Oslo Metropolitan University

BUILDING A SURFBOARD FOR E FOILING

European Project Semester

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Abbreviations

- EPS Expanded polystyrene
- EPS European project semester
- MGS Mission, Goal, Scope
- 3D Three dimensions
- CNC Computer numerical control
- XPS Extruded polystyrene
- PU Polyurethane
- NBR Nitrile butadiene rubber
- DIY Do it yourself
- EVA Ethylene-vinyl acetate
- CFRP carbon fibre-reinforced plastic
- PVC Polychlorinated
- PLA Poly-lactic Acid
- ESC Electric speed control
- BOM Bill of materials
- PC Polycarbonate
- XPE Cross-linked polyethylene

Introduction

E-foiling is a modern and innovative water sports activity which combines surfing and hydrofoiling but in this case its powered by an electrical driven motor. As a result of the hydrofoil fin under the board, the rider gets lifted out of the water and planes with high speed above it. This concept is the same as used in wings of airplanes and is copied from natural shapes such as wings of a bird. Unfortunately buying an e-foil is expensive, good quality starting models cost €8000 but on average the price is around €12000 ("All efoil products", n.d.). A reason for that is the use of needed quality materials and waterproof electric motors powered by advanced, rechargeable, lithium-ion batteries. The quality and capacity of these components have an big impact on the performance and push up the price of the e-foil. Which caused it to be a niche sport that until now most people can not afford. As a result, many people are trying to make a cheap version of an e-foil themselves. On YouTube and foil communities you can find self-build e-foils for around €3000. It requires handcrafting skills and sometimes expensive tools, like a 3D printer. Nonetheless you don't have to make everything yourself, you can buy board kits, batteries, motors, the foil and other stuff for assembling it. Depending on your knowledge and what materials you need to buy is it still cheaper than buying the final product. As the brief is to create a board from commercially available components, the project contributes to this DIY knowledge base which is beneficial for the less equipped and new to handcrafting group of diy'ers and it aids with reducing the costs of this sport.

As a part of the European Project Semester we were given the task to make a proof-of-concept for an electronic surfboard with a lifting foil, using commercially available components. The previous group has already worked on an e foil board like that. Their main focus has been designing the propeller and the motor attachment to the strut. Next to that they paid attention to the attachment of the battery case to the board. Other components such as the board itself, the whole foil including strut and wings, the speed-controller and the case itself they have bought online 1.1. The current group examined the previous board for what already worked well and what could be the points of improvement. We found one of the major problems of the previous board is the battery case. Because of the placement on the board the rider does not have enough space on the board left for normal foot placement. On top of that, the case being big and rigid is not safe for a novice surfer that will fall more often during their first times surfing on the water. As a result of this, the project group has decided to focus on the construction of a completely new board itself. Focussing on a waterproof battery case inside, hydro- and aerodynamical design and a strut attachment compatible with the foil of the previous group. Because of the mechanical engineering, design, physics and purchase engineering background of the group, this project will fit the competences we have.

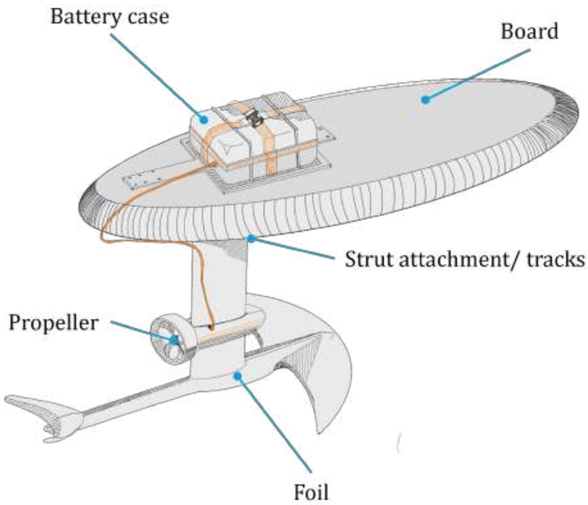


Figure 1.1: Overview of parts from the previous project

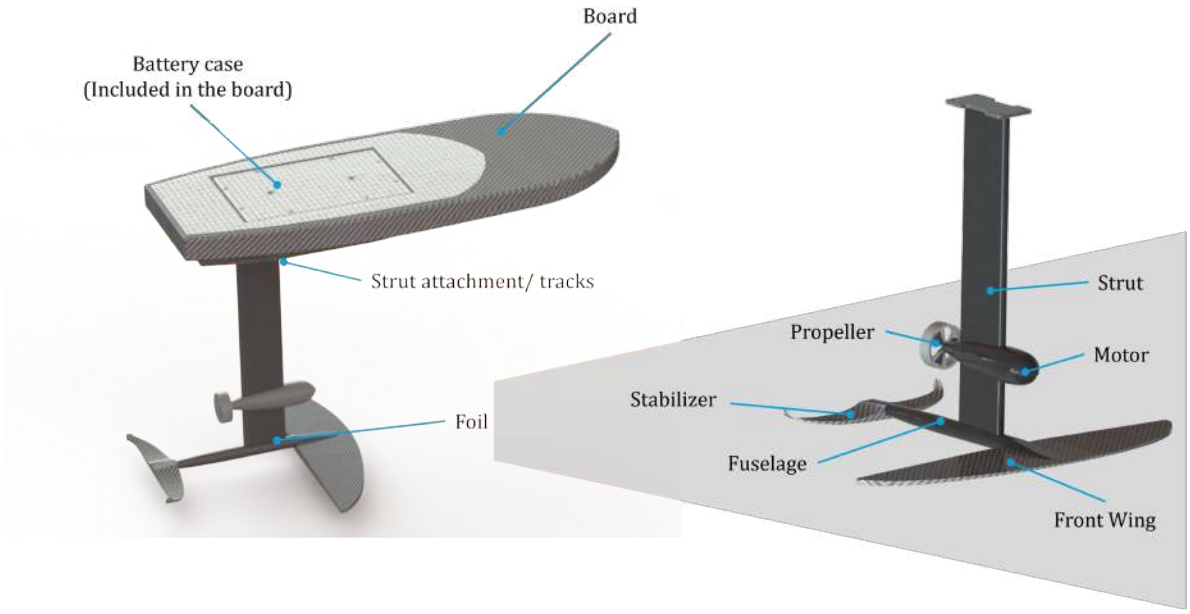


Figure 1.2: Overview of parts from our project and specification of parts from the foil.

Project management

2.1 About the team

This project has been carried out by a multidisciplinary team. We are not only from different fields, but also from different countries. We have been working in the Ocean Lab. This laboratory is part of Oslo Metropolitan University and is located in the harbor by the sea. Throughout this semester, we have been developing, designing, and building a functional prototype of an e-foil.

As a multidisciplinary team, we embraced our diverse backgrounds. Although we worked collaboratively throughout the entire project, we divided responsibilities based on each member's individual strengths.

The members of this team are:

- Aitana Aragones Camacho, Product Development and Industrial Design Engineer and Mechanical Engineer.
- Juliëtte Aimée Marini Kuijpers, Applied Physics
- Carmen Rodríguez Ledesma, Product Development and Industrial Design Enginieer.
- Luca Städing, Industrial Engineering and Management International Sales and Purchasing

2.2 Communication and collaboration

Due to our diverse academic and cultural backgrounds, we knew from the very beginning that communication would be a key element in the success of our project. Maintaining clear and consistent communication helps prevent misunderstandings and ensures that every team member stays informed about the work being carried out by the others.

To stay organized and connected, we used a variety of tools:

- **WhatsApp** for quick, day-to-day communication and updates.
- **Notion** for planning the upcoming weeks, store reference links and note relevant information for the entire team.
- **E-mail** to communicate with our supervisor.
- **One-drive** to share documents which all team members needed access to.

As the aim of the project was to make a proof of concept it was required to make decisions right in the place while the designing and building process. That is why we chose to meet in person as much as possible. Although we initially set Tuesdays, Wednesdays, and Thursdays as our main working days, this schedule changed as the project progressed. During the construction phase, we had to work throughout the entire week. To build the prototype, we used epoxy, which required full-day drying periods between each use. Because of this, we split into two working groups, pairing up to use our time more efficiently. At the beginning of each week, we planned the days ahead and agreed on a work schedule based on everyone's availability. This approach helped us maintain a positive group atmosphere while ensuring that the workload was distributed fairly among all members.

At the beginning of the semester, we drafted a group contract to define certain guidelines and set expectations. In case of disagreements regarding any of the specified aspects, the contract served as a reference for resolving the issue. It established our agreed working days and hours, defined what would be considered arriving late, and outlined the procedure to follow if someone wanted to change a workday or take one of those days off.

Although we spent most of our time working together, we divided certain tasks based on our prior knowledge in different subjects. Even if we were involved to a greater or lesser extent in all parts of the project, we assigned a person in charge of each section. That person was responsible for ensuring that their part was completed on time and effectively.

2.3 Mission Goals Scope statement

Starting the project we found there where three very different directions the project could take. Learning more about the topic and our abilities, we improved these possibilities and scoped it down to two different options. In appendix A, that previous version of the mission, goals, and scope (MGS) document is listed. This earlier version was developed during a phase when the project direction had not been defined yet. It focussed on continuing the work of the previous team, primarily through assembling, testing, and identifying places of improvement in the existing components. The main mission was to "redesign a rider-controlled efoil surfboard using commercially available components," and the goals were: verifying the functionality of the parts, such as the motor, battery, and control systems without significant changes unless we found out that it would be necessary. After reading the paper of the group prior to us, we found out their testing failed because they had an insufficient battery. So this project would primarily consist of fixing small mistakes that the previous group had made and finding a battery that could generate enough energy for the motor. Because this did not feel like a fulltime project for a group of four students and we would be too much dependent on finding a proper battery, the mission of the project changed. In the meantime we already found they made one other big mistake. Namely the battery case that was attached on top, in the middle of the board. This would hinder the surfer while riding because there was no proper space for foot placement and falling on top of that case would hurt the surfer a lot. Hence it was not safe to drive this board. That is why the project mission changed into: "Design and develop a board for efoiling with integrated space for the electrical components, focusing on strength, waterproofing and using commercially available components." This can be read in detail in 2.3.1.
This new document shows a shift from fixing mistakes in the existing solution to creating a new prototype for the board, focusing on design and building. The earlier document was the plan during the first phase when the direction of the project was uncertain, while the current document defines a more precise and achievable framework which showed that our understanding of the bigger picture grew a lot in this first stage.

2.3.1 Final MGS

The mission of the project became: "Design and develop a board for efoiling with integrated space for the electrical components, focusing on strength, waterproofing and using commercially available components."

The project can be scoped down to three major goals. Those are the design, the building and the testing of the board. To specify it, there are smaller goals for the three bigger subgoals.

- Design the board
  - Research the best hydrodynamic and aerodynamic form of a board and do simulations to check the design for mistakes
  - Research 3 material options
  - Research 2 strut attachment methods
  - Research waterproof lid
  - Research holes for cables and ventilation
  - Design a 3D model that is able to be manufacture with the available resources
- Build the board.
  - Build structure of the board
  - Build waterproof battery case big enough for a larger battery in the future
  - Build strut attachment
  - Reduce drag by sanding and epoxying
- Test
  - Test water tightness of battery case
  - Test forces on strut attachment
  - Test float ability of the board in water
  - Test the board behind the motorboat of the Ocean-lab

We are not focusing on what already works from the previous version of the project such as the propeller with strut attachment or the remote control because we will not be testing that due to a missing sufficient battery.

We are making a prototype, so most of the building process can be handmade and the priority is functionality and efficiency, but never aesthetics.

The prototype will not be a final product but will set a strong foundation for future projects.

Workflow overview

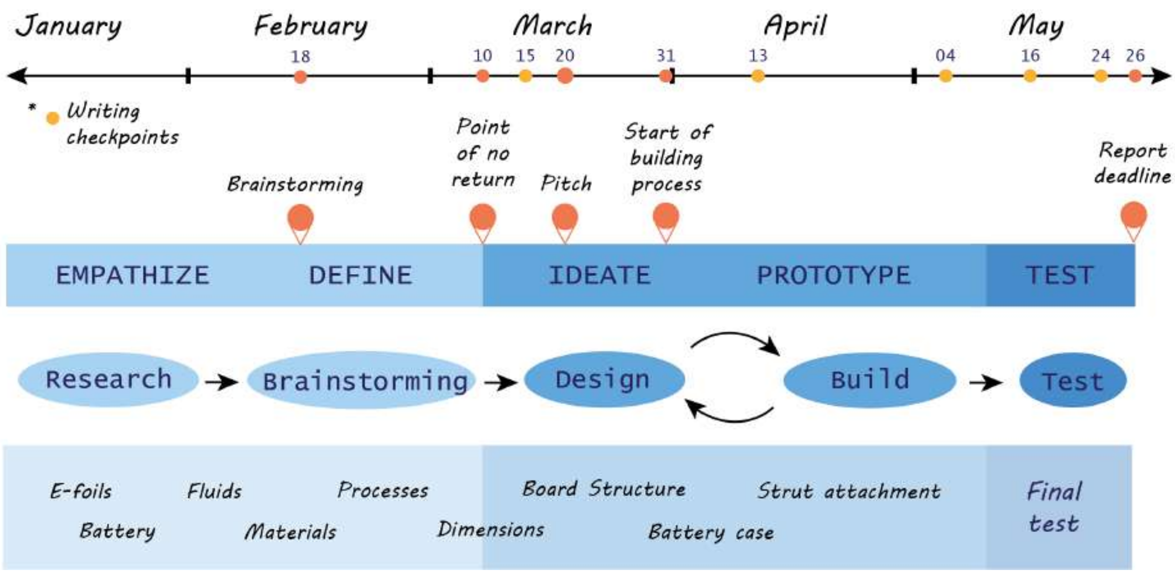


Figure 3.1: Project timeline based on the design and thinking method

In this project, this design thinking method was used as the main approach for creative problem-solving. As shown in the image above, this method is divided into five phases: empathize, define, ideate, prototype, and test. Throughout the development process, these stages were applied to define and understand the design challenges, generate innovative ideas, build viable solutions, and eventually test them in a real environment.

- **Empathize**. For us most of this phase consist of research. We understand how the previous project was developed. We also did general research about e-foils and later on focus on their components and characteristics, battery, shape, materials, manufacturing processes and hydrodynamics. Chapter 4.4.3.
- **Define**. After having a deep understanding of all this concepts we could define our ultimate goal for our project. We also did the brainstorming at the beginning of this phase. Chapter 5.1.
- **Ideate**. During this phase we brought all our ideas together and turned them into specific plans. Chapters 5.3 and 5.4.
- **Prototype**. This was mainly the building phase which was kind of an iterative process carried out alongside the design/ideate phase. Since sometimes some corrections in the design were needed. Chapter 7.
- **Test**. This was the final testing for our finished prototype. Chapter 9.3.

Research

Building the surfboard as we had it in mind would not be possible without researching the fluid dynamics, materials, different components and process options. In this chapter all these options are explained so that in the next chapter the design can be chosen wisely.

4.1 Fluid

One of the goals is to design an efficient e-foil board. Minimizing the total hydrodynamic resistance is crucial for using the battery life in its most efficient way. There are endless options to research that, so this fluid dynamics study is scoped down to evaluating two characteristics. These are the drag and lift forces because they are crucial for performance and accessible through the available software Solidworks 2024. Focusing on these characteristics prevents too complex simulations and is in general, a better fit for this EPS project. Next to that, it is important for the geometry to be able to be manufactured, which is why the geometry is made relatively simple. Without overdoing too much detail.

The previous group calculated that the speed when foiling starts varies from 4.4 to 4.8 m/s. Taking into account that the self-made board including electrical components will be around 1.5 times heavier than the previous board, the speed at which foiling starts will be around 4.9 m/s or 17.8 km/h. This also depends on the level of proficiency of the surfer and the angle of attack of the foil. It is assumed that this is already mastered at the moment of taking of. During this phase, the highest load is put on the system. The battery is delivering a current to the engine, and the engine operates at near-maximum power output to get the board foiling out of the water. To minimize energy losses and use the battery efficiently, it is essential that the board shape supports lift generation and minimizes unnecessary drag to work against. (Yunus. A. Cengel, 2022)

4.1.1 Drag

The force a flowing fluid exerts on a body in the flow direction is called drag. (Yunus. A. Cengel, 2022) This can be divided by skin friction and pressure drag.

Skin friction drag

This drag is dependent on viscosity of the fluid and the speed of the object. And its also dependent on roughness of skin, for that the board will be sanded and have a last layer of epoxy glassing so the surface will be as smooth as possible. In general the total drag is less dependent on the skin friction when there is a high Reynolds number. The Reynolds number in the Oslo fjord will be in such order of magnitude that skin friction will not be significant enough to impact the total drag enough. (Beggs, 2009)

Pressure drag

The pressure drag is dependent on the frontal area and the difference in pressure between the front (slightly higher pressure) and rear part (lower pressure) of the board. This is most important for blunt bodies where the fluid cannot follow the streamline of the hull so that flow separation appears (Yunus. A. Cengel, 2022, p.518). The first thing to do when minimizing drag for bodies at lower velocities is round of edges on the rear side of the body (Faber, 2004, p.268). This would be taken into account while designing the board. For that reason, wake regions with disturbed flow on the back of the board will be searched for in streamline plots in the simulation results.

4.1.2 Lift

Lift is the force perpendicular to the direction of motion. In other words, the force upward. The foil is supposed to create the lift to start foiling over the water. So, it is not wanted that the board shape itself is designed so that it is creating unnecessary force downward or suction on the bottom, against the lift. In 4.1.1 is mentioned that the body needs streamlining so that minimal wake appears. That is best for when the board is steady foiling over the water or steady driving through the water. But for the board to take of foiling, flow separation is needed. To achieve this, chine strips are often used in planing boat hulls, water is compressed under the surfboard which causes the pressure to rise and flow to separate.**source**

4.2 Material options

As stated in the goals, the group decided that it was useful to research and consider different material options 2.3.1. This is beneficial for comparing the strength of materials to make sure it is possible to use it in our specific project and it is necessary to be able to keep track of our budget. In this paragraph there will be discussed different options available for this project. All the material options considered during the development are explained with more detail in appendix B.

4.2.1 Board structure

In the table below, a comparison of the materials considered for the core of the board structure is presented based on various criteria.

	Foam			Others	
	PU	**EPS**	**XPS**	**Wood**	**PLA**
Name	Polyurethane	Expanded polystyrene	Extruded polystyrene	Paulownia wood	Polylactic acid
Shaping	Easy	Easy	Easy	Machine Needed	3D Printed
Density (kg/m^3)	36	11	27	350	1240
Price	1111 kr/m^2	1980 kr/m^3	4387 kr/m^3	34200 kr/m^3	522 kr/Kg
Durability	Medium	High	High	Low	Low
Residence to break	Medium	Medium	Low	High	Medium
Biodegradable	No	No	No	Yes	Yes
Availability	Very Low	High	High	Low	High
UV exposure Resistance	Medium	High	High	High	Low
High temperature resistance	Medium	High	High	High	Low
Type of covering required	Fibre layering	Fibre layering	Fibre layering	Chemical	Fibre layering

Figure 4.1: Comparison of the considered materials with the relevant criterias.

Figure 4.2: EPS on the right, XPS on the left(Supplies, 2025).

After shaping the core of the structure, the board will be layered in fibreglass cloth, shown in the figure 4.3 in order to make it resistant(Christopher R. Gibson, 2017).
Fibreglass is a composite material that is made of very fine glass fibres. Woven together, these glass fibres build an ultra strong fabric, which have a better tensile strength than steel. Tensile strength is the resistance of a material to pulling or stretching forces before breaking apart.Once it's created, fibreglass typically has a density of between 2.4 and 2.76 g/cm^3. The advantages are the light weight, the durability and stiffness as well as the moisture resistance (Kat de Naoum, 2024).

Figure 4.3: fibreglass fabric(AZoNetwork, 2025).

Another option for the board layering process is carbon fibre-reinforced plastic (CFRP) or short carbon fibre4.4, which most E-foil manufacturers use for their boards(Dwelle, 2024)(Dinh Nguyen, 2024).

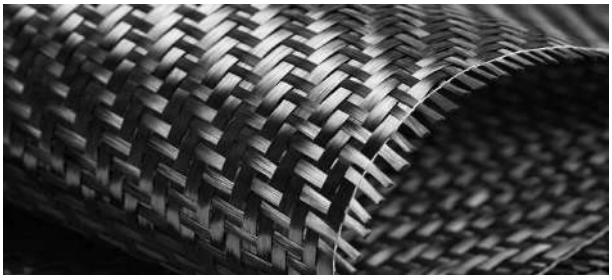


Figure 4.4: carbon fibre reinforced plastic fabric(Innovates, 2025).

With a density of 1.5 g/cm^3 it is very lightweight and at the same time has a high tensile strength of 900 MPa depending on the weave direction(swiss-composite, n.d.). It is also very resistant to external weather influences, such as degradation due to the sun and seawater(Al-Nuaimi-Ph.D., 2021). In contrast, it is more expensive than fibreglass, because of the several complicated manufacturing processes(H. G. I. Limited, n.d.).
Resin is used to adhere the weaves of carbon or glass fibre together. Furthermore, it finishes the board with the last coating, in order to protect and smooth the surface(Christopher R. Gibson, 2017). There are two types of resin that are often used, polyester and epoxy. Epoxy resins are stronger and more adhesive to the fibreglass sheeting compared to polyester resins. However, epoxy is only suitable for use with EPS and XPS blanks because the resin adversely reacts with traditional PU foam, causing discolouration.

Epoxy resin is also more difficult to spread over the blank and more expensive than traditional polyester resins(Christopher R. Gibson, 2017).

4.2.2 Battery case lid

The lid case consists of 6 parts, the cover, a connecting plank, the sealant, screws, air vents and grip on top.

