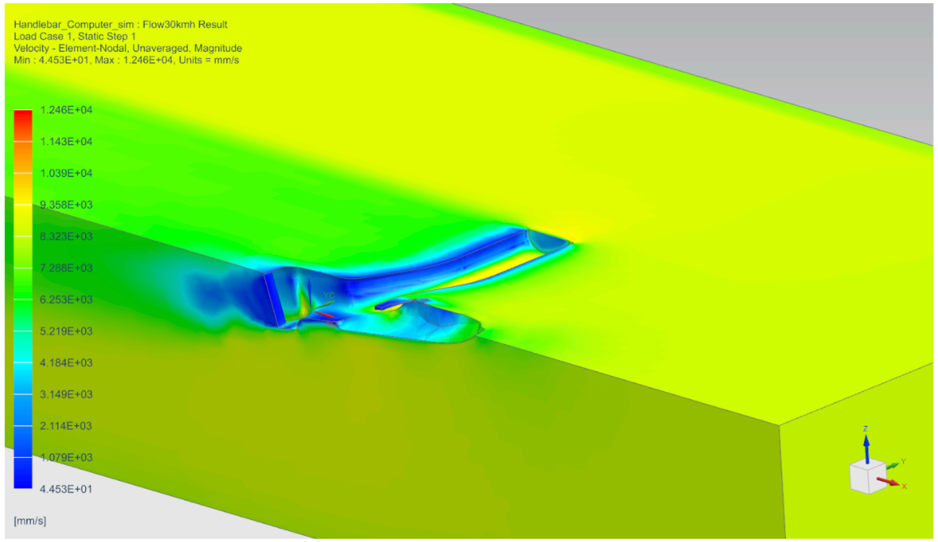
Length	Temperature	Pressure	Force	Velocity	Volume Flow Rate	Mass Flow Rate	Heat Load	Heat Flux	Heat Transfer Coeff.
m	C	N/m^2	N	m/s	m^3/s	kg/s	W	W/m^2	W/m^2-C

Lift Drag

Group	Time	LIFT-X	LIFT-Y	LIFT-Z	LIFT-Mag.	LIFT-Coef.	DRAG-X	DRAG-Y	DRAG-Z	DRAG-Mag.	DRAG-Coef.	SIDE-X	SIDE-Y	SIDE-Z	SIDE-Mag.	SIDE-Coef.	PITCH-X	PITCH-Y	PITCH-Z	PITCH-Mag.	PITCH-Coef.	ROLL-X	ROLL-Y	ROLL-Z	ROLL-Mag.	ROLL-Coef.	YA X
LiftandDrag	0	0	0	1	0.0591203	0.327679	-1	0	0	0.114998	0.637387	0	-1	0	-0.0347315	0.192502	0	-1	0	0.00588386	0.143034	-1	0	0	-0.00333116	0.080979	0