Cover
In general, the cover can be made of any material as long as it is a light material, to not contribute more weight to the board than needed. Aluminium is an interesting material option. It is a strong metal, durable, flexible, impermeable, lightweight, corrosion resistant and infinitely recyclable (A. A. C. Ltd, 2025). Another material option occurred is polycarbonate (PC). It is a technical thermoplastic, which is characterized by its very high impact resistance, lightweight and low moisture absorption. (HANSER, n.d.) Polycarbonate is more affordable, but less durable and cannot withstand the same harsh weather conditions as aluminium. (Troop, 2021)

Sealant
The battery case needs to be watertight. It is important to seal everything right, to prevent water coming in. Therefore, two widely used options nitrile-rubber and silicone have been researched. Nitrile rubber, also known as nitrile butadiene rubber (NBR), is a synthetic polymer material. The main advantage is its exceptional resistance to fluids. Nevertheless, it also shows a good temperature resistant. Finally, it offers good wear and tear resistance, which contributes to the durability and longevity of seals(Group, n.d.).
Silicone is a synthetic compound that comes in a variety of forms like oil, rubber or resin. It is typically, heat- and water-resistant and present in sealants. Due to its different forms, it has excellent spread and coating capabilities.(ASA, 2025)

Air Vents
To provide air ventilation for the battery case, the following solution appeared during the research. Air vents, which are located at the back of the lid, provide an air stream to prevent moisture from inside the battery case. They need to be waterproof and act like a gasket. They can be made out of plastic but are also available from stainless steel(AS, n.d.). **Plank**
For the connecting plank between the battery case and the seal, we looked for a lightweight yet stable plate, that could be drilled through. Two options were then discussed again through the research, aluminium and polycarbonate. Especially the polycarbonate characteristic of having a high impact resistance, but also the lower price make it an interesting option.(HANSER, n.d.)

Grip
Lastly, a material option for the rider's standing area was needed. To have a good riding experience, riders need to stand properly on the board. That is why most manufacturers put a grip area on the board. For a good grip, the surface needs to be anti-slip, waterproof and durable enough to withstand external weather influences. The frequently used solution is ethylene vinyl acetate, (EVA). This kind of foam is elastic, lightweight, resistant to wear, waterproof, resistant to UV radiation. EVA foam is a much more durable and effective material than polyethylene or rubber (EKI, 2025).

4.2.3 Strut attachment tracks

Another research goal was to find a way to attach the existing strut to the new board.2.3.1 The traditional option is to use tracks. With this mechanism, the driver can adjust the optimal position of the strut.
In addition to previously parts, the material should be lightweight and resistant enough to withstand external influences.
People with access to a 3D printer have the opportunity print them. The frequently used print material is polylactic acid (PLA), a renewable thermoplastic. Besides being eco-friendly, the material does not meet the requirements, due to its low heat resistance and low strength. The best option for self-prints with a carbon like quality, is a print material, called "Onyx". It is a micro carbon fibre filled nylon. "Onyx" offers high strength, toughness, and chemical resistance. Compared to PLA it is expensive and not compatible with every 3D printer(Markforged, 2025b). To withstand the forces, a method was found to absorb and distribute them across the board. One option is to use rectangular tracks made from a single carbon fibre layer—strong but expensive (okarbon, 2025). A cheaper alternative is using a pre-moulded or self-shaped XPS plate, which offers some benefits similar to carbon.

4.3 Manufacturing process options

Another part of the research conducted was to find possible or approved process options, to build the board. The building process consists of three major parts: the shaping of the board, laminating, and the sanding.

4.3.1 Shaping

The first step is the shaping process.It is the process of crafting the outline and curves of a surfboard to achieve the desired design. During the research three ways of shaping were found:hand shaping, machine shaping or 3D printing the shape of the board.

The comparative overview between the options is shown in the next table.

Characteristics	CNC	3D PRINTED	Handmade
Shape	It is possible do shapes that are exact replicas of the 3D model, so we can do deep into designs based on fluid and statics.		The designs should be as simple as they can be. Rigorous shape is not secured
Time	The machine is fast, but we depend on the availability of the service provider.	It is at least 50 pieces of 20 hours each.	At least 20 days.
Budget	Expensive: Foam itself, payment per hours for the service and drills used.	Cheap: The material is provided by the university.	Cheap: Foam and tools.
Independence	Medium: Creativity freedom, but limited time schedule by the service Provider.	Medium: Availability of the 3D printers.	Totally Independent.

Figure 4.5: Comparison of the different manufacturing processes

The selected option is explained in more detail in the following section. The decision to reject the other options is explained further in the appendix. C.

Machine-shaped

Another method is to let a machine do the work. **C**omputer **N**umerical **C**ontrol (CNC) machines operate by using the designed shape of the board, and the programmed software tells the machine the exact movements and the task to complete it(Matheus Vinícius Gregory Zimmermann, 2024).

Precision	CNC machines achieve details and exact measurements that are challenging to replicate consistently with traditional hand-shaping methods.
Speed	Once programmed, CNC machines can produce faster than manual shaping, reducing lead times and increasing production capacity
Innovation	The precision provided by CNC machining minimizes errors and enhances the overall quality and performance
Quality control	CNC technology empowers surfboard shapers and manufacturers to explore new shapes, designs, and materials, pushing the boundaries of performance and aesthetics

Figure 4.6: Main advantages of CNC equipment

This especially suits people, who do not have much handcrafting skills. In contrast, depending on the size of the machine, you cannot shape in one piece. And it is more expensive than doing the shaping yourself. The reason is that the core is usually one complete part and not divided into different pieces. So solutions of gluing were needed. One option was to use epoxy resin. Due to its compatibility with EPS and its proven usage for the following laminating processes, this was a serious option.(Christopher R. Gibson, 2017) However, the consistency is fluid and therefore not ideal for gluing parts with a small surface. Second, the hardening time is at least 24 hours. This is not desirable because it is best to put pressure on the surface while drying. Option two is a special polyurethane (PU) glue for EPS plates. It has an extremely good adhesive strength and a foam-like consistence. With a foam gun it is easy and precise to apply.(KGAA, 2025)

4.3.2 Laminating

Laminating is the second step of the building process. It begins with layering the finished shape with lengths of fibreglass cloth or carbon fibre. Next, the liquefied resin will be spread on the board to begin the sealing process.(Christopher R. Gibson, 2017) This step will be repeated as often as required. Normally, 2 to 4 coats are recommended.(Epoxycraft, 2025)

4.3.3 Sanding

The last process step consists of properly sanding the whole board and then coating it with a last layer of resin. The sanding should have been done in between the steps of layering the fibre cloths, but especially the last sanding is to get rid of unwanted epoxy droplets, rough bumps, and imperfections. For this, either a sanding machine could be used or sandpaper for doing it per hand. The coating gives the surface a nice finish and ensures the longevity of the board. Once the fill coat cures the board, it is again intensively sanded with different grit sizes. The board is then cleaned with an acetone and polished to achieve a dull finish. After this, the building process is completed. (Christopher R. Gibson, 2017)

4.4 Dimensions board

Lastly, we had to research which dimensions, measures, shapes, etc. are normally used for the board, the tracks, and the battery case, in order to proceed with the design process.

4.4.1 Board volume

For beginner e Foil riders, the board's shape and dimensions in terms of length, width, and thickness are far less important than the overall volume of the board, which is stated in litres. The Volume translates directly into how much weight the board can support. One litre of volume floats 1 kg of the rider's weight. To be able to easily stand on the board, with good stability, you will need a board with more than your weight in board volume. Furthermore, you have to take into account the gear you wear, for example a wetsuit, helmet and a vest, but also the weight of the battery and electronics located inside the board. A good general rule for beginners is to choose a board that is at least 20-30 litres larger than your weight in kilograms. E foil boards come in sizes ranging from 170 litres all the way down to around 40 litres. (Dwelle, 2024)

4.4.2 Tracks

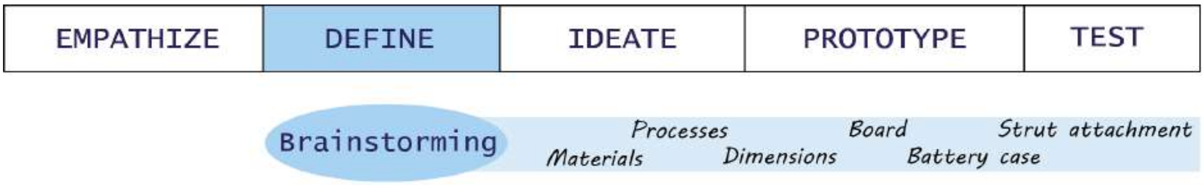
Tracks are located at the back of the board and are designed to hold the special screws from the strut, called track nuts. They are inserted at the start or middle of the track, depending on the model. With this mechanism, the driver can adjust the optimal position of the strut. The size of tracks depend on the measurements of the strut base. In our case it is 18cm long, and the holes are 1cm wide. Commercially available tracks are 20cm long, 2,5 cm wide and 3cm deep.(Fluid, 2025)

4.4.3 Battery case

The battery case needed to be capable enough to provide space not only for the battery itself, but also for the other electronics, like the electronic speed controller (ESC), anti-spark connector and the fuse. Because of the weight in the case it is usually located rectangular in the middle of the board. Batteries that are usually used are packs of 10 to 14s lithium-Ion batteries(Jan.T, 2023). The length of batteries connected in series depends on how many cells they have. To provide enough space for the different batteries and electronics, the case needs to be at least 30 cm long, 9,5 cm high, and 26 cm wide. (electric-foil gmbhCoKg, 2024)

Design

5.1 Brainstorming



The design phase started with a brainstorm, a creative technique that helped us develop the first ideas and point out some critical elements in the design of the board. Our main reason for building a whole new board was to place the battery inside, instead of on top, where the previous one was located. We divided our brainstorming into two rounds,twenty-five minutes each, to develop our proposals. Then we discuss and share our ideas with the group.

5.1.1 First round

Below, the points covered during the first round, along with their relevance to other decisions.

- Materials; will influence the choice of the manufacturing process, the required components, and their configuration.
- Shape of the board; will affect hydrodynamics.
- Battery placement; will affect the surfer's comfort and will influence the design of the board structure.
- Cables' placement; will affect surfer's comfort and will influence the design of the structure of the board.

During this first round, we decided that our board would be made of foam. Because commercially available foam plates were not wide enough, our only option for using this material was to glue several layers of it. Also, they weren't long enough either, so we had to find the best displacement of the pieces to obtain a resistant board. We debated different configurations (Figure 5.1).

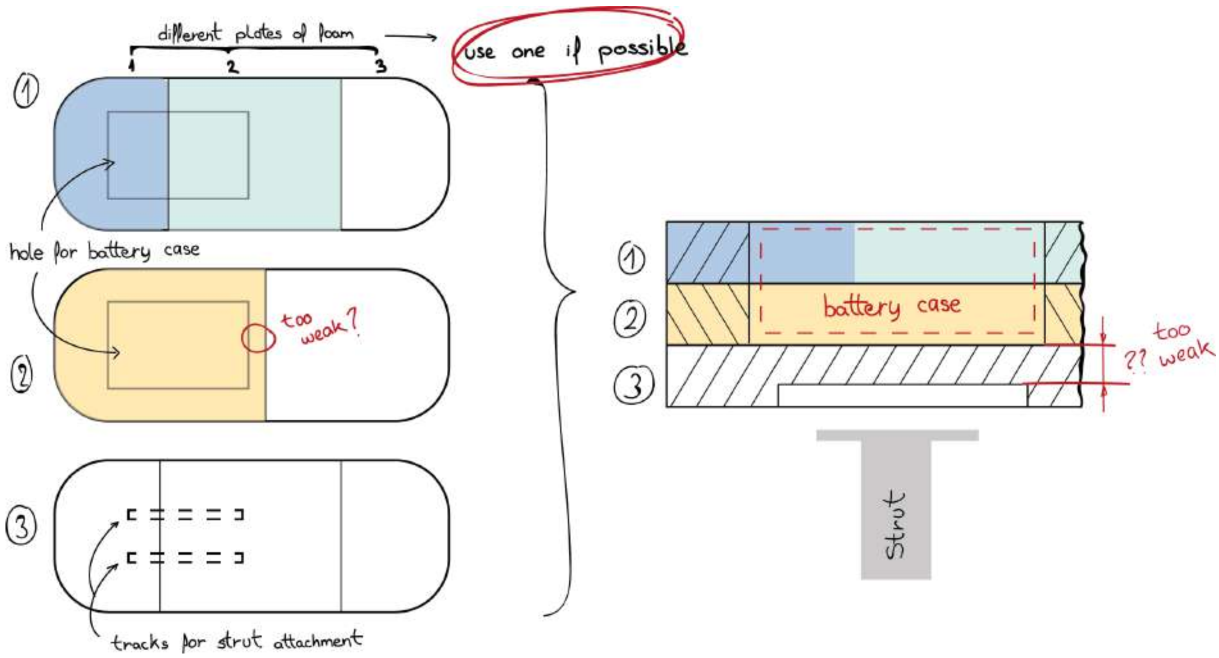


Figure 5.1: Brainstorming sketches 1

The shape that the board would eventually take was the next topic of discussion since it had to be good for the hydrodynamics but also comfortable for the person riding the board.
Finally,talking about the battery, we knew that during the previous iteration of this project the battery case was displayed on top of the board. Due to the handcrafting requirements, the previous group used a wing-surf board instead of an e-foil one. In this board, there was no possibility to carve out a case for the battery to place it inside. Therefore, it was placed on top, in the back part of it, inside a waterproof case together with the remote-control system. The cables were sealed with silicon to the case and hung loosely until they reached the motor, in the lowest part of the strut. However, with this battery placement the surfer has two options. Either stand in front of the case, which affects balance and results in less manoeuvrability, or stand with the case between your legs, which is uncomfortable and can be dangerous in the event of a fall. So, eventually as shown in the drafts, we kept the battery inside the board, right above the mast because we considered it to be the best option to keep the mass centre balanced. In the image 5.2 are some of the options for the cables placement with the new position of the battery.

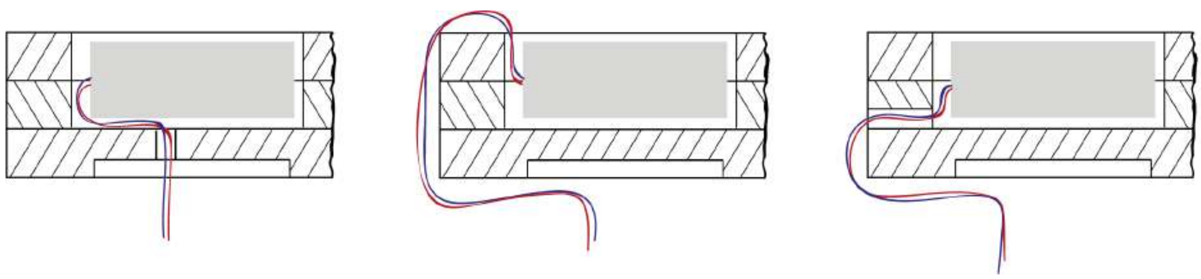


Figure 5.2: Brainstorming sketches 2

5.1.2 Second round

Below, the points covered during the second round, along with their relevance to other decisions.

- Point of maximum stress; will affect board's resistance.
- Battery case waterproofness was crucial
- Strut attachment; will affect the shape of the board, the position of the strut and balance.

Because the hole for the battery was right above the hole for the strut attachment, we decideed to fill up the second one with a harder material either XPS foam or a piece of wood, to make it more rigid, and carved the rails for the strut attachment on it.
For the waterproofness of the battery case, different shapes were considered (see figure 5.3) and tested

later during the 3D modelling and simulation stage. However, all of them were based on the idea of covering the hole with a lid that would have a piece of rubber or silicon to prevent water from coming in. The main decision about the cables was to choose between placing them around the board or making a tunnel for them. This was the best option for the user, but it was also difficult to ensure that all of its surfaces were covered safely with a layer of epoxy.

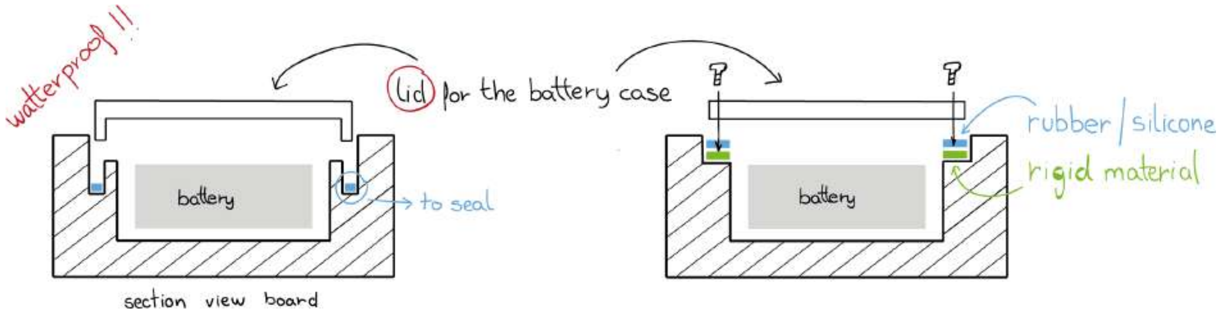


Figure 5.3: Brainstorming sketches 3

For the strut attachment, we chose to follow the same method as in previous iterations. We chose tracks instead of a fixed position. That is because thanks to the tracks, the user will be able to adjust the position of the mast. Furthermore, it enables to adjust the balance.
These decisions, made during the early stages of the design process, are explained in more detail in the following chapters. However, as time passed, some aspects of the design evolved, leading to our final product.

5.2 Bill of materials (BOM)

After the brainstorming, we decided what the board concept would be, what parts we wanted to build, and how we would assemble them. To represent that in a scheme, we used one technical tool named Bill of materials(BOM). There, every piece of a product is named and organized by assembles, where every assemble has a level. This tool is useful to understand the components, how are they related, and also how we are going to refer to them in this document. In figure 5.4 is the BOM, where all the pieces of the entire e foil are visible. The upper part outlined in blue is the part that we are focused on.

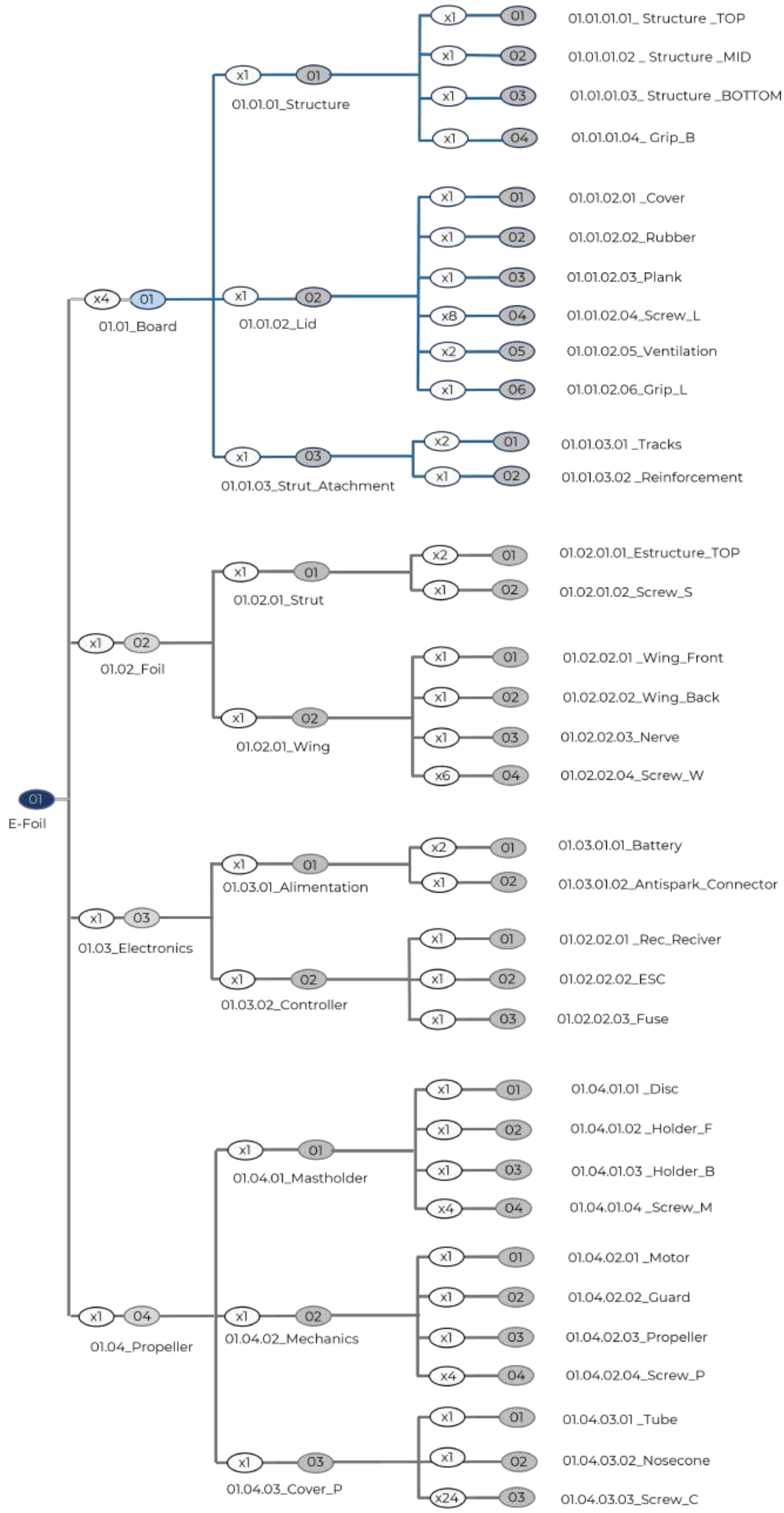
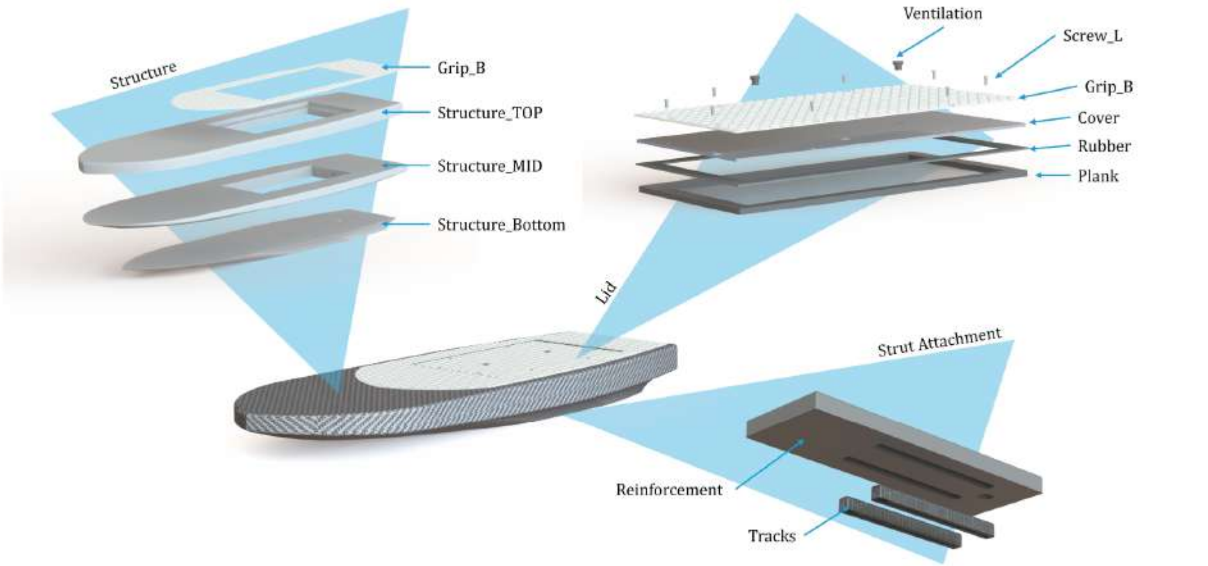


Figure 5.4: Bill of materials, highlighted are parts that we worked on.

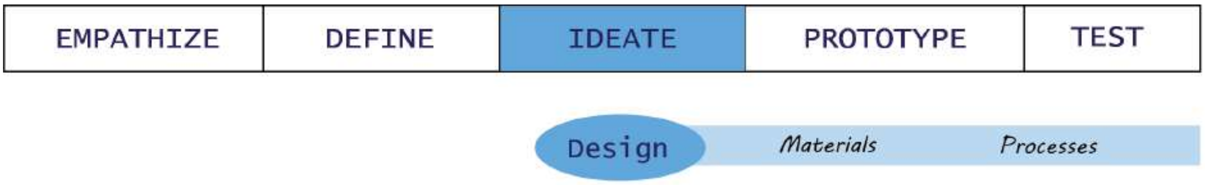
To make graphic the previous statement it is necessary to make a diagram to illustrate what we are actually building.



Board:	All the pieces that we are building together are going to have as a result a board compatible to make an e-foil.
Lid:	It is a system that closes the battery box and makes it watertight. The lid has six parts: Ventilation, Screws L, Cover, Rubber, and the plank.
Ventilation:	A watertight ventilation system that extracts moisture from the inside of the box and prevents overheating.
Grip:	Helps rider's feet stick to the board so you don't slip when surfing. There are two, one on the top of the lid, and another on the top of the board. It has to cover all the standing surface.
Cover:	Plate that covers the battery box. It has to be resistant because a lot of forces are going to interfere with this piece.
Plank:	Plate attached to the board where the rest of the lid is going to be attached using screws.
Rubber:	Sealing material that is going to make sure that when the cover is screwed, it gets smashed and provides waterproofness.
Structure:	Main body of the board. It is going to be divided into three parts that will be assembled (TOP, MID, and BOTTOM), and also includes the grip.
Strut attachment:	System that connects the strut of the foil with the board. It has two components: the reinforcement and the tracks.
Tracks:	Two rails where the screws of the strut can be adjusted. It has to be resistant and compatible with the existing foil.
Reinforcement:	Plate where the tracks are placed. It has to be resistant because all the tensions from the foil are going to be collapsing in this system. It is also used as a reinforcement for the structure.

Figure 5.5: Exploded diagram of the board's parts we are building.

5.3 Process and materials



Once we researched different materials and process options, we combined those ideas during the brainstorm to make our final choices.

5.3.1 Manufacturing process

First, we must choose the manufacturing method and then we choose the materials. The characteristics, advantages and disadvantages of the methods described previously compared in table 4.5. To explain the final decision and its implications, the following paragraphs outline the choices made. All discarded options are detailed in the appendix D.

Board structure
Our choice was to perform the shaping part with a CNC machine. This choice was based on the fact that we have both the knowledge and the resources to design a board that matches the fluid dynamic characteristics of the environment. It was a priority to have as much freedom as possible to design and obtain accurate results. However, the maker space at Oslo Met didn't have a CNC big enough to build the board, so we found an external provider for it. "Fellesverkstedet" is an external maker space where you can use the tools they have, including a CNC (Fellesverkstedet, 2025). The only limitation was that the CNC machine available there was only able to work with pieces of 5 mm height, so we adapted our design to that.

Tracks
We needed them to be strong enough to withstand the forces acting on them. We chose to 3D print because we could use a carbon fibre printer available in the Ocean Lab, where we were working.

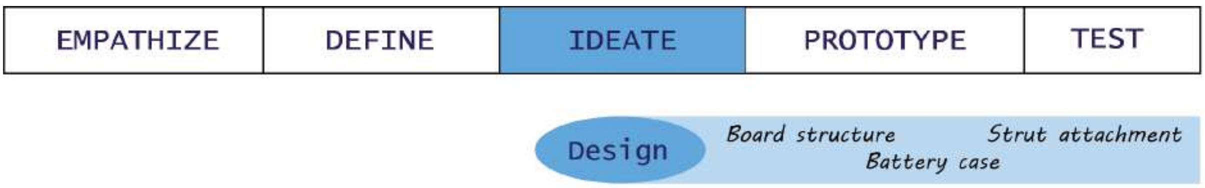
5.3.2 Materials

Once the manufacturing process is determined, the appropriate materials should also be selected. In this chapter, a summary of the decisions taken based on the research is given. The claims are justified and explained extensively in the appendix D.

Part	Material		Justification
Board Structure	EPS Foam	Covered with Fiberglass and a layer of carbon fiber	It is cheap and easy to work with it.
Reinforcement	XPS Foam		It is easy to work, and it is going to be used as reinforcement of the structure.
Tracks	ONYX		The material is lightweight; it can be printed precisely and is resistant.
Cover	Aluminum		It is the optimum material so the lit can be as thin and rigid as possible, so it can manage all the weight.
Rubber	Rubber		It is flexible, watertight sealant.
Plank	Polycarbonate		It is cheap, light and through its impact resistance, it is suitable to make threads by tapping.
Grip	EVA foam		It ensures great grip and comfort, while being lightweight, watertight, and sun- and saltwater-resistant.

Figure 5.6: Summarized material decisions

5.4 Product design



This chapter focuses on the key design decisions made throughout the development process and the reason behind them. It provides information on how each choice contributes to the functionality and usability of the product. Our product can be divided into three main parts, shown in figure 5.7. To see technical drawings of every part that is going to be in this chapter, see appendix E.

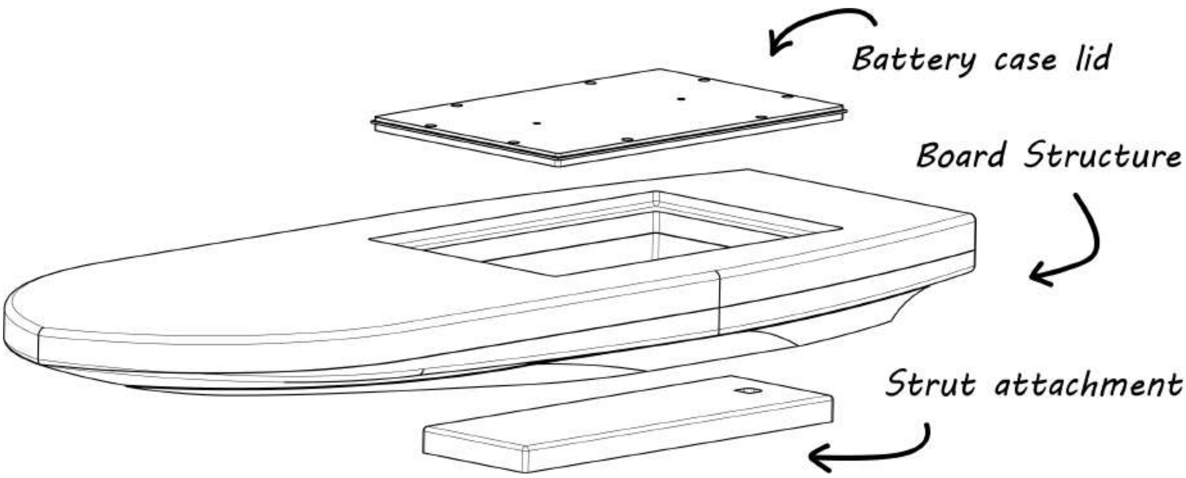


Figure 5.7: Simplified diagram of the board

5.4.1 Board structure

Inside the board assembly that we build, is a part called structure.and in this part we are going to explain and justify the decisions taken to get to the final design of the structure.

First, we have to sum up the basic requirements and characteristics that were mandatory for completing this task. Afterwards, we are going to explain, how we accomplished each of them. The primary requirements for the board are as follows:

- Allows the driver to stand on it without being hindered.
- Include a compartment to place all the electronic components safely inside.
- Space for the strut attachment.
- Size and volume should provide. enough stability and floating ability including all weights.
- Adapt design to CNC capacity.
- Design an efficient shape for smooth gliding and quick lift from the water.

Sizes and volume distribution
Although, the characteristics of the battery case are going to be described in the next chapter, it is necessary to mention the sizes for explaining the general shape.

For the battery case we decided to provide as much space as possible, with a minimum height of 100 mm. With that, some of the biggest batteries on the marked could fit in.The box dimensions are 500x300x100 mm. As we offer a beginner-friendly and universal e-foil board, it is important to make it as large as possible while still being able to use the existing foil.The chosen dimensions are 1600x600x150mm. Because the board is not a prism, the volume should be distributed properly to enable the lifting. Therefore, we have concentrated as much volume as possible in the 2/3 part of the board where the rider stands and where the strut is placed.

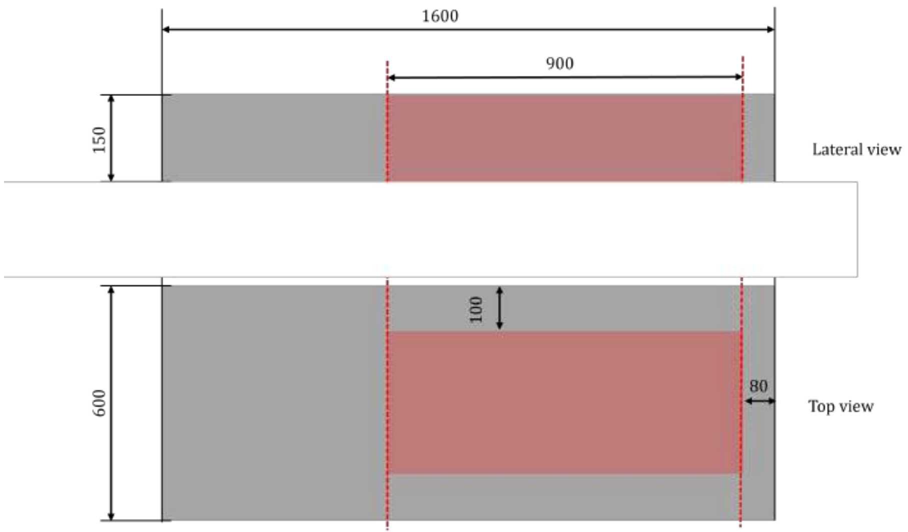


Figure 5.8: Diagram of the proposed volume distribution

As it can be seen in the picture 5.8, the red areas are the zones where we believe the majority of the volume should be located. Also, it is the zone where the battery box and the strut attachment is going to be located. The grey zones are the parts where the design could be modified for other reasons, like the benefit of the waterflow.

Shape and concept building of the structure
Once we have decided where the volume should be distributed, we can design the board so that it glides through the water as easily as possible. In this part we are going to explain the concept design, while in the "Fluid design" part 5.5 it is going to be justified and analysed properly.

Here is the idea of the concept design5.9

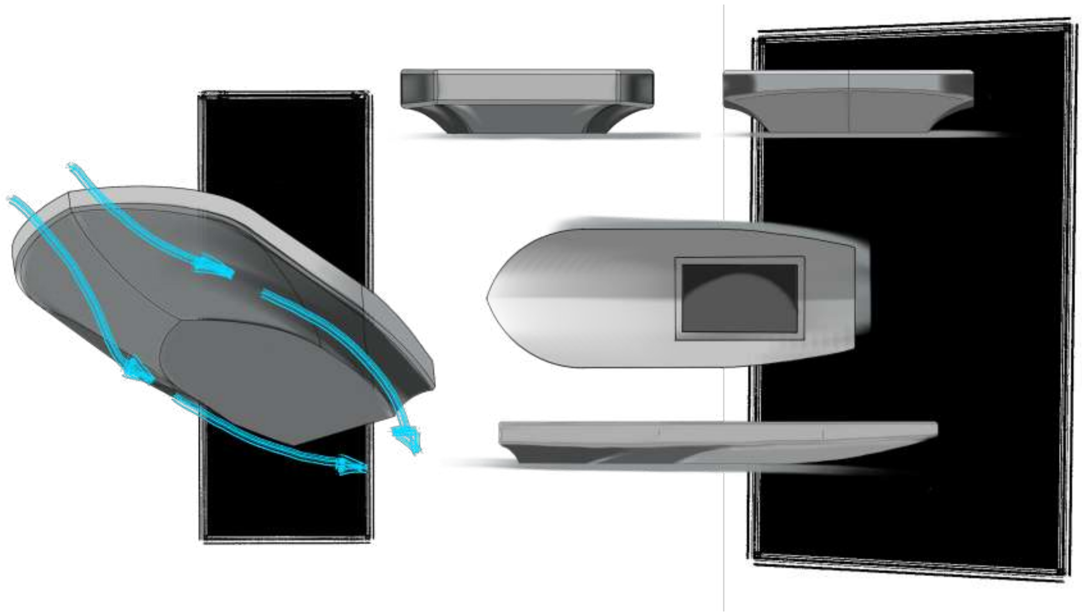


Figure 5.9: Concept design ilustration

Once we did that, a 3D model was made of it, to start with the building process, proper technical drawings and the simulations.

Here we see a comparison between the proposed distribution of the volume(see in figure5.8) and the actual distribution of the volume witch is 175 L (see figure 5.10).

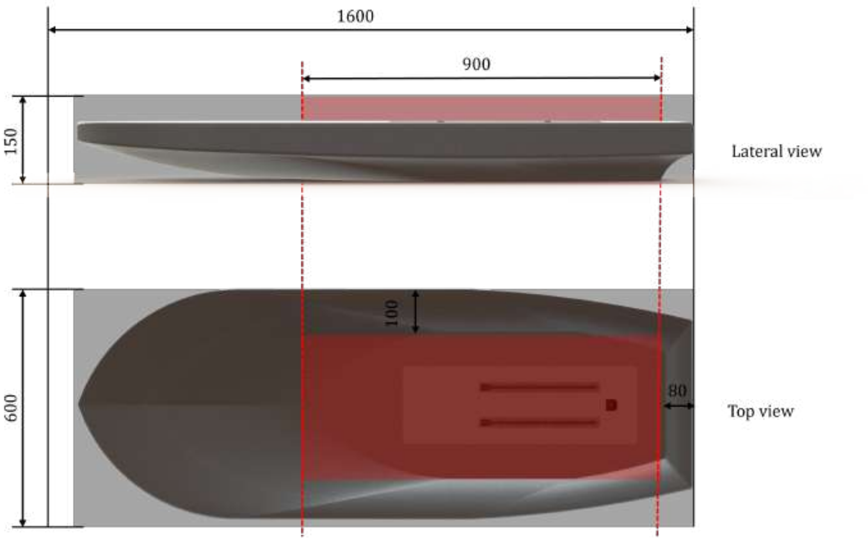


Figure 5.10: Volume distribution compared

Adaptation of the design to the CNC.
The available CNC machine at Fellesverkstedet, can only cut a height of 50mm. To make the construction possible, we had to divide the design into three parts, creating a flat surface every 50 mm. The result is shown in the figure 5.12.

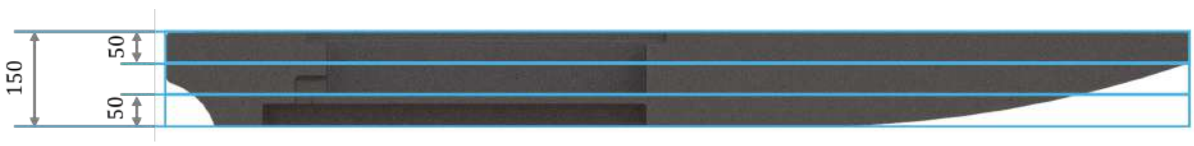


Figure 5.11: Scheme of the cut so it can be possible to be manufactured with the CNC machine.

Figure 5.12: 3D representation of the three parts and their respective names

5.4.2 Battery case

The battery powers the motor which propels the foil. That is why it needs to be kept in a safe place. Most currently available efoils on the market placed the battery inside of it, in an internal compartment. This placement helps maintain balance and stability by distributing its weight across the board. Moreover, keeping the battery within the board provides protection from water exposure, ensuring the electrical components remain dry and functional. Because we also chose to place the battery inside the board we design its structure consecutively.

E foil batteries need to be powerful, in order to provide enough power for the motor and to ensure a proper riding time, which makes them large and heavy. Even though our project does not focus on the electrical components, we want to ensure, that any future team working, with the prototype, has enough space to put in a battery as big and powerful as they need. The compartment we have designed to house both the battery and the remote-control system measures 50x30cm. The remote-control system has dimensions of 26x10cm, leaving a rectangular space of 40x30cm available for installing a new battery. This compartment was initially designed with 12 cm depth, because we wanted to make it as big as possible. However, due to the layering required for CNC cutting (see Figure: 5.13) and the height of the foam plates (5 cm), we reduced the depth to 10 cm. This allowed the final layer of foam to be completely flat on one side, which was essential for the CNC process.

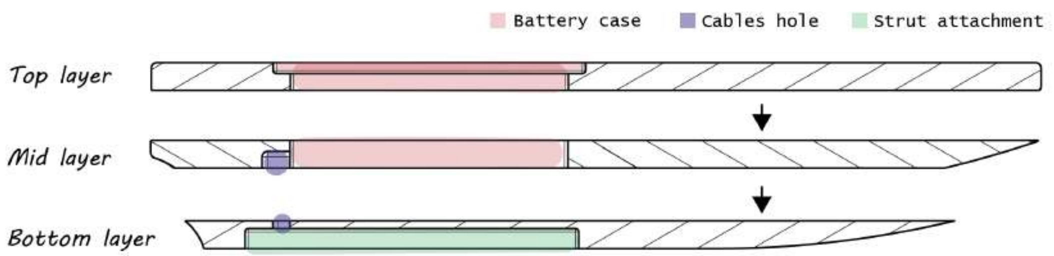


Figure 5.13: Diagram of the board layers

Since we couldn't determine the exact weight of the battery to be used, we decided to place the compartment right above the strut, where the board's centre of mass is located. This placement was chosen to maintain balanced weight distribution, making it easier for the rider to stand on it.

To keep the electrical components safe, we designed a special waterproof lid. To fit the lid into the compartment, we adapted its shape. As shown in the image below 5.14, which represents a section view of the board. The opening at the top is wider than the rest of the compartment. The lid fits into this 3 cm deep step so that it equalises the height of the board and the top remains completely flat.

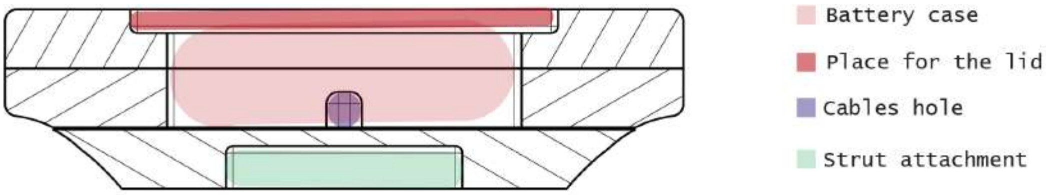


Figure 5.14: Section view of the board showing battery compartment

Lid

The designed waterproof lid consists of three parts. An aluminium cover, a rectangle of rubber and another rectangle made out of a polycarbonate plank, which is completely fixed to the battery compartment in the board (see figure 5.15).