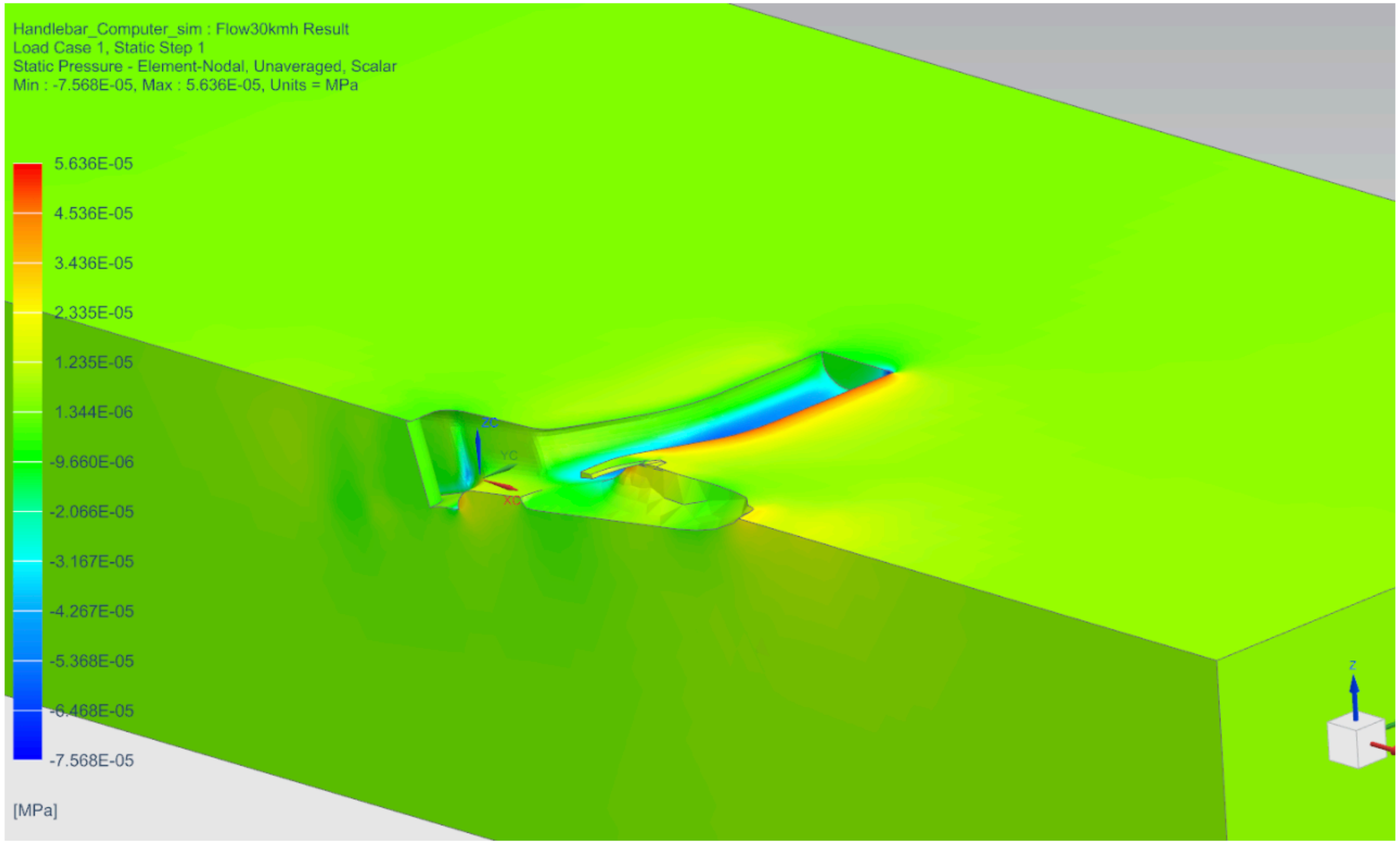
Units

Length	Temperature	Pressure	Force	Velocity	Volume Flow Rate	Mass Flow Rate	Heat Load	Heat Flux	Heat Transfer Coeff.
m	C	N/m^2	N	m/s	m^3/s	kg/s	W	W/m^2	W/m^2-C

Lift Drag

Group	Time	LIFT-X	LIFT-Y	LIFT-Z	LIFT-Mag.	LIFT-Coef.	DRAG-X	DRAG-Y	DRAG-Z	DRAG-Mag.	DRAG-Coef.
LiftandDrag	0	0	0	1	0.0586753	0.325213	-1	0	0	0.111573	0.618404

Group	SIDE-X	SIDE-Y	SIDE-Z	SIDE-Mag.	SIDE-Coef.	PITCH-X	PITCH-Y	PITCH-Z	PITCH-Mag.	PITCH-Coef.	ROLL-X	ROLL-Y	ROLL-Z	ROLL-Mag.	ROLL-Coef.	YA X
LiftandDrag	0	-1	0	-0.047892	0.265445	0	-1	0	0.00512499	0.124586	-1	0	0	-0.00319794	0.0777405	0



Units

Length	Temperature	Pressure	Force	Velocity	Volume Flow Rate	Mass Flow Rate	Heat Load	Heat Flux	Heat Transfer Coeff.
m	C	N/m^2	N	m/s	m^3/s	kg/s	W	W/m^2	W/m^2-C

Lift Drag

Group	Time	LIFT-X	LIFT-Y	LIFT-Z	LIFT-Mag.	LIFT-Coef.	DRAG-X	DRAG-Y	DRAG-Z	DRAG-Mag.	DRAG-Coef.	SIDE-X	SIDE-Y	SIDE-Z	SIDE-Mag.	SIDE-Coef.	PITCH-X	PITCH-Y	PITCH-Z	PITCH-Mag.	PITCH-Coef.	ROLL-X	ROLL-Y	ROLL-Z	ROLL-Mag.	ROLL-Coef.	YAW X
LiftandDrag	0	0	0	1	0.081259	0.450384	-1	0	0	0.128745	0.713581	0	-1	0	-0.0290778	0.161166	0	-1	0	0.0104758	0.254662	-1	0	0	-0.00388362	0.0944092	0