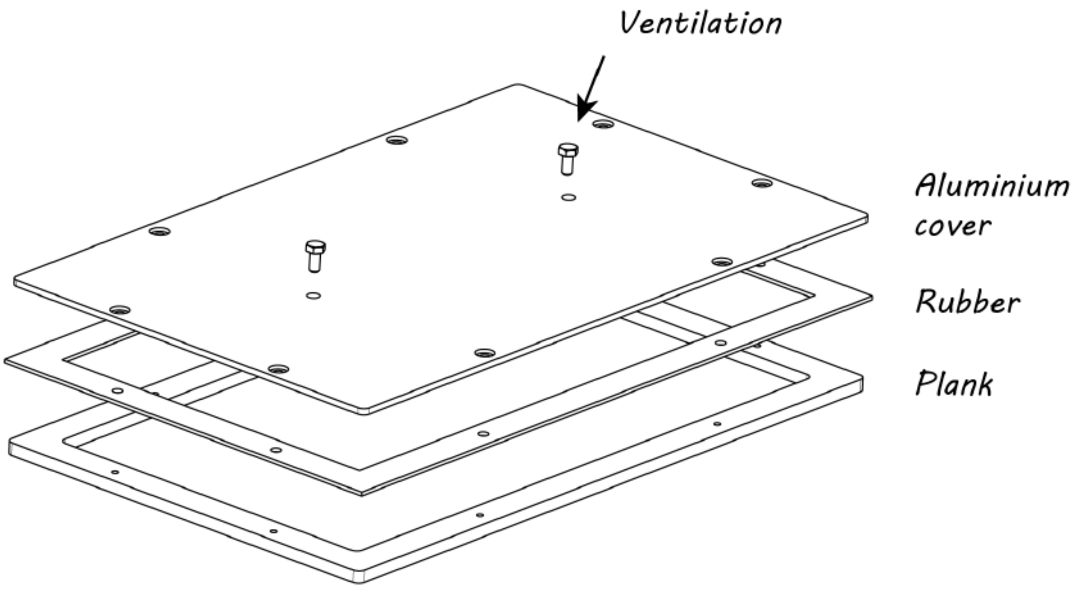


Figure 5.15: Diagram of the board layers

The aluminium cover got attached to the polycarbonate plank,which was already glued to the board with epoxy,using eight M6 screws. To achieve water tightness, a piece of rubber, was glued on the edges of the aluminium cover, to seal the space between the cover and the plank. When the screws are tightened, the nitrile rubber get compressed and fills all the potential leaks. While the cover has been designed, we considered different materials options.4.2 We were mainly debating between polycarbonate and aluminium. For the decision we had to take into account several factors and requirements, such as:

- Lightweight.
- Durability
- Degradation rate
- Costs
- Machinability for the CNC.
- Thermal conductivity, due to the generated heat of the electrical components and sunlight

The aluminium cover has total of ten screw holes, two at each side and another two in the middle of the cover for ventilation screws.They are waterproof, but release the generated heat by the electronic components and cool them down.

A layer of EVA foam is placed on top of the board completely covering the lid. This is meant to be for surfer's grip, making the surface of the board non-slip.

Cables hole
Since the battery needs to be connected with the motor, which is found in the lowest part of the strut, we included an internal passage for routing the cables. We initially considered to create an opening in the cover to route the cables around the back of the board. However, we dismissed the idea so that the surfer is not hindered while riding. Instead, the cables route directly downward from inside the battery case.

The designed cable hole has an L-shaped geometry, which posed a challenge during production. Because the used CNC machine could only mill vertically, it could not create internal L-shaped cut in one continuous operation. As a solution, the horizontal section was separated from the vertical one, into two different layers of foam. By stacking the two layers together (see Figure: 5.13), we effectively created the wanted angle channel, while making it compatible with the CNC process.

5.4.3 Strut attachment

Our priority, while designing the strut attachment, was to make sure, that it was compatible with the strut bought by the previous group.

Two possibilities were compared. Either to fix it with screws, to a wood or aluminium plank set in the bottom part of the board, or design a mechanism, consisting of two tracks that allow the user to place the strut in different positions. Although, fixing it with screws would be easier, we decided to design the adjustable mechanism.

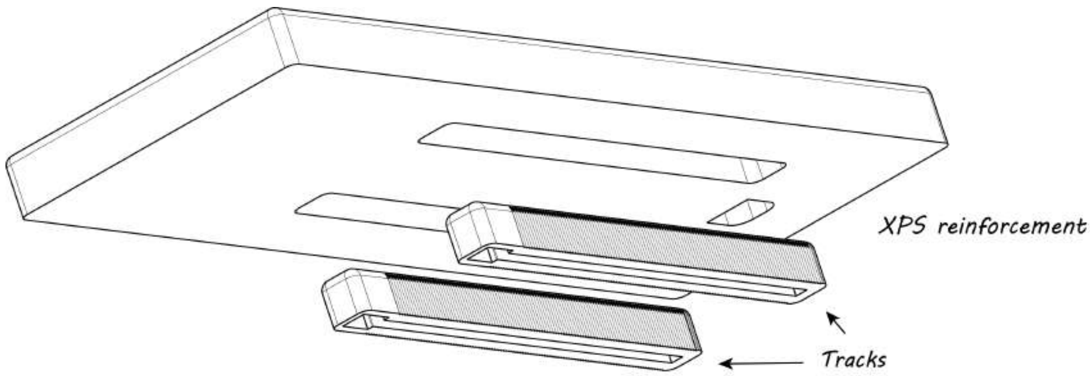


Figure 5.16: Strut attachment pieces

The strut attachment consists of two pieces, a XPS plate, integrated into the bottom of the board, and two tracks glued into the XPS, shown in5.16. With these tracks and the four adjustable track screws, from the strut base(see figure5.17), it can be moved into different positions.

Figure 5.17: Track nuts and screws from the strut base.

Track nuts get inserted at the opening of the track and then placed to the desired position as well as the strut base. Once the screws have been inserted and tightened, the strut is attached.This mechanism is also used in actual e-foils.

Figure 5.18: Overview of the functionality of tracks

This choice has the following benefits.

The most important point is, that the adjustable position of the strut makes it possible to compensate for small imbalances in the structure. This is a great advantage, since we built a prototype, which does not guarantee full precision when carrying out the design. That's why some measurements might differ from the initial ones. Secondly, this option enabled compatibility not only with the current strut, but also with others. This opened up the possibility of buying or building a new one in the future. Finally, the strut will remain a removable component for the user's comfort.

Tracks

Tracks were the key component of this adjustable mechanism. To have more control over their characteristics we have decided to design and 3D print them. They are meant to be compatible with the strut, bought by the previous group, so it was important, to keep the general measurements of it in mind.

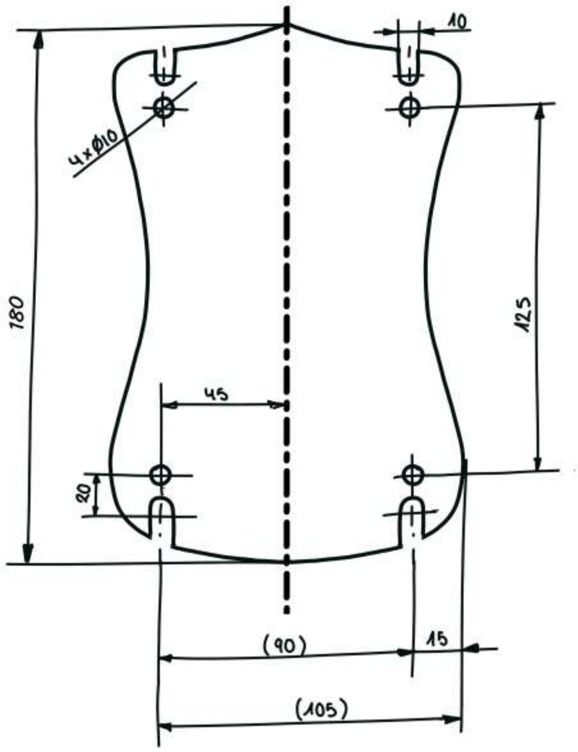


Figure 5.19: Sketch with general measurements from the strut base

Since the strut is positioned in the centre of mass, the point of maximum stress, we decided to reinforce this area using XPS foam. Compared to EPS, this foam offers greater strength, providing a better foundation for the attachment B. The XPS plate is located directly beneath the battery case. The tracks were carved into the XPS plate. To determine the exact position and length of the tracks, we considered the spacing, between the screw holes at the base of the strut.

The screws used to attach the strut to these tracks are called track screws and have a very specific shape so that they can move in the rail before being attached. They get slide into the track through a wider opening located at the beginning of the slot. Figure 5.20 shows a sketch with different views. In section view A-A, the different widths of the slot can be recognized. These are specifically designed to restrict the screws' movement along the vertical axis.

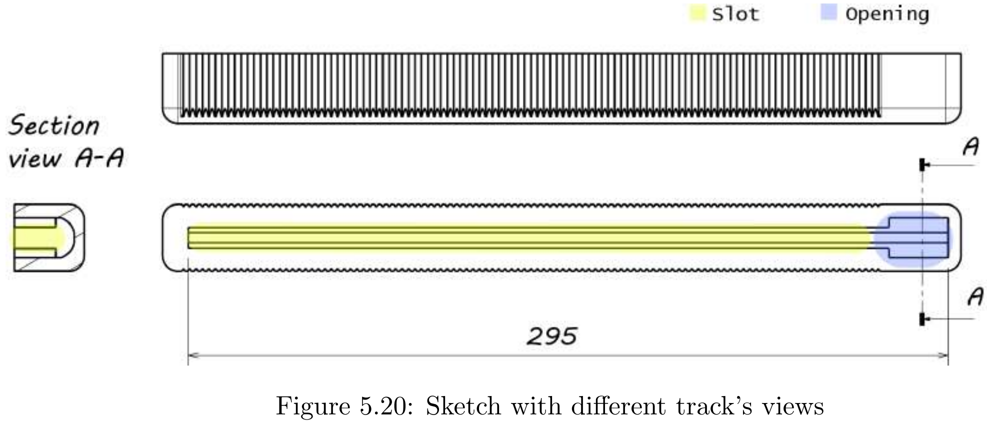


Figure 5.20: Sketch with different track's views

The use of inclined planes in the walls of the slot, (shown in this section view5.20) is justified by the choice of 3D printing as the manufacturing method. 3D printers require support structures, for overhanging parts, which are removed after printing is complete. With this design, fewer supports are needed, and easier to remove.

5.5 Fluids design

The shape of the board is going to be studied in this paragraph. This will be done by following existing shaping techniques and evaluations of simulations in SolidWorks.

Board shape

In figure 5.21 are some basic surfboard shapes shown. The goals for an efoiling surfboard are stability, planing and easy turning. For our board design we combined a squared tail, V-shaped / flat bottom and chine rails. The squared back is the most responsive, the v-shaped combined with the flat bottom has efficient planing surface and it makes the board easier to turn and the chine rails give more control over the board (Orbelian, 2017). These claims are applicable to normal surfboards in water, so this will be evaluated with waterflow simulations to see how the board behaves around take off of planing. Because we build a board that is supposed to go foiling we also use SolidWorks simulations to see how this design will react while planing through airflow.

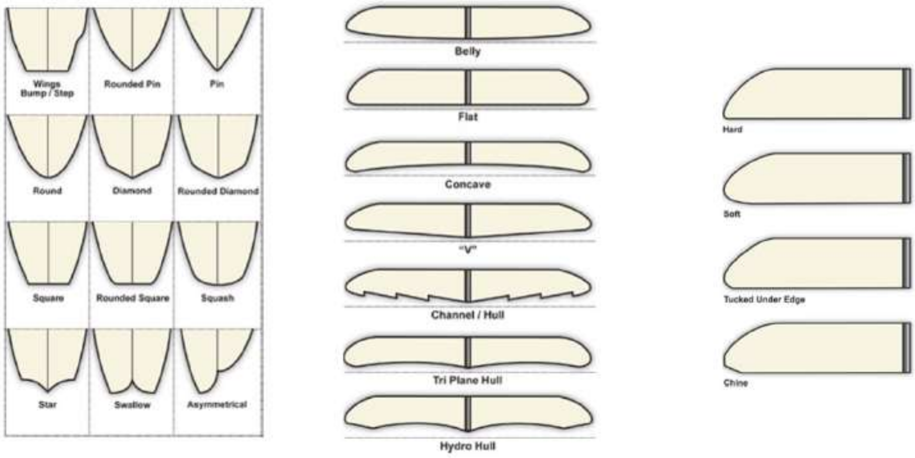
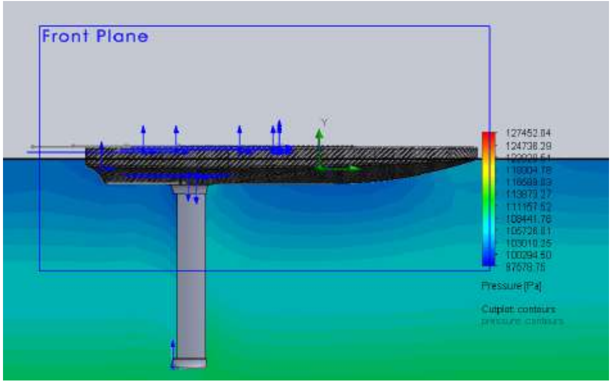


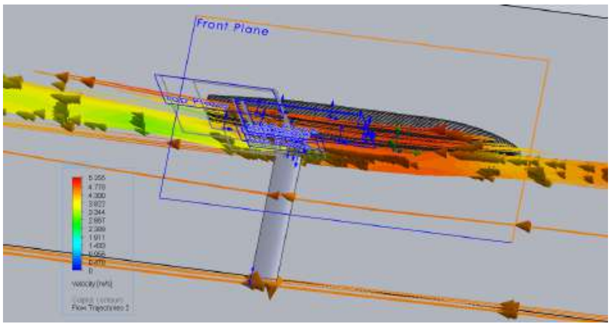
Figure 5.21: Possible shapes of surfboards

Water-flow simulation

To take off foiling, flow separation on the bottom of the board can help take off earlier, unfortunately that is not visible. Due to the size of the battery case needed and usage of the CNC it is not possible to add streamlined chine strips in the design that can cause this flow separation. Due to the layers of fibres and epoxy, those details would fade and not make a difference on the end product. Because the top of the board drives through air we are not comparing the pressure with the ambient air pressure. What we see in 5.22a is higher pressure under the nose (lightblue region) and lower pressure under the middle and back part of the board (darkblue region), this causes a small moment or rotational force. Due to the higher pressure being in the front, the rotational force is counter-clockwise. This is called pitch up. So for take off there is a force upward created by the design of the board, which is positive. The goal of researching a hydrodynamical board that helps foiling is achieved. In 5.22b there is a wake region with lower velocities (green and yellow arrows) visible behind the board. During designing we rounded the edges of the back of the board to minimalize this, for this design taking into account enough space for the battery and strength in the middle, this was the optimal choice.



(a) Pressure plot board moving through water



(b) FLow trajectory velocity

Airflow simulation

While foiling the board is planing or flying over the water, to check what the board does in this state i simulated airflow of 4.5 m/s. In 5.23 its visible that the pressure difference between the top and the bottom of the board (inbetween the blue line on top and the green line on the bottom) 10 Pascal is. With a surface area of $0.62\,\mathrm{m}^2$ we use bernoulli's equation along a streamline

$$F = \Delta P \cdot A$$

to find that the lift is 6.2 N or 0.63 kg (Yunus. A. Cengel, 2022). This seems to be not that much, but the board will be in between 8 and 12 kg. So the board even without lift force of the foil will be able to lift 5 to 8 percent of its own weight. Next to that there is a small dark blue lower pressure region visible on the top of the nose. With higher pressure below the board and lower pressure on top, the goal regarding the aerodynamics, that the design should not work against the lift generated by the foil is accomplished.

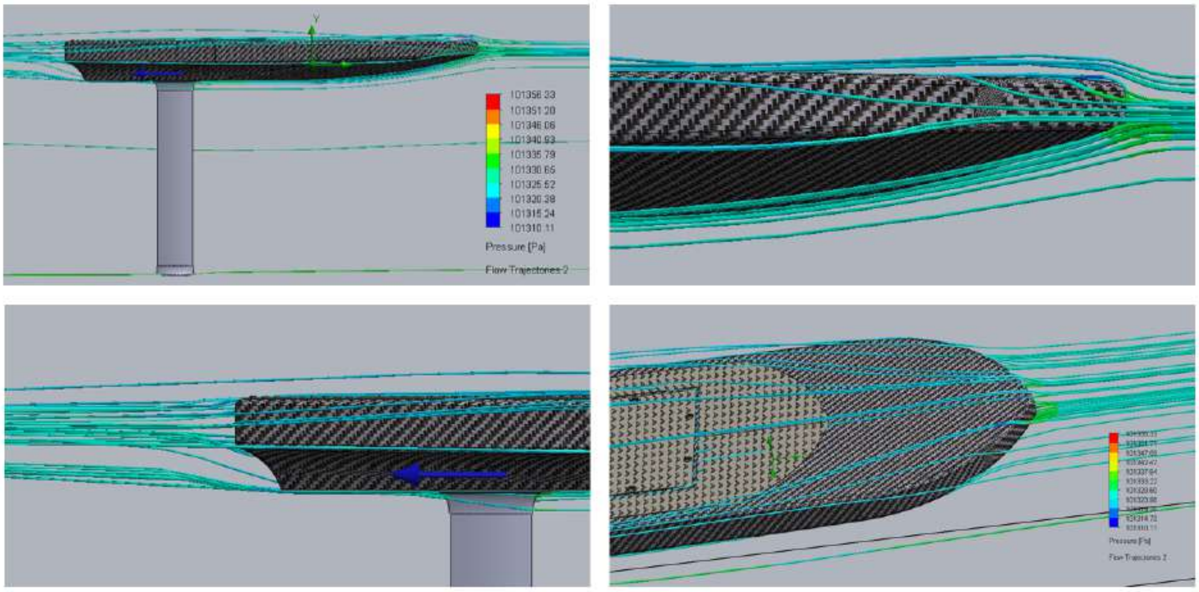


Figure 5.23: Pressure trajectory around board

5.5.1 Budget

After considering the previous steps, a budget of 6926,43 kroners was set up to accomplish this project. A detailed calculation and explanation can be found in the appendixF

Diagram of solution

To sum up all the decisions there is three diagrams.

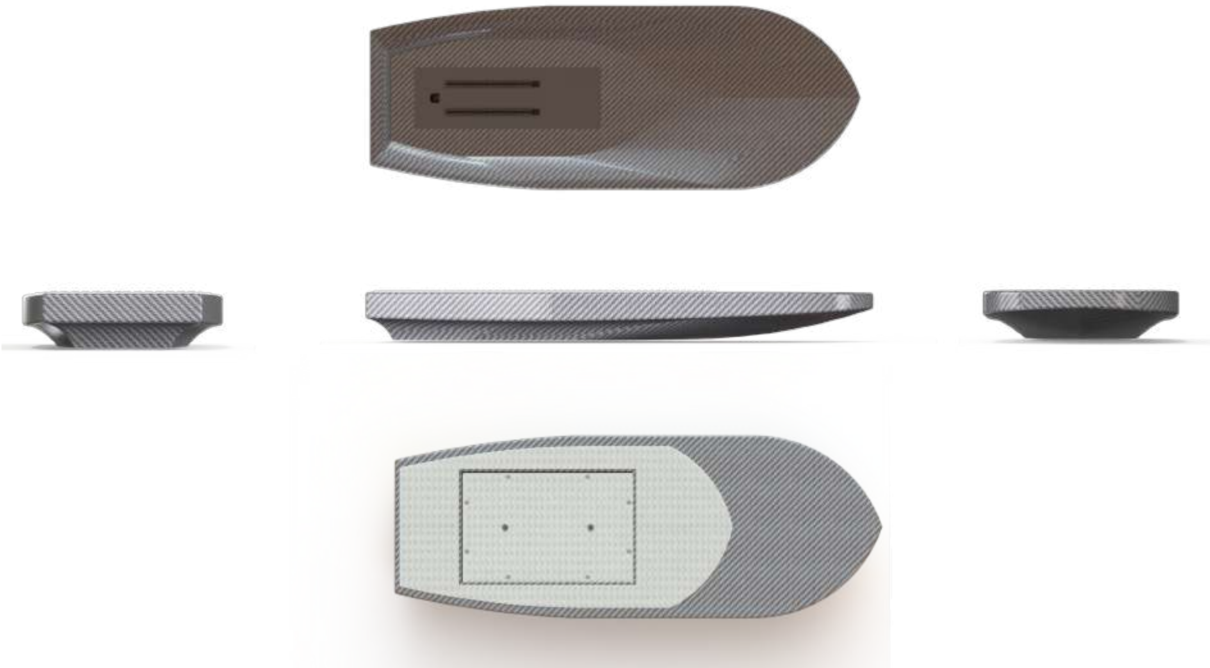


Figure 6.1: Orthogonal views of the design

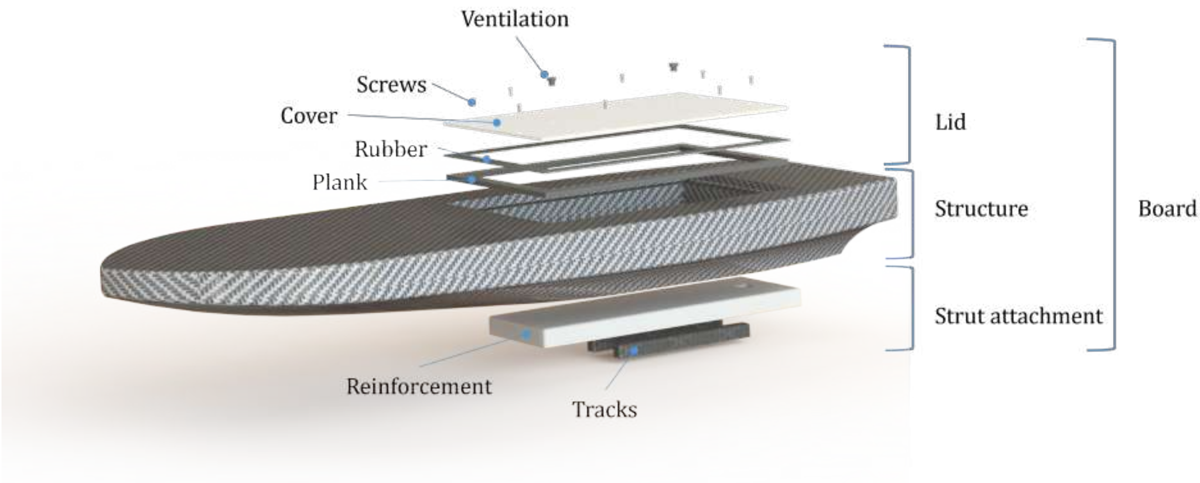


Figure 6.2: Diagram with parts and modules

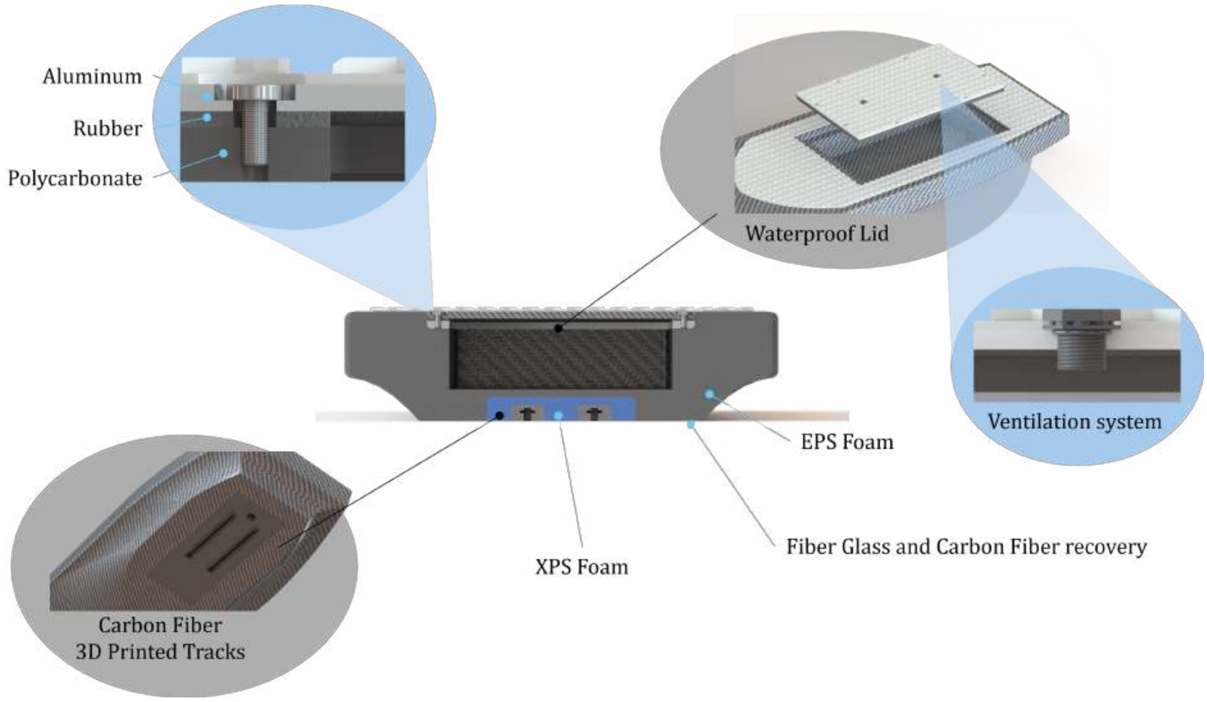


Figure 6.3: Overview parts of the board

Building process

The building process is defined by different steps, which will be explained in this chapter.

7.1 CNC cutting

There are two main points to consider, in order to adapt the design to the correct construction of the pieces: the files and the materials. In order to transfer the information to the CNC, it is necessary to have both a 2D design of the part and a 3D design. The procedure for building all parts varies from case to case and is explained in more detail in the following sections.

7.1.1 Board structure

The CNC machine that we used, has only a cutting capacity of 5 cm height, so the design was divided into three structure pieces. In order to find the point of origin, it was necessary to create a reference for the boundaries of the materials in the 3D model so that it would not cut through them.

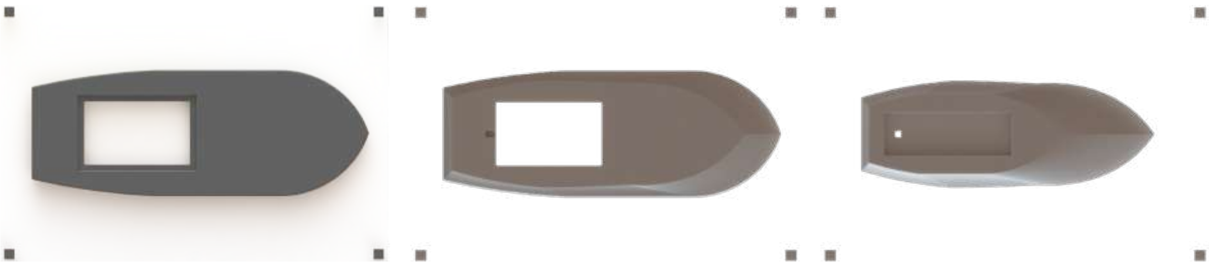


Figure 7.1: Structure pieces

At that time, each structural piece was to be made from three 1200x600x50 mm EPS foam planks. To ensure that the board fits and that the boundaries of these three boards are the same as those of the references, the EPS boards were fastened to the edge of the work surface with screws.

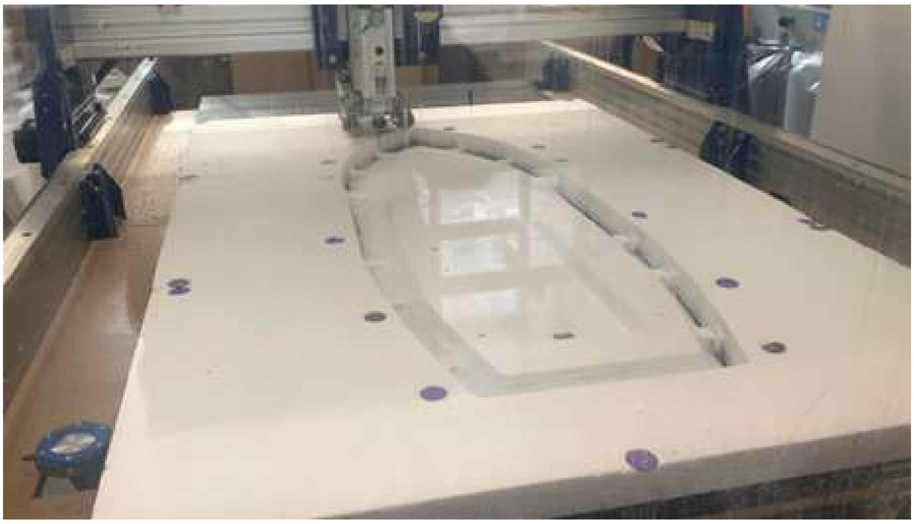


Figure 7.2: CNC milling foam

The parts to be cut should be fixed to the EPS planks to hold them in their original position and prevent movement. To achieve this, it is necessary to add 'tabs' to the 3D model. These are pieces of material that are not cut with the CNC, but are subsequently removed by hand. Once the entire board

Figure 7.3: Example of foam piece

structure had been cut to size and the tabs removed, we had a total of nine individual parts for the construction.

7.1.2 Reinforcement

The reinforcement is made out of XPS foam. As it is only a small piece, a 1185x585x50 mm XPS sheet is sufficient. The precautions before cutting, such as taking tabs, references and the entire cutting process into account, are identical to EPS foam.

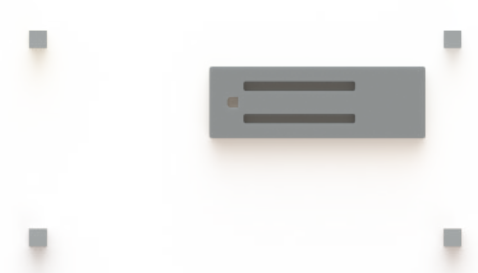


Figure 7.4: Reinforcment map

The height of the piece is 36mm and the plank is 50mm, so it was necessary to do a pocket before start the cutting.

7.1.3 Cover

The material for the cover is an aluminium plank of 5mm thickness. The first step in production is CNC milling. Only a 2D model is needed for the design. As the metal is a hard material and we could not fasten it directly to the table with screws, the first task of the CNC machine was to drill holes with the drill into which the fastening screws would later be inserted.

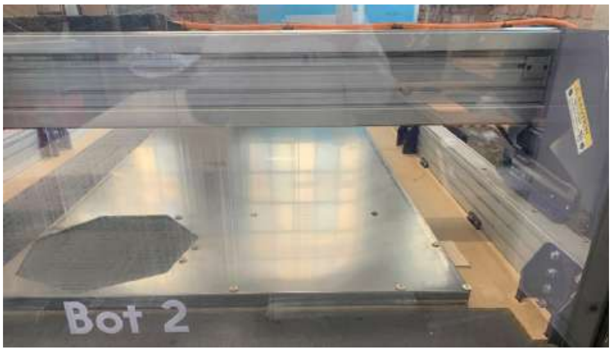


Figure 7.5: CNC with aluminium

All the holes have been made with the pocket tool as they were with more surface than the drill of the machine. To cut the aluminium was necessary to get different drill so it can be milled properly.

Figure 7.6: Tabs and braquet

Aluminium also requires tabs to secure the part to the plank during processing. This meant that we first had to break the finished panel out of the tabs and then cut off the remnants. To achieve this, we used a manual milling machine, which also served to remove sharp edges so that the user could grip them safely.

Figure 7.7: Edges

Two M12 threads were required for the ventilation of the battery box. To produce the thread manually, we used a technique called ”tapping”. This is a process, where threads in a pre-drilled hole get produced. In this way, bolts or screws can be screwed into the threaded hole, creating a threaded connection.

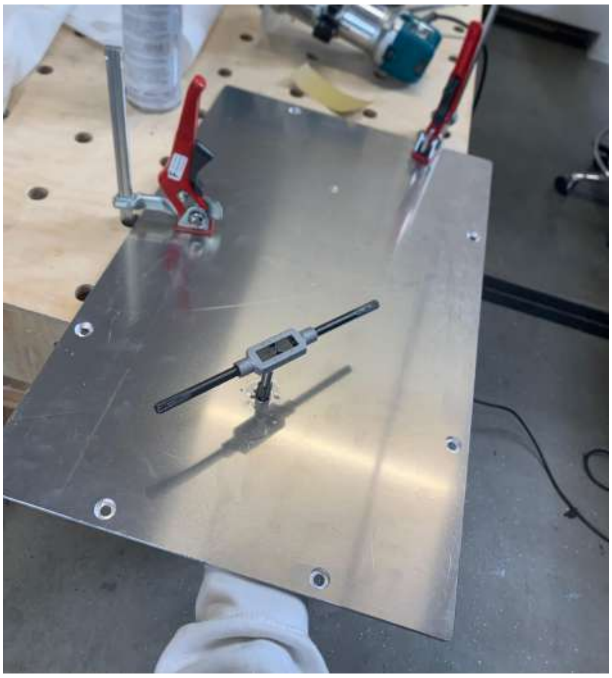


Figure 7.8: Aluminium tapping

7.1.4 Plank

The process for making the plank is quite similar for the cover, except that the tabs were removed with a cutter knife instead of a manual milling machine.

Figure 7.9: Cuting tabs with a cutter knife

7.1.5 Tracks

The tracks were produced in the Ocean Lab using a special 3D printer that can print with 'Onyx'B.(Markforged, 2025a)
The machine was set to fill 37% of the piece in a triangular pattern. The fully filled wall layers, on the opposite side of the piece are two, but for the floor and the roof of the piece, 4 layers were necessary. With these settings the printing took 46 hours of printing.

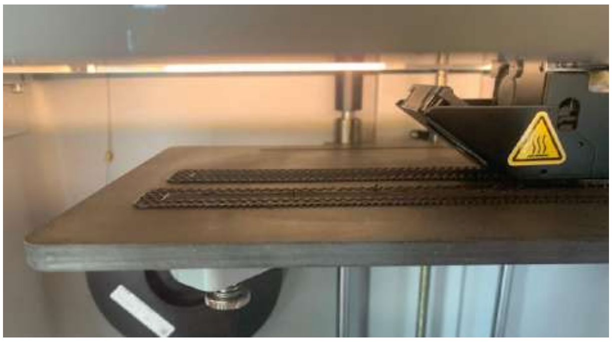


Figure 7.10: 3D printing patern inside tracks; triangular filling

In order to achieve the desired shape and functionality, the rails had to be manufactured with support material. After printing, this was carefully removed with pliers to achieve a clean result.

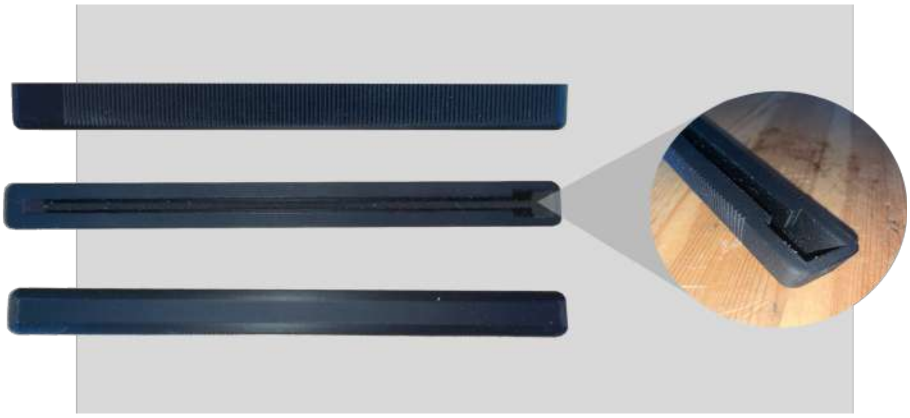


Figure 7.11: Overview of the resulting tracks

7.1.6 Grip

To make the grip, we used the lid as a reference for the centre part and adapted the remaining part to the shape of the board. The material was cut to size with a cutter knife. In addition, cut-outs were made for screws and two holes for ventilation. As the EVA foam mats had a puzzle pattern, some parts were customised.
Here we can see the process, of building the grip for the cover:

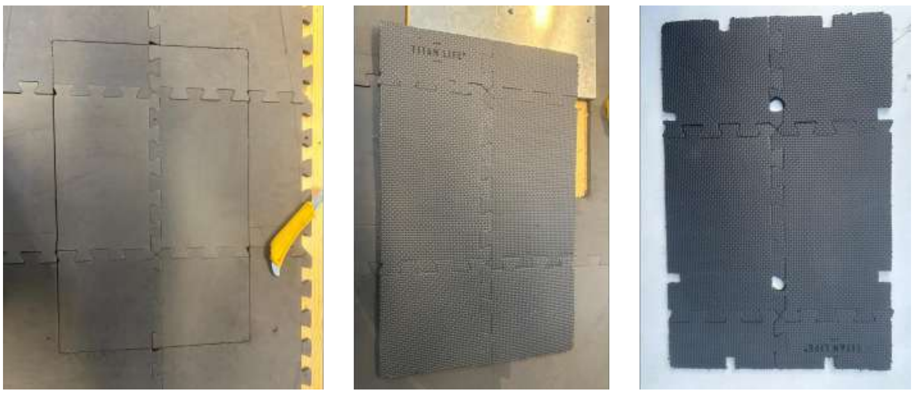


Figure 7.12: Proces of cuting the grip forthe cover since the initial drawing until the screw placement.

And here the process of building the grip for the board:

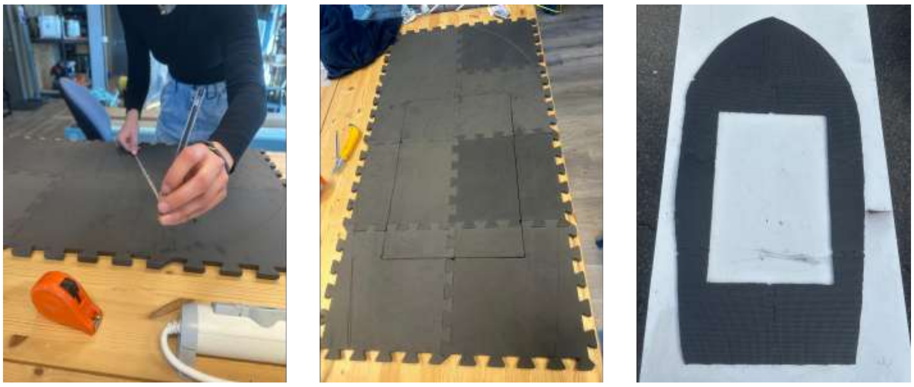


Figure 7.13: Process of cuting the grip for the board, since de inicial handmade drawings unil the final cut.

7.1.7 Assembling the board structure

Before we could start applying the layers, the nine individual parts and the reinforcement of the tracks had to be joined together to create the board structure. The first step before assembling was to sand down all the tabs to achieve the desired smooth surface.

Figure 7.14: Sanding down the tabs

As the parts were made of EPS foam, it was necessary to glue them together with epoxy. To mix the epoxy resin, a ratio of 2:1 between the resin and the hardener was required according to the packaging instructions. We then had to mix the two substances together in the beaker. At first, a hazy mixture forms, which must be stirred until the liquid is clear and transparent.

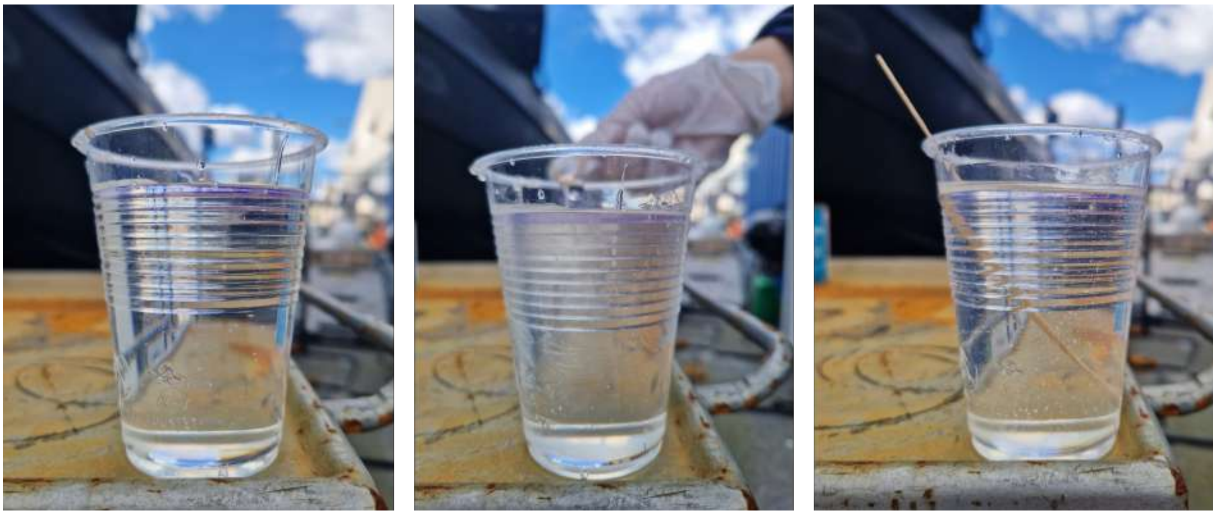


Figure 7.15: Epoxy phases

As the parts had to be joined horizontally, applying and bonding them with the liquid resin was a challenge. Furthermore, the epoxy needed at least 24 hours to harden. To hold all the parts in place, weight discs were placed on the board.
After the curing time, it was discovered that the newspaper used as a base was stuck to the top of the board. As EPS is a fragile material, holes appeared after removing the paper, which had to be filled with glass fibre filler. Although this affected the aesthetics and the smoothness of the surface of some parts disappeared, but we ensured that the structure was hard and waterproof.

Figure 7.16: Result after gluing

7.1.8 Layering and epoxying

The layering process is systematic; we have used a method that is described in the next steps.
Each layer is sanded beforehand and then coated with epoxy resin. The cut-to-size glass fibre product is then placed on the surface. The material is applied tightly to the surface with spatulas to remove any air bubbles. Finally, epoxy resin is applied once more and spread with the spatulas. It must then be left to dry for 24 hours.

Figure 7.17: Layering phases

To ensure the necessary hardness and quality of the board, we decided to use 4 layers of glass fibre and half a layer of carbon fibre on each side. The schedule was distributed as follows:

DAY	Material	Task
1	Fiber Glass	Layer 1 Bottom
2		Layer 1 Top
3		Layer 1 Battery Box
4		Layer 1 Battery Box
5		Layer 1 Cable hole Bottom
6		Layer 2 Bottom
7		Layer 2 Top
8		Layer 3 Bottom
9		Layer 3 Top
10		Layer 4 Bottom
11		Layer 4 Top
12	Carbon Fiber	Layer 1 Bottom
13		Layer 1 Top
14	Glassing	Layer 1 Bottom
15		Layer 1 Top

Figure 7.18: Layering plan

Before each application of the underside, the tracks and the cable hole were masked with adhesive tape to avoid contamination, and once dry, the masked areas were cut out and covered again for the next layer.

Figure 7.19: Process for final glacing since protecting the tracks with masking tape until afteran uniform distribution have the final result.

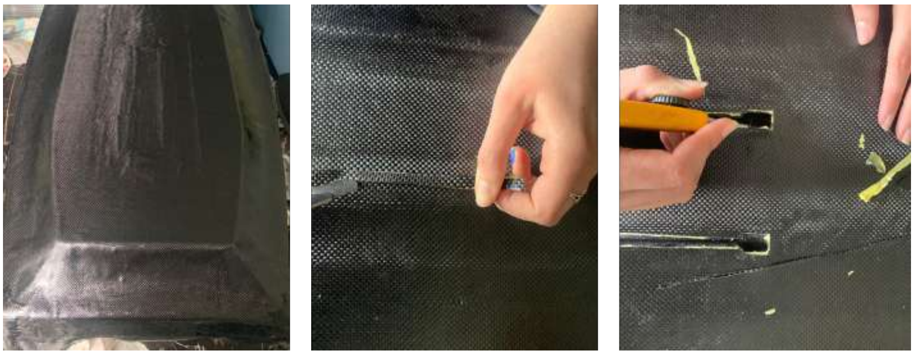


Figure 7.20: Process of cutting the textile above the tracks after every layer. It was necessary to do the first cut wit tactile references and after cutting the exceeded masking tape and perfection it.

7.1.9 Reinforcing edges

With the last layer, the edges were too sharp and uneven. To reinforce them and ensure there were no holes, we filled the critical areas with fibreglass filler, waited 30 to 40 minutes, sanded and repeated until a uniform surface was achieved.

Figure 7.21: Process of filling the edges. It was necessary to make it by hand, and sand it after drying to have an uniform result.

7.1.10 Painting and glassing

Although the focus of the project was never on aesthetics, we wanted to hide the inconsistent use of different materials. We therefore developed a design that hides the irregularities of the glass fibre and at the same time creates a transition to carbon fibre. To do this, we covered the parts we wanted to keep with newspaper and then sprayed them with black mate spray.The edges were also painted to conceal the filler at the edges.

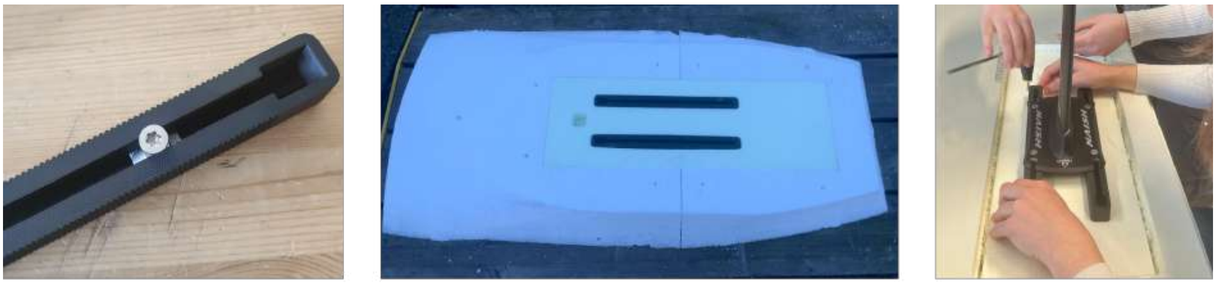
Figure 7.22: Painting process

Figure 7.23: Before and after the edges have been filled.

After painting, the surface had to be made flat and waterproof to protect the integrity of the fibres from sun or impact. Therefore, we carried out a process called glazing, which consisted of applying a final layer of epoxy to the surfaces.

7.1.11 Assembling final product

In this section, we will explain the various assembly tasks that we had to carry out during the construction process until the board was ready.
The first assembly took place right at the beginning, when the tracks were glued into the reinforcement. A lot of epoxy was needed to fill the jagged cut-outs of the constructed track walls without allowing it to get into the slot. Beforehand, the screws were checked to ensure that they worked and also with the dimensions of the strut.



Track - Screw   Track - Reinforcement   Track - Strut

Figure 7.24: Track assembly

After everything else was done, the lid should be mounted on the board.
The first step was to fix the plank with the board. We applied epoxy resin to the corresponding area of the battery compartment. However, since the surface was uneven, the plank did not stick well enough everywhere, and the gaps had to be filled with fibreglass filler. Additionally, the walls were sealed with silicone to ensure that no water could enter.

The last part was to assemble the lid.As a first step, the ventilation had to be screwed in the threads. Because the screw is made out of plastic and the plate out of metal, we had to put oil on the screw, and the thread and turn it with a wrench.

Figure 7.25: Ventilation system assembled to the cover

The second step was to cut the nitrile rubber into stripes. Then we glued them with epoxy onto the aluminium. One half of the cover was made and the other half after 24 hours, to connect them properly.

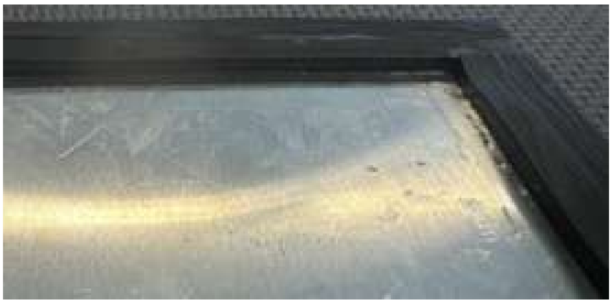


Figure 7.26: Rubber attached to the cover with epoxy

The third step was to drill holes through the rubber, so the screw can go through it tightly. The last step was to glue the designed grip onto the lid with epoxy.

Figure 7.27: Drill holes trough the attached rubber

Afterwards we did the same with the other parts of the grip and checked if everything fitted.

Figure 7.28: Lid anatomy

Final product

Below is the final result of our project: overall images of the developed design, along with photos of the fully built and assembled prototype.

Figure 8.1: Top and bottom of the final product without attached foil.

Figure 8.2: Final product, with attached foil, prepared to go into the water.

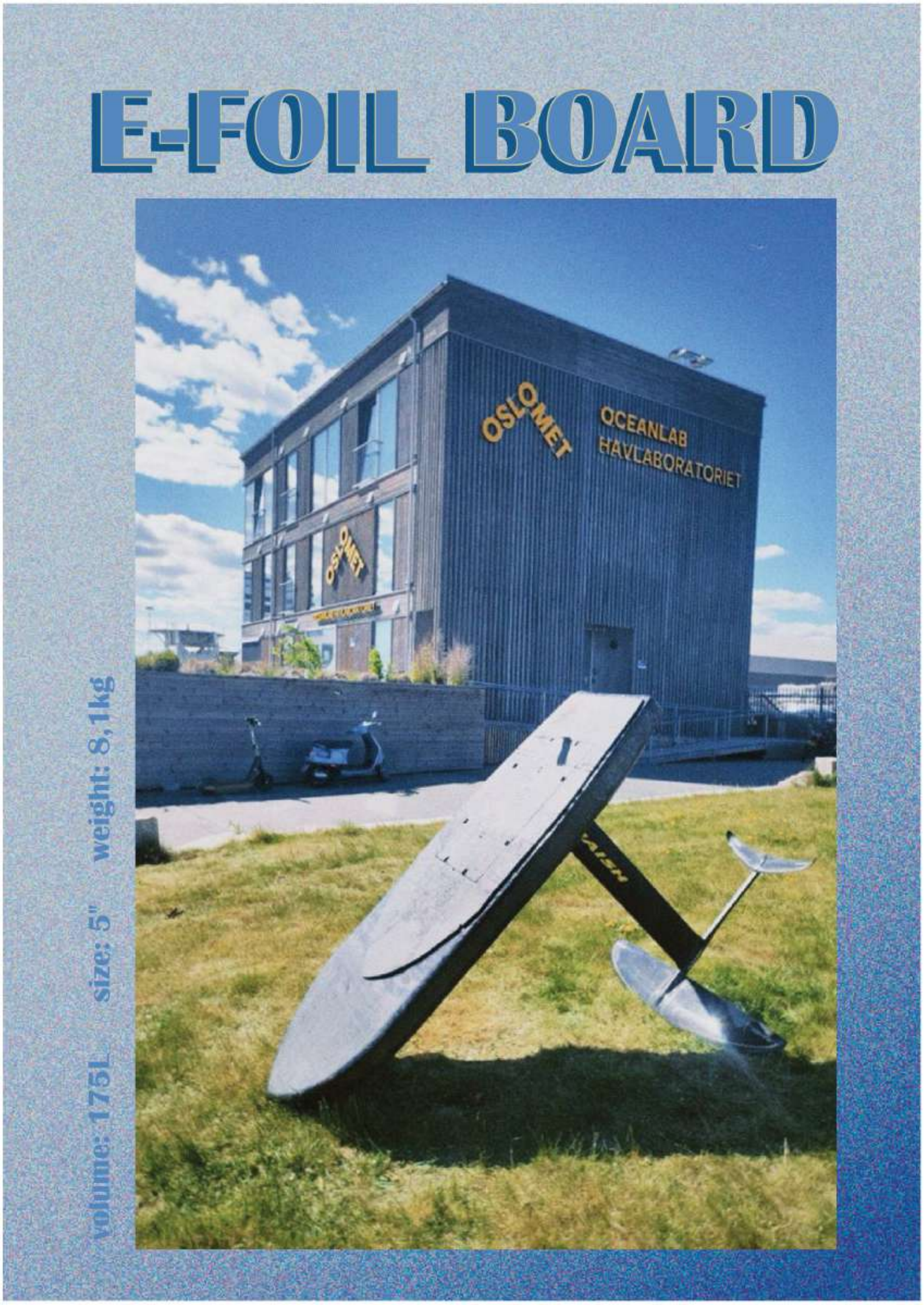
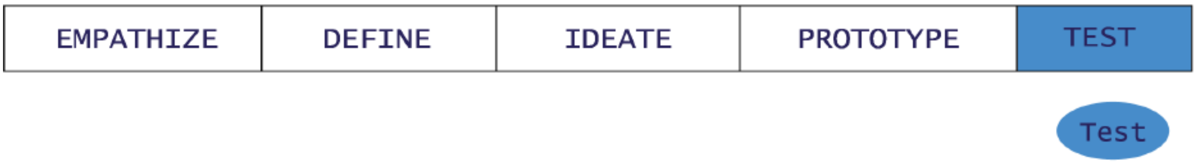


Figure 8.3: Poster with the final specifications of the board and the Ocean Lab in the background

Testing



After the building process was completed, the next step was to start the testing phase. It was divided into two outdoor tests.

9.1 How and what we test

The first test will be conducted on the "Tjuvholmen bystrand". In this first test the board will be put onto the water to check the overall floating ability. This part will be done first without and then again with someone standing on the board. In this test, we will look for how far the board sinks into the water and we will have a look at the general float ability in the water.

The second part of the test will check the most crucial part of the board, the battery case. The battery case will be filled with toilet paper and tightly sealed with the lid. The holes for the cables were sealed with duck tape and on the inside with fibreglass. Then the board will be put 5 cm under the water. After taking the board out of the water we will look out for any leaks or water drops on the toilet paper.

Thanks to the Ocean-Lab and our supervisor Vahid Hassani we were given the possibility of doing a real driving and durability test on the sea, by using the motorboat from the Ocean Lab. The plan is to connect the driver on the board with the motorboat using a long rope, it will be attached on the bridge of the boat like it is normally done for wake boarding. The driver is standing on our board and holds the rope in their hands. The boat will slowly increase its velocity and so it will simulate a realistic start. One member on the boat will film the surfing so the reaction of the board on the water can be analyzed after the testing. For safety reasons there will also always be one member on the boat watching the surfer, this person will stay in contact with the driver of the boat. When the surfer falls, that person alarms the driver of the boat so it can decelerate the boat and the boat can turn around.(JOBE, 2020)

The first test round would be successful when:

- The board floats.
- The battery case is waterproof.

And the second test round would be successful when:

- The board foiled over the water.
- The surfboard will come out of the water the same as it went in. So no parts are missing or broken.

For safety reasons, the surfer will wear a wetsuit to keep warm, a life vest for impact when falling and to keep floating while being in the water and the surfer will wear a helmet to protect the head while possibly falling. Besides that, the surfer won't be in the water longer than 30 minutes at the time and will get out of the water as soon as the person gets too cold. To assure communication will be smoothly the group will decide on easy gestures with the arms and hands to communicate how its going.

9.2 Evaluation

First test round
The first test was for 50 percent successful. The board was put into the water and the floating was checked, which turned out good. The board floated perfectly on the water and there was not more than 1 cm of the board under the water surface.

Then a person went on the board to check the overall floating ability again with a person's weight included. We found that the board sunk more under the surface of the water, which was expected. There was approximately 1 to 5 cm left of the nose of the board, while the back of the board where the person was lying was fully covered with water. It depended on the weight distribution of the person, but we expected the board to float a little better. During this phase the person balancing on the board found while moving on the board or when waves were faced, the board had a hard time staying stable on the water.

The second part of the test was to check if any water touched the paper in the battery case. So two persons were standing in the water and pushed the board under for roughly 10 seconds. The only thing they noticed, were air bubbles coming out of the air vents. After that, we took the board out of the water to unscrew the lid and check if any water came into the battery box. Sadly we noticed that almost the complete box was wet.

Back at the Ocean Lab we conducted another test to find out which part of the board was leaking. The possible causes in our perspective were the sides of the lid and the covered hole of the bottom. Therefore we covered the battery-box again with paper and screwed the lid on the board tightly. Then we poured a glass of water on the sides of the lid and on the air vents. We saw that the water stuck on the air vents but on the other hand, disappeared relatively fast on the sides and the screw holes. After we unscrewed the lid again, we noticed that the paper in the box was completely soaked with water. We closed the lid again and we turned the board upside down. With that method, we checked in which places the water was dripping out. It was observed that most of the water dripped out from the corners of the lid. As a result we thought the lid and the open places between the plate and the case's walls were the main cause of the leaking.

Second test round
The second test was to simulate a real driving experience. With the boat from the Ocean Lab we drove to a testing area between the islands "Lindoya" and "Hovedoya". While driving, the strut with the foil, got attached to the board. Then a group member went with the assembled board into the water. An approximately 18 meter long rope was attached to the boat.

In the first attempt, the person was sitting on the board and holding the rope. The speed was slowly increased to simulate a start. Meanwhile the person tried to balance the board. After reaching an approximate speed of 15 km/h the board began to lift out of the water, this is visible in the picture below. Because the person fell of we had to end this attempt.

Figure 9.1: Board lifts out of the water

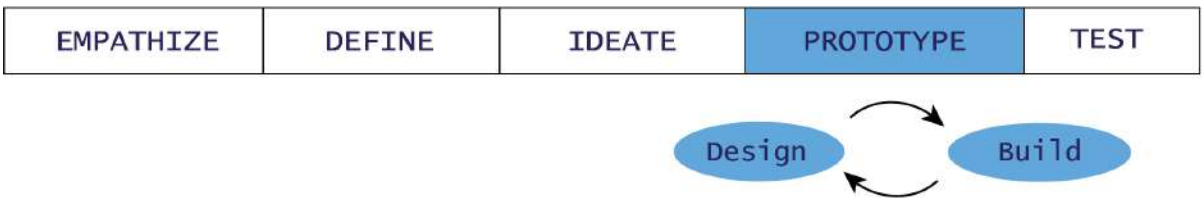
In the second attempt, the person on the board started in a kneeling position. Then the speed of the boat got increased again and similar to the first attempt, the board started to lift out of the water. While kneeling the surfer felt more control over the lift that was generated by the foil. It was possible to control the board to go up and down a little bit. Eventually the rider fell of again and the attempt was over.

The last attempt was not successful, the wind picked up and almost flipped the board during foiling take off. Due to time concerns of the boat driver, the test was ended.

Because of the wavy and windy weather conditions, it was hard for the rider to keep the board in balance. Therefore, the person was not able to stand on the board and ride it properly. Nevertheless, the test showed that the board is able to foil. Furthermore, the board came out of the water the same as it went in, which underlines its durability and the strength of the strut attachment. Under the circumstances, the test can be viewed as a success.

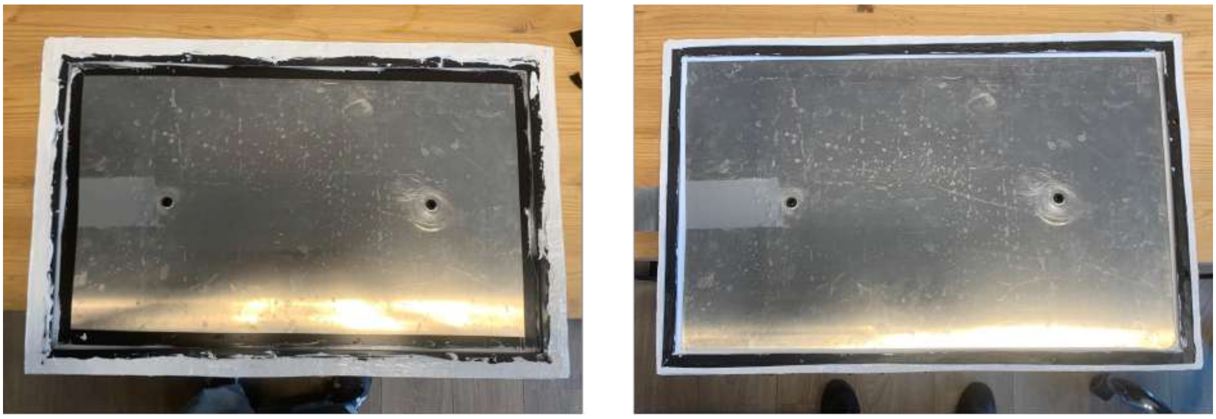
Extra test round
We doubted if the imbalance of the board was due to the wind and wave conditions during our first test day. That is why we went back on the water a day with almost no wind and waves on the sea. The rider experienced that it was still not possible to keep the board steadily foiling over the water. The maximum foiling time the board reached was approximately 5 seconds. One of the reasons we could think of causing this problem is the turbulence the motor of the boat caused, this turbulence is visible in the water in 9.1. The foil is very sensitive for this and responds very nervous to this turbulent water. After the correct battery has been purchased, using the board as an efoil with its own motor as it is meant to be would probably fix this problem.

9.3 Changes as result of the test-phase



To achieve the goal of providing a waterproof battery case, we improved the overall sealing. With silicone we filled the gaps between the plate and the battery box. After it dried, we did the test again and as a result less water was inside the case, but still something. To make sure the battery will be safe in the case, silicone was also put inside and outside of the rubber. Then the watertightness was tested again. Again, it was not waterproof but also less water then before.

Figure 9.2: Silicon in the gaps between plate and battery case



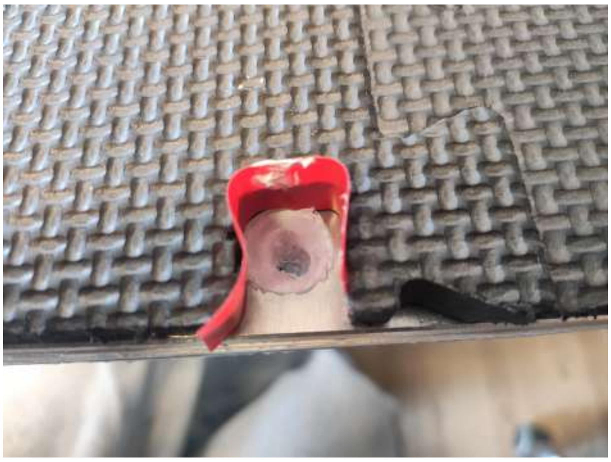
A

B

Figure 9.3: A: Much silicone applied and covered with tape B: Result without tape.

Afterwards, the focus was switched to the screw holes being the cause. A test was conducted to see if the screw holes were watertight. The lid was held with the screws in, and then water was poured on top. It was observed that the water runs through the sides of the screw, into the hole. As a solution we put silicon on the side of all the screws.

(a) Water in screw hole



(b) Screw hole with silicon

Discussion

10.1 Things we could have done differently

The first day of the building process took eight hours because we were glueing the ten parts of the board together. While doing this we were uncertain the foam parts would be properly attached to each other the next day, because the epoxy we used for glueing took seven hours to fully harden and the surfaces that we tried to glue together had a small surface area. If we would have made those parts as a puzzle sothat the three different layers would have more overlap together, the surface area would expand. This would have saved us a lot of time, stress and epoxy spillage on the floor.

The fibreglass filler we used for filling the holes the CNC machine made, caused to actually eat out the EPS foam. This is visible in image 7.16. Because of this, the surface was not flat anymore but slightly shrinked. That's why we had difficulty with the layers of epoxy over those surfaces. Even in the last layers there was some unusual texture visible at those spots. A solution for this was to not fix those holes because eventually they would be under 4 layers of fibreglass and epoxy and would not cause any problems.

The imbalance we found during testing with just floating in water is possibly due to the shape of the bottom of the board. This shape was chosen this way because the large battery case that was needed inside. And due to the characteristics chosen in 5.5. We designed a very responsive board, this might have caused the board to be too responsive and thus a little bit unstable.
The imbalance disappeared a little during testing the board behind the boat. But the moment the board wanted to take of foiling the board started to react very fast. This made it impossible to start standing on the board during these tests. This is caused by the turbulent water stream the motor of the boat causes and will be of no problem when the efoil would be using its own motor.

For smoother foiling take off it would be beneficial to add extra chine strips to the bottom of the board. In the first place this seemed impossible to fix, but a different approach to it could be with adding these strips after the whole board would be finished. These strips enhance flow separation and cause planing lift and more stability and therefore would stabilize the board and decrease take off velocity for foiling.

10.1.1 Budget comparison

After the project was finished, we compared the estimated costs with our actual ones and noticed that we are 1176,09 kroners over the calculated budget. An explanation is located in appendix F.

Conclusion

In the beginning of the semester we explored via several Mission Goals Scope documents that the mission of the project will be: "Design and develop a board for e foiling with integrated space for the electrical components, focusing on strength, waterproofing and using commercially available components." After this we started researching about what e foiling is, and methods and materials that are possible using. We used this knowledge to start designing the board and its different components. Then the building process started. First we went to the CNC workplace and cut the foam, after this the fibreglass and epoxying layering started. This was an iterative process and we worked in a feedback loop. If some parts turned out not well, we redid them. This was also the case to get the battery case waterproof. Afterwards we tested the board for float ability, foiling and general strength. During the testing on the water we found the board capable on these three specifications. Because we did some iterations in the building part and fixed some inconveniences we are very proud of our final product.

To sum it up these following goals are achieved by the project group.

- Research that included how to build an e foil surfboard, fluids, materials and process options.
- Design the board itself in an aero- and hydrodynamical way and design the strut attachment and the battery case.
- The board and components of it are built using CNC, a 3D printer and handcrafting with epoxy and fibres and we ended up with a final product.
- The board has been tested and it is compatible with the strut, has a waterproof battery case, it floats and foils.

In conclusion the project has been a succes, the goals we set in the MGS are all accomplished.

	Previous	Present	Upcoming
Propulsion	Build a propulsion system (motor and propeller).	DONE	DONE
Board	Wing foil board: Not enough volume and not specific shape to hold the challenges of having a hole electric system on the top.	Specific characteristics for the use. Several over volume to give freedom for upcoming decisions on the electric system and the riders.	DONE
Battery	Planted solution, failing results. The battery system braked before proper testing	Not contemplate	Build an electrical system capable of supplying the efoil's requirements.
Battery Case	On the top of the board: Doesn't permit a rider to stand on it.	Bigger capacity. Inside the board.	Make final closings and structure to ensure the water tightness once all the electric devices are on place.

Figure 11.1: Sum up of progress and upcoming work for each iteration

For the upcoming group to take this efoil project to a next level would be to connect the electrical components and buy or build a battery with sufficient power. So our recommendations for the next iteration of the project are:

- The system should have proper remote controls, battery and a good connection with the propulsion system. It should have enough power to maintain 20 Km/h on the propeller at least for several minutes.
- The battery case should be finished. There is a hole where the cables should pass through. On the testing phase we covered it temporarily, but once all the devices are put on position and the cables go through the hole, it should be properly fixed and sealed. We recommend to do this with marine silicone available in the Ocean Lab.
- We advise our teachers to find a next projectgroup with students that have an electrical engineering and mechatronic background.

Group reflection

EPS is a unique experience that brings together students from various disciplines, different universities, and countries of origin. All these people come together to work on a project within the scientific and technological field, testing the participants' ability to apply what they have learned throughout their academic career to real-life situations. In our case, OsloMet offered several different projects, one of which was from the OceanLab.

At the beginning of the semester, we were all very excited, not only because we were about to face a challenge that was quite different from anything we had done before in our studies, but also because we were all at the beginning of our Erasmus experience. The project assigned to our group was the prototyping of an efoil surfboard. When building a prototype, things don't always go well on the first try. We learned that with time. Our prototype was a relatively large-scale product and we knew the final prototype had to be functional. This made it more complicated and it put more pressure on the group. There were moments when things didn't turn out as expected, and that felt frustrating, because we had to extra iterations which were very time consuming. Sometimes we were even afraid that all our work might not lead to a successful outcome.

The most stressful moments came when we started building the prototype. We used materials none of us had worked with before, so we didn't have much experience handling them, and at times they didn't behave the way we hoped or needed them to.

Despite all the stress, we managed to achieve our goals. We spent many hours working together and the small problems combined with the fatigue from not getting the results we wanted, sometimes led to disagreements. So we learned from this that the planning of a project of this magnitude was a big challenge. We found it useful that every new part of the process we entered, to sit together and plan the upcoming weeks. This helped us in tense moments because there was always someone who managed to stay calm and take a step back, helping to resolve misunderstandings and keep us moving forward.

Eventually we believe we achieved very good cooperation within the team. This semester has been a highly rewarding and enriching one. We believe we have gained a lot of experience in team building and collaborative work, which will be extremely valuable in our future professional careers.

For future projects of this kind, we will be more aware of the time consumed by unexpected issues. Although we had included a time buffer in our planning, we did not expect to actually need all of it. Looking back, it would have been better to plan smaller buffers at the end of each phase rather than only at the end of the whole project. This approach might help us in the future to reduce pressure during the most crucial weeks of a project and would probably help to avoid disagreements in groupwork.

Appendices

A MGS 1

Mission

"Redesign a rider-controlled eFoil surfboard using commercially available components."

Goals

Build and test the previous design and identify the improvement areas

- Assemble the previous parts
- Test the previous parts
- Identify improvement areas

The engine should be compatible and able to lift the surfboard out of the water while a person is standing on it.

- Calculate the power required for the motor to lift the person on the board out of the water.
- Buy battery
- Connect battery, engine, speed control system and remote control.
- test engine

Motor with propeller should be firmly attached to the foil strut

- Create a strong connection between the motor and propeller
- Build a stable attachment for connecting the motor with the strut

Battery should be firmly attached to the board

- Redesign the attachment of the battery case so it doesn't bother the person who is riding the board.
- Design a system for the battery case so it is still easily removable if needed.

Scope

We are not going to make changes for parts that already work, for example to the foil. We are not going to generate new programs or control systems unless it is the only option. As a prototype we are not incorporating safety measures or emergency systems.

B Material research

As stated in the goals, the group decided it was useful to research and consider different material options 2.3.1. This is beneficial for comparing the strength of materials to make sure it is possible to use it in our specific project and it is necessary to be able to keep track of our budget. In this paragraph there will be discussed three different options available for this project.

Board structure

Foams are usually the core of a standard manufactured board. The first option, is polyurethane (PU) foam. It is the most used surfboard structure material. The tight cell structure makes the foam perfectly for the shaping process as it allows shapers to work with very high attention to detail. Furthermore, with a usual density of $36\,\mathrm{kg/m^3}$ it is lightweight.(Australia, 2025) PU foam offers a great resistance to wear and tear and is compatible with polyester and epoxy resins (SAS, 2024). Price wise it is a cost effective material (Dalinghaus, 2023). The downside of polyurethane is its limited biodegradability and overall durability. PU foam can degrade over time, especially with exposure to sunlight and extreme temperatures. This can affect its appearance and performance in certain applications.(C. H. C. Limited, 2022).

The other main materials used instead of PU foam for the structure are expanded polystyrene (EPS) and extruded polystyrene (XPS). Those boards last longer than PU ones – an immediate advantage on the sustainability front(Christopher R. Gibson, 2017). Expanded polystyrene is a synthetic polymer foam that is very lightweight with a density from $11\,\mathrm{kg/m^3}$ (Matheus Vinícius Gregory Zimmermann, 2024) (Styrene, n.d.). EPS cores now compete in the market by offering several performance advantages, including greater buoyancy, suitable mechanical properties, and reduced water permeation(Matheus Vinícius Gregory Zimmermann, 2024). It is ideal for self-builds because it is cheap and can be found in almost every hardware store (Maxbo, 2025a). The material is also easy to work with, when trying to achieve the desired shape of the board. However, care should be taken as it can break very quickly.

On the other hand, extruded polystyrene is a high performing, rigid, foam. It is known as an insulating material. Despite providing the structure it and can be used to reinforce crucial parts of the board, like the strut attachment. XPS consists of tightly packed cells with no gaps between them. This closed-cell structure makes the foam super water resistant and results in a smoother surface and higher density from $27\,\mathrm{kg/m^3}$, compared to EPS (Matheus Vinícius Gregory Zimmermann, 2024). The difference is displayed in the figure. 1. On the contrary, it is heavier and more expensive.(Keisecker, 2014) (Maxbo, 2025b)

Figure 1: EPS on the right, XPS on the left(Supplies, 2025).

A less common option, but one that can be convenient for those looking to 3D print the board structure, is polylactic acid (PLA). While the cost per kilogram is relatively high and its raw density is greater than the other materials,$1240\,\mathrm{kg/m^3}$, the printed structure consists mostly of hollow cells. This results in a lightweight board with minimal material usage. PLA is also biodegradable, which is an environmental advantage. However, this comes with a downside: after about a year (especially with UV exposure) its mechanical properties degrade significantly, making the board very fragile. (Brello, 2025)

The last option, but very rarely used, are boards made from wood. These are more sustainable than the options described before. Wooden boards are robust and durable. But to ensure this, they need to be maintained regularly (Herold, 2015). Furthermore, wood is heavier than the materials mentioned above. The frequently used paulownia wood, which is one of the lightest types, has a density of $250\,\mathrm{kg/m^3}$. (Schröder, n.d.) On the other hand, wood is a commercially available component and with the right tools and know how, easy to shape. But it is more expensive than all the foams. (fallendfelled, 2025)

After the surfboard's shape is finished, the board will be layered in fibreglass cloth, shown in the figure 2 in order to make it resistant(Christopher R. Gibson, 2017).
Fibreglass is a composite material that is made of very fine glass fibres. Woven together, these glass fibres build an ultra strong fabric, which have a better tensile strength than steel. Tensile strength is the resistance of a material to pulling or stretching forces before breaking apart.Once it's created, fibreglass typically has a density of between 2.4 and $2.76\,\mathrm{g/cm^3}$. The advantages are the light weight, the durability and stiffness as well as the moisture resistance (Kat de Naoum, 2024).

Figure 2: fibreglass fabric(AZoNetwork, 2025).

Another option for the board layering process is carbon fibre-reinforced plastic (CFRP) or short carbon fibre3, which most E-foil manufacturers use for their boards(Dwelle, 2024)(Dinh Nguyen, 2024).

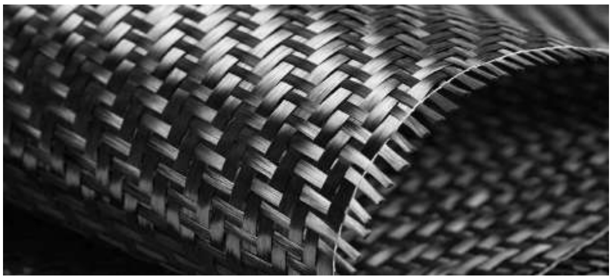


Figure 3: Carbon fibre reinforced plastic fabric(Innovates, 2025).

With a density of $1.5\,\mathrm{g/cm^3}$ it is very lightweight and at the same time has a high tensile strength of 900 MPa depending on the weave direction(swiss-composite, n.d.). It is also very resistant to external weather influences, such as degradation due to the sun and seawater(Al-Nuaimi-Ph.D., 2021). On the contrary it is more expensive than fibreglass, due to the several complicated manufacturing processes, which require specialized equipment and highly skilled labour. Secondly, although the demand for carbon fibre products is increasing, the overall production volume is yet to match up to that of traditional materials(H. G. I. Limited, n.d.).

Resin is used to stick the weaves of carbon or glass fibre together. Furthermore, it finishes the board with the last coating in order to protect and smooth the surface(Christopher R. Gibson, 2017). There are two types of resin that are often used, polyester and epoxy. Epoxy resins are stronger and more adhesive to the fibreglass sheeting compared with polyester resins. But epoxy is only suited for use with EPS and XPS blanks because the resin adversely reacts with traditional PU foam, causing discolouration. Epoxy resin is also more difficult to spread over the blank and more expensive than traditional polyester resins(Christopher R. Gibson, 2017).

Battery case lid
The lid consists of 6 parts, the cover, a connecting plank, the sealant, screws, air vents and grip on top.

Cover
To achieve the research goal of designing a waterproof lid with two possible ways of sealing, the following options occur. In general, the lid can be out of any material as long as it is a light material, to not contribute more weight to the board than needed. Aluminium is an interesting material option. It is a strong metal, durable, flexible, impermeable, lightweight, corrosion resistant and infinitely recyclable (A. A. C. Ltd, 2025). Another material option occured is polycarbonate (PC). It is a technical thermoplastic, which is characterized by its very high impact resistance, lightweight and low moisture absorption. (HANSER, n.d.)

For people doing it themselves, wood is a common option, because of its high accessibility. The choice depends on the budget. aluminium is more expensive, but is known to be the most durable material. It will not corrode or fade in harsh weather conditions. Polycarbonate is more affordable, but less durable and cannot withstand the same harsh weather conditions as aluminium. (Troop, 2021)

Sealant
The battery case needs to be watertight. It is important to seal everything right, to prevent water coming in. Therefore, two widely used options nitrile-rubber and silicone have been researched. Nitrile rubber, also known as nitrile butadiene rubber (NBR), is a synthetic polymer material, widely used in industry for the manufacture of gaskets. The main advantage is its exceptional resistance to fluids. Nevertheless, it also shows a good temperature resistant, from -40 to 120 degrees Celsius, depending on the mixture. Finally, it offers good wear and tear resistance, which contributes to the durability and longevity of seals(Group, n.d.).

Silicone is a synthetic compound that comes in a variety of forms like oil, rubber or resin. It is typically, heat- and water-resistant and present in sealants. It operates with temperatures from -80 to 250 degrees celsius. Due to its different forms, it has excellent spread and coating capabilities.ASA, 2025

Screws
To keep the lid in place and guarantee water tightness, a common option is to put screws in it. They are usually made from stainless steel(eFoil Holland, n.d.). The reason for this is, it needs to be strong enough to absorb forces as well as to withstand the weather conditions.Thanks to their high-quality material,the screws are resistant, rust-free and durable. This makes them ideal for applications with high exposure to moisture and weather. A cheaper option, which is as strong as stainless-steel screws are galvanised ones. On the contrary they are only suitable for a temporarily outside use and corrode.DE, 2025

Air vents
To provide air ventilation for the battery case, the following solution appeared during the research. Air vents, which are located at the back of the lid, provide an air stream to prevent moisture from inside the battery case. They need to be waterproof and act like a gasket. The one in figure 4 is made out of plastic but they are also available out of stainless steel(AS, n.d.).

Figure 4: Waterproof vent(AS, n.d.).

Plank
For the connecting plank between the battery case and the seal, we looked for a lightweight yet stable plate, that could be drilled through. Two options occurred again through the research, aluminium and polycarbonate. Especially the polycarbonate characteristic of having a high impact resistance, but also the lower price make it an interesting option.(HANSER, n.d.)

Grip
Lastly, a material option for the rider's standing area was needed. To have a good riding experience, riders need to stand properly on the board. That's why most manufacturers put a grip area on the board. For a good grip, the surface needs to be anti slip, waterproof and durable enough to withstand the external weather influences. The frequently used solution is ethylene vinyl acetate, (EVA). This kind of foam is elastic, lightweight, resistant to wear, waterproof, resistant to UV radiation. EVA foam is a much more durable and effective material than polyethylene or rubber (EKI, 2025). An alternative option is cross-linked polyethylene (XPE), which is a closed-cell foam. To create a durable bond, the polymers are chained together and heated to make the "cross-linked" structure. It offers impact absorption, water resistance, heat and UV resistance(Foam Factory, 2025).The cheap material can be for example found in simple outdoor mats. On the other hand, the surface is not very anti slippery under the influence of much water.

The last option is an anti slip floor mat, made out of polyvinyl chloride (PVC). The matting is elastic, lightweight and can be used in wet conditions (R. C. Ltd, n.d.).On the contrary the functionality and longevity can be damaged under the influence of sun rays.

Strut attachment Tracks
As well as previously parts, the material should be lightweight and resistant enough to withstand the external influences. Because of the material advantages, the frequently used or offered option are tracks made out of carbon(okarbon, 2025).

The second option, which is offered in shops or used by manufacturers, are tracks from polyvinyl chloride (PVC). They are commercially available and cheaper than carbon ones, but on the other hand not that durable.

People with access to a 3D printer have the opportunity print them to either design their own tracks or download templates from the internet, instead of buying them. The frequently used print material is polylactic acid (PLA), a renewable thermoplastic. Besides being eco-friendly, the material not fulfils the requirements, due to its low heat resistance and low strength. The best option for self-prints with a carbon like quality, is a print material, called "Onyx". It is a micro carbon fibre filled nylon. "Onyx" offers high strength, toughness, and chemical resistance. Compared to PLA it is expensive and not compatible with every 3D printer(Markforged, 2025b).

An option that needs to be mentioned would be to just screw in the strut in at the usual position. The downside of this would be, that you can not adjust the strut. Therefore everything needed to be perfectly balanced beforehand.

Because the small tracks need to withstand the occurring forces, during the research a method was found, that absorbs and distributes the forces on the whole board. One opportunity is to buy tracks shaped in a rectangular plate made out of a single carbon fibre formation. It is uses the benefits of carbon and is therefore an expensive option.(okarbon, 2025)

The second option would be, either to buy a pre-moulded XPS plate, to glue the tracks in or shape one yourself. The material is cheaper than carbon and in terms of the advantages, in some parts close to those of carbon. To withstand the forces, a method was found to absorb and distribute them across the board. One option is to use rectangular tracks made from a single carbon fibre layer—strong but expensive (okarbon, 2025). A cheaper alternative is using a pre-moulded or self-shaped XPS plate, which offers some benefits similar to carbon.

An even cheaper option, depending on the type, is wood. Like XPS, it is possible to buy either a mould or shape the insert for gluing the tracks yourself.It is not the ideal material, due to its higher weight. Furthermore, it is harder to shape then XPS.

C Manufacturing process research

Hand-shaped
One method is, that the EPS or XPS plates can be hand-shaped; after selecting an appropriate mould the shaper traces the outline of the surfboard onto the blank. Next a handsaw or electric jigsaw is used to cut out the blank. After this the shaper begins planning rougher sections of foam, working to achieve a smooth and even finish along the rails, while reducing thickness through the blank to suit the design they have created. Eventually the shaper uses surface form tools to fine-tune the details of the design. (Christopher R. Gibson, 2017)

3D printed shape
Another very rarely used variant to build the blanks is 3D printing (Matheus Vinícius Gregory Zimmermann, 2024). The advantage is that you don't have to be skilled in terms of designing a board, there are a lot of templates on the internet to download. Furthermore, you don't have to shape very much like you need, when working with EPS blanks. On the contrary, a normal 3D printer cannot print the whole core in one piece. Therefore, the design needs to be divided into certain pieces, which are then printed. After printing all the pieces, which takes long due to the overall size of the board, the parts can be glued together. After that the board will be laminated like the usual process.

D Materials and manufacturing processes design decisions

Process Justification

To explain the final decision and the consequences of it we should also explain the options that were discard.

Board structure
The first option we discarded was 3D printing due to the lack of availability of them. To make a whole board out of cells would take at least four 3D printers completely available for at least one month. At university we have access to a maker space with several of them, and we could have managed to have all the cells in approximately 1 months. Taking into account the time that takes making a proper design based on cells along with the printing phase and later on the finishing process, we would not have been able to complete our project within the given timeframe. But the inference point to discard this option was that the 3D printers available were only able to print with polylactic acid (PLA), which is a biodegradable plastic. It has a great performance for prototypes, but it loses all the proprieties with sun and heat exposure. In one year the board would have been spoiled.

At one point, the idea of shaping it by hand was considered. This was a cheap option, and it also gave us freedom and independence for making decisions along the process. However due to the lack of experience, that would have force us to build a very simple design which could have affect to the performance of the board. As the layering have to be by hand, it would cause several irregularities, we coudn't take the risk of not having a symmetrical board. That's why handmade building was discarded.

Our actual choice was doing the shaping part with a CNC machine. This choice was based on the fact that we have both the knowledge and the resources to design a board that matches the fluid dynamic characteristics of the environment. It was a priority to have as much freedom as possible to design and obtain accurate results. However, the maker space at OsloMet didn't have a CNC big enough to build the board, so we found an external provider for it. Fellesverkstedet is an external maker space where you can use the tools that they have, including the CNC (Fellesverkstedet, 2025). The only limitation was that the CNC machine available there was only able to work with pieces of 5 mm height so we adapted our design to that.

Tracks
Since we needed them to be strong enough to withstand the forces acting on them. We chose to 3D print them since we could use a carbon fibre printer available in the Ocean Lab, where we were working.

Material Justification

Board structure and reinforcement
As we have decided the manufacturing processes it left us with two material option for the board structure. Either foam or wood. Wood was discarded from the options because of the difficulty of the treatment. To make it perdurable through time, a maintenance routine carried out by professionals was needed. This could not be ensured in a product like this. So even if it takes a lot time to do the laminating process to prepare pieces to be cut by the CNC, using foam for the structure and for the reinforcement was the best option. In this case, for the hole structure we used EPS, because is cheap, light and easy to work with. On the other side we chose XPS since it presents better qualities for the reinforcement (explained in detail in 4.2). This design choice will be later explained in 5.4.3 Strut attachment.

Both parts were later recovered by four layers of fibre glass and one of carbon fibre, to ensure the hardness. The chosen resin to stick this layers together was Epoxy instead of polyester. Epoxy is stronger, lasts longer, and works well with EPS foam. It is also safer to use and gives more time to work with it. Although is more expensive, the results are better.

Tracks
The tracks are a crucial part of the board. The strut is attached to them an they should be resistant, light and have proper sizes. Some of the commercially available tracks are made from polyvinyl chloride (PVC), but manufacturing them with this material is impossible on a small scale. Then this option was discarded. For manufacturing them in small scale as we wanted, the best option was to 3D print. Printing them with PLA was discarded, because as commented previously, it is not a good long-term option. On the other hand, printing them with carbon fibre derivatives would offer high performance characteristics of resistance and durability while being extremely light. The derivative material choose

was Onyx, without the reinforcement with pure carbon fibre nerves, because it is not required for the use.

Cover
The first approach considered for the cover was to create a foam prism and reinforce it with fibreglass and carbon fibre. However, this option was ultimately discarded. To achieve sufficient strength, the minimum thickness would need to be at least 10 mm, which would reduce the available space for the battery compartment. Additionally, the fibre reinforcement process could cause unpredictable dimensional changes. Given that the fit of the cover is already very tight, even small deviations could lead to serious issues. Another drawback is that reworking the screw holes after fibre application would be difficult, and using them in such a scenario could compromise the structural integrity of the lid—something that is unacceptable. For these reasons, covering foam with fibres was ruled out as a viable option for the cover.
For the cover we considered polycarbonate. For a proper resistance for the predicted use, a piece of 10 mm height was needed, this took too much of the usable space for the battery case. It was also heavy it weighed around 2.5 kg. Even with that dimensions it would get slightly deformed when pressure was applied to the centre. Even though it was a viable option, as the holes for the screws and the fittings with the rest of the board could be made precisely and functioned as intended.

The final decision was to make it out of aluminium. The design and fitting can be perfectly executed, and it would have the best performance in resisting weight with just a 5 mm height piece. Even with that dimensions the lid was heavy, but lighter than the other options it weighed 1.5 kg. It represented a increase in the budged, because of the need of proper tools to manufacture it, but the relevance of this piece in the design led us to that decision.

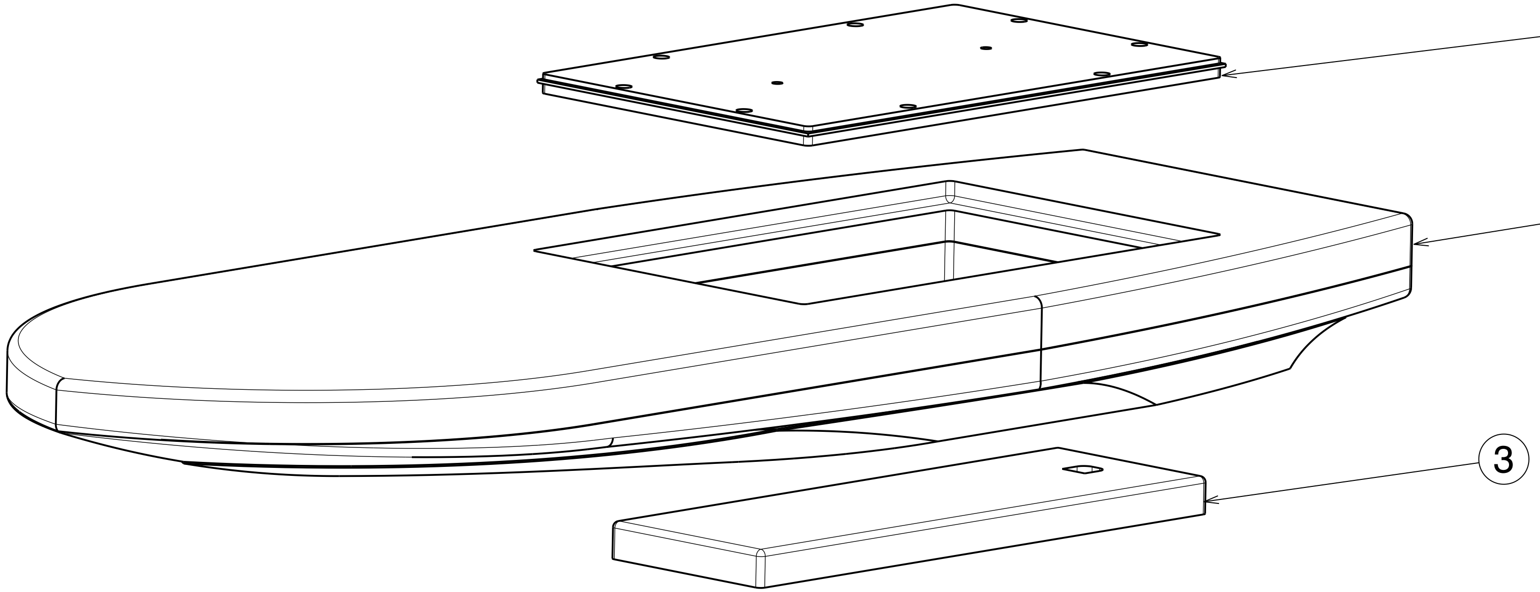
Rubber
This material has to be resistant but also flexible and the most important, it has to be waterproof. For this part we had two clear options Nitrile Rubber or Silicone. Both have great characteristics to accomplish the mission, but due to the manufacturing options, the material used was Nitrile Rubber, because is easy to manipulate and cleaner.

Plank
For the plank the aluminium was discarded because a piece of 10 mm height was needed, witch was not possible because there was no availability of aluminium with this characteristics. As this part is not exposed to demanding forces, making the piece with plastic it would be a light and cheap option. We discarded methacrylate because of its tendency to crack or fracture. So the remaining option was polycarbonate; it is a hard material, with great long term resistance and good proprieties for technical manipulation for example making threads.

Grip
The main material options for the grip were cross-linked polyethylene (XPE), PVC or EVA foam. The XPE had great proprieties of absorbing impact, water resistance, heat and UV resistance. This material was not considered because it is not anti slippery, which was a mandatory requirement for this.
The grip was made of EVA foam. It's the material that actual grips are made of. It provides excellent traction and cushioning. It is also lightweight, water-resistant, and durable under sun and saltwater exposure. And it is available in several forms in the market, such as yoga mats or tatamis.

The PVC, is not a possible option because although it have the same proprieties as EVA foam, but it could be damaged especially with the deterioration caused by UV radiation.

E Technical drawings



Nº PIECES	NAME	BALLON	SHEET	MATERIAL
1	Strut Attachment	3	10	
1	Battery Case Lid	2	6	
1	Board Structure	1	2	

DESIGNED BY: Ocean Mates

DATE: Spring semester 2025

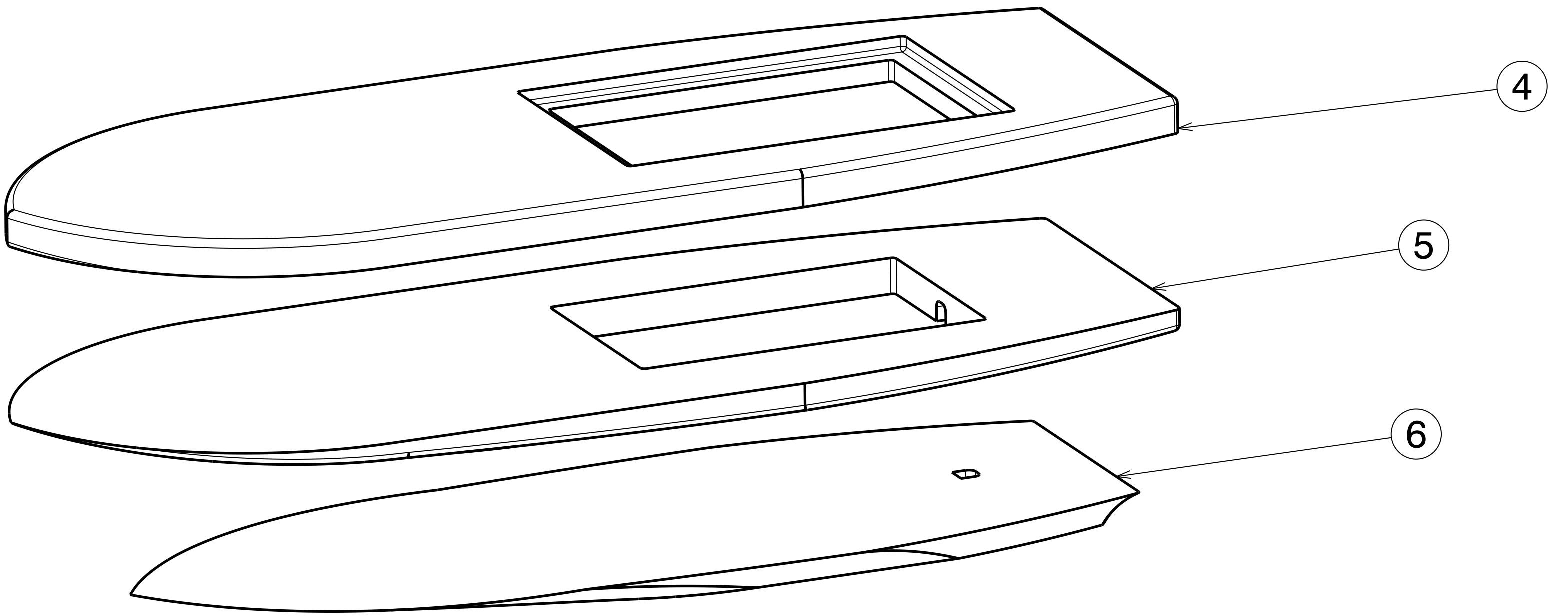
E-FOIL BOARD

SIZE: A4

SCALE:

Overall drawing 1

SHEET: 1/12



Nº PIECES	NAME	BALLON	SHEET	MATERIAL
1	Bottom part	6	5	EPS
1	Mid part	5	4	EPS
1	Top part	4	3	EPS

DESIGNED BY: Ocean Mates

DATE: Spring semester 2025

BOARD STRUCTURE

SIZE: A4

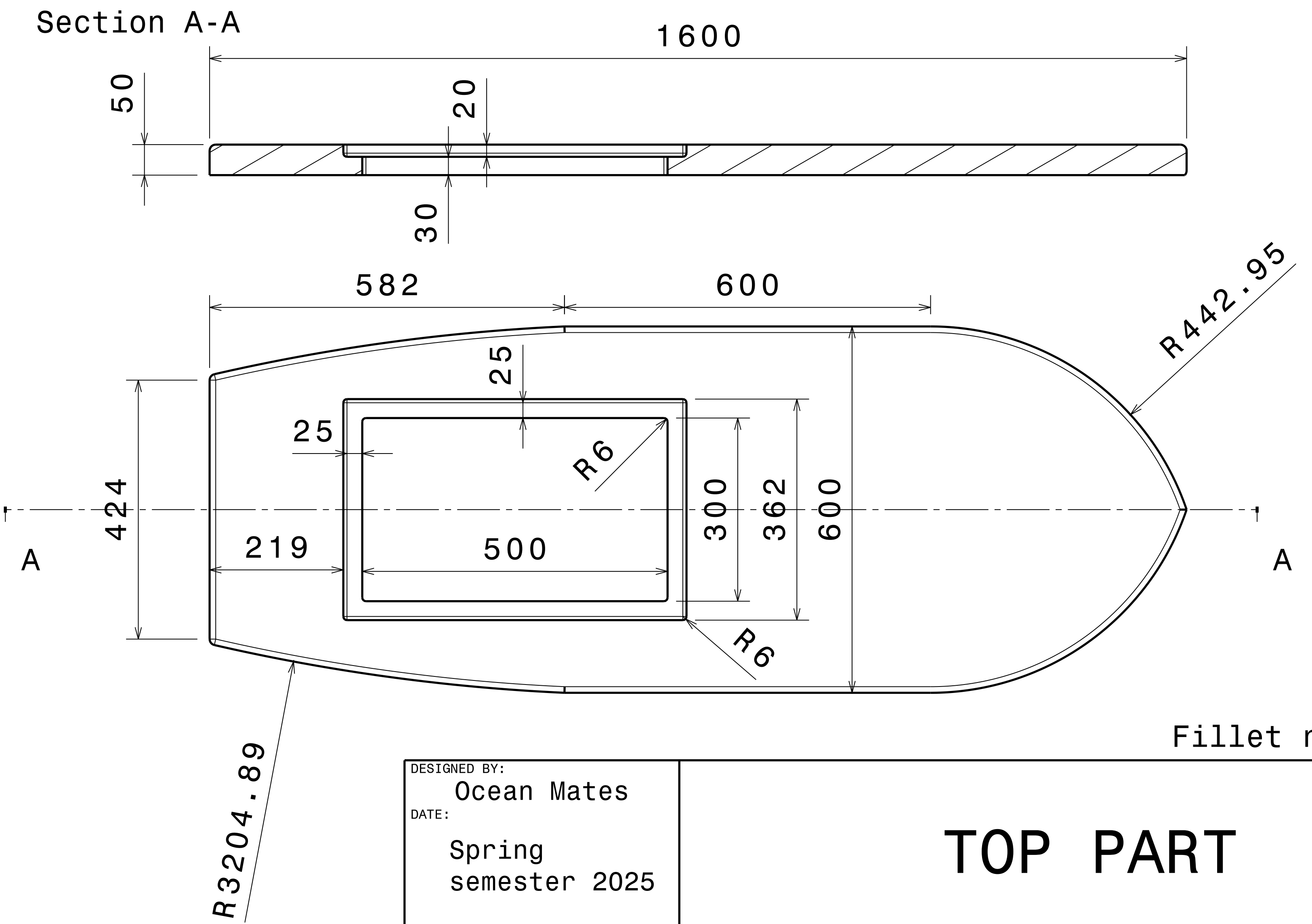
E-FOIL BOARD

SCALE:

Balloon 1

Overall drawing 2

SHEET 2/12



Fillet radii: 10 mm

DESIGNED BY: Ocean Mates

DATE: Spring semester 2025

TOP PART

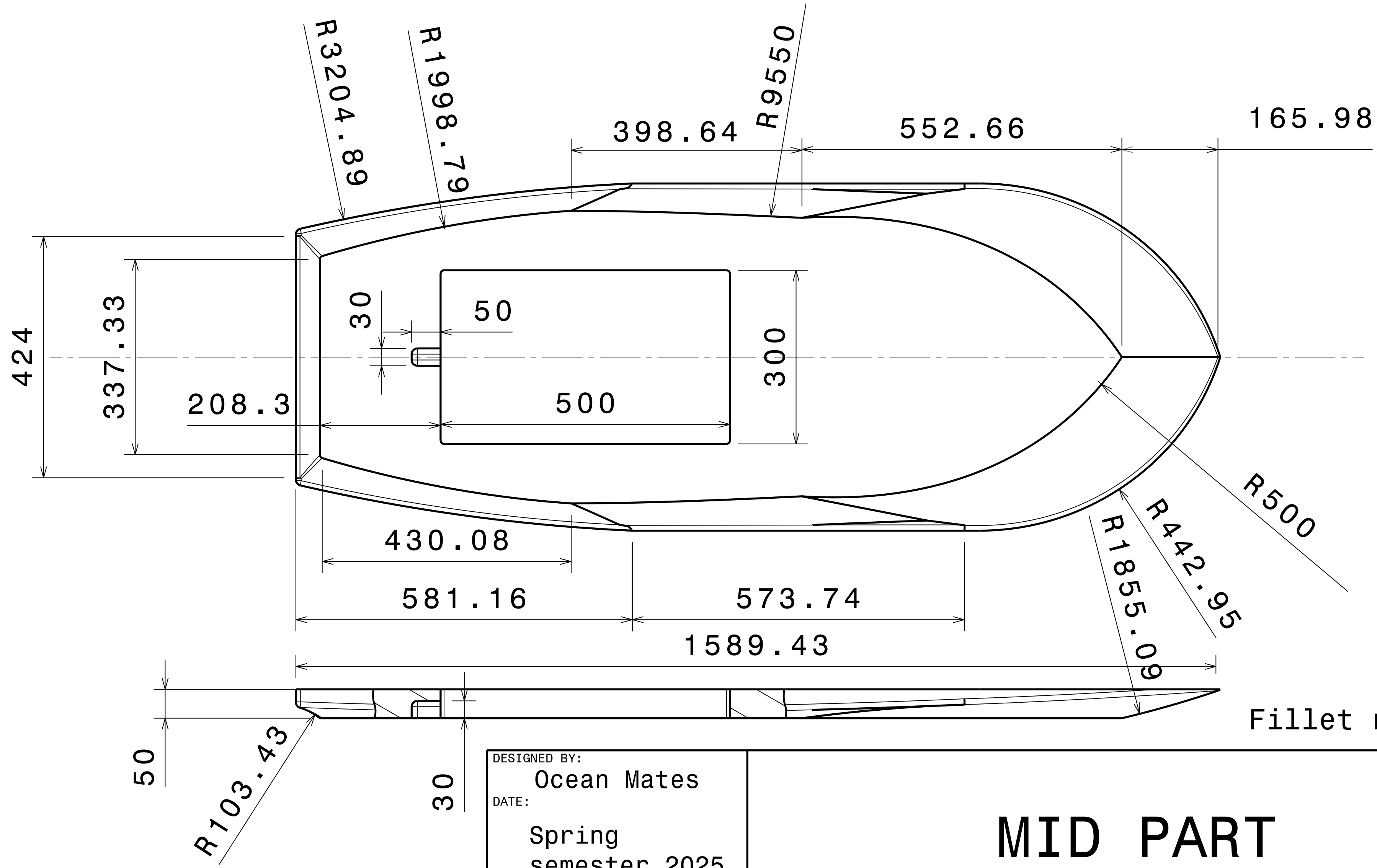
SIZE A4

BOARD STRUCTURE

SCALE 1:10

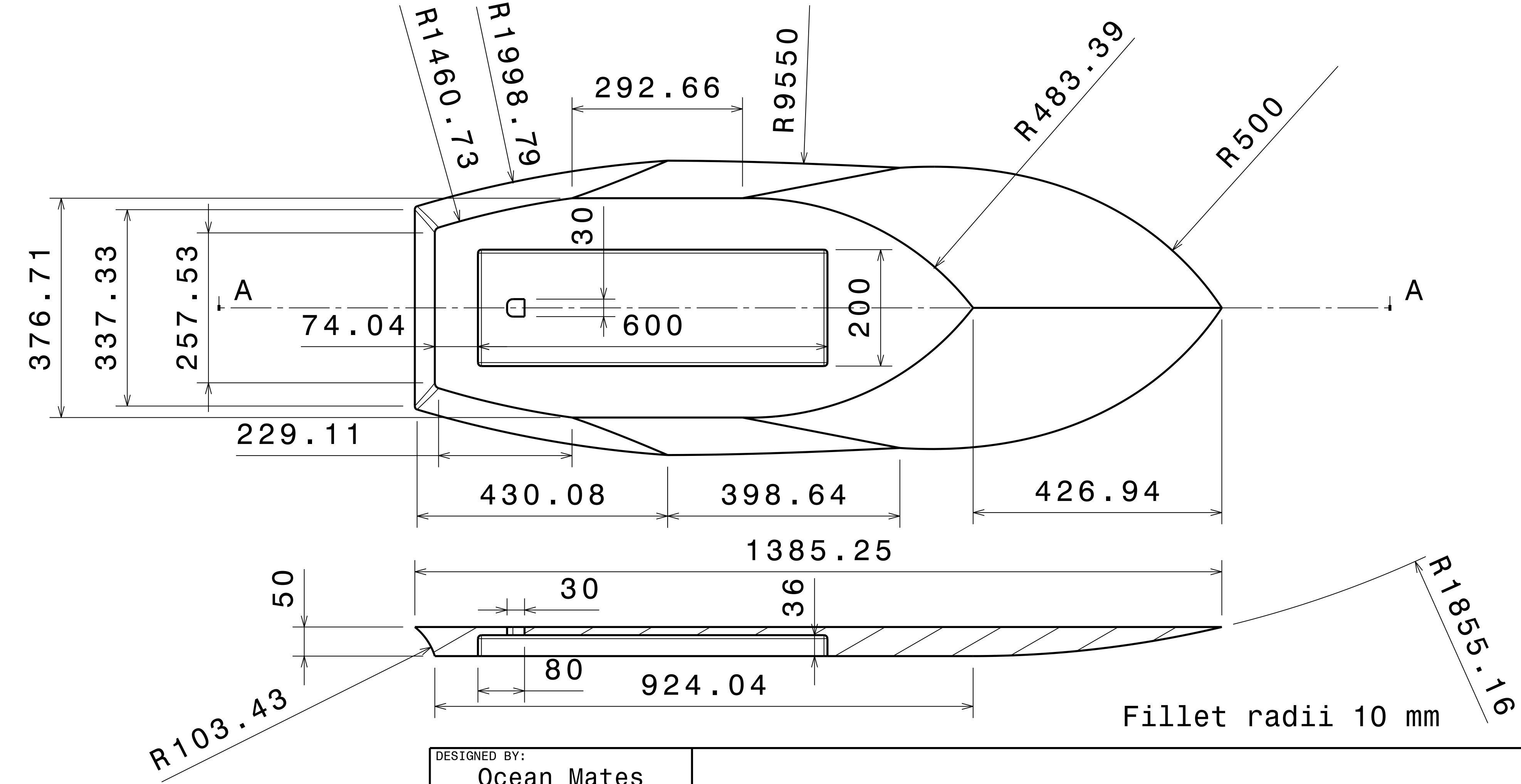
Balloon 4

SHEET 3/12



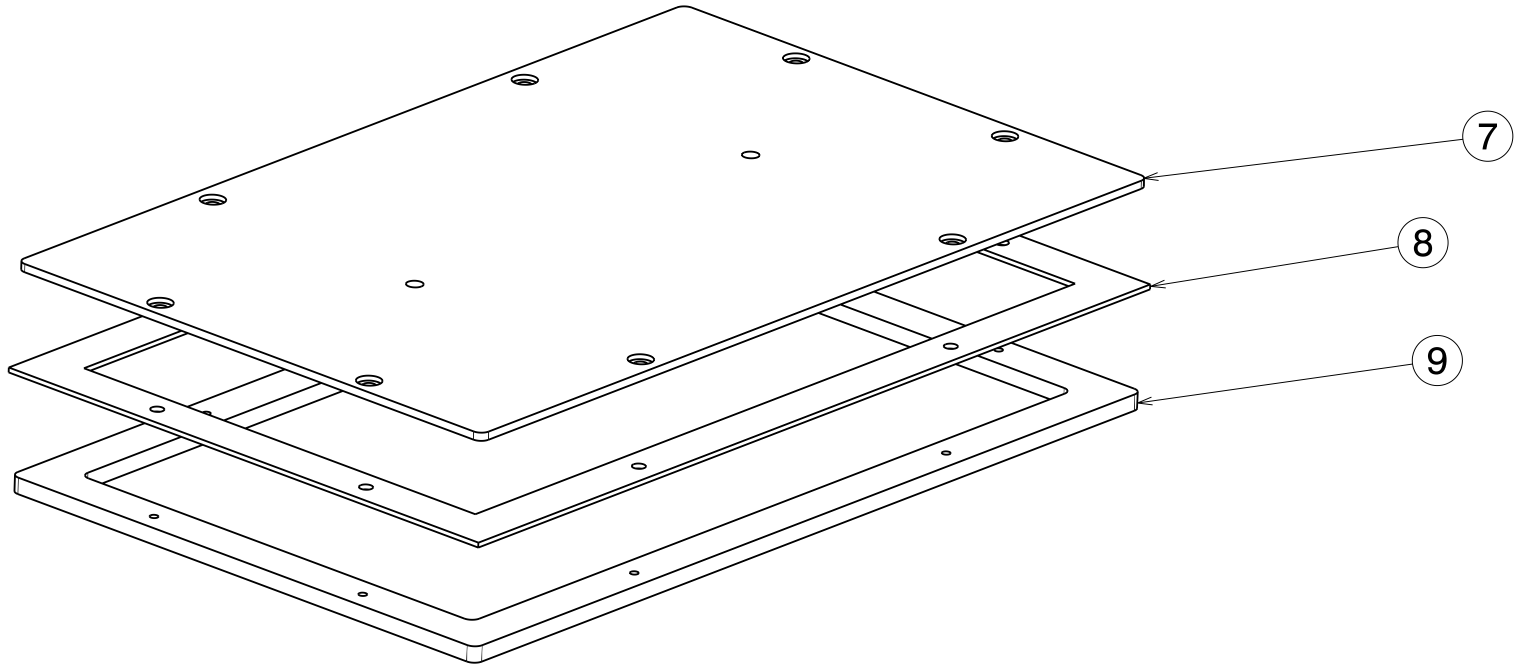
Fillet radii 10 mm

DESIGNED BY: Ocean Mates DATE: Spring semester 2025	MID PART	
SIZE A4	BOARD STRUCTURE	
SCALE 1:10	Balloon 5	SHEET 4/12



Fillet radii 10 mm

DESIGNED BY: Ocean Mates DATE: Spring semester 2025	BOTTOM PART	
SIZE A4	BOARD STRUCTURE	
SCALE 1:10	Balloon 6	SHEET 5/12



Nº PIECES	NAME	BALLON	SHEET	MATERIAL
1	Plank	9	9	PC
1	Rubber	8	8	Synthetic rubber
1	Cover	7	7	Aluminium

DESIGNED BY: Ocean Mates

DATE: Spring semester 2025

BATTERY CASE LID

SIZE: A4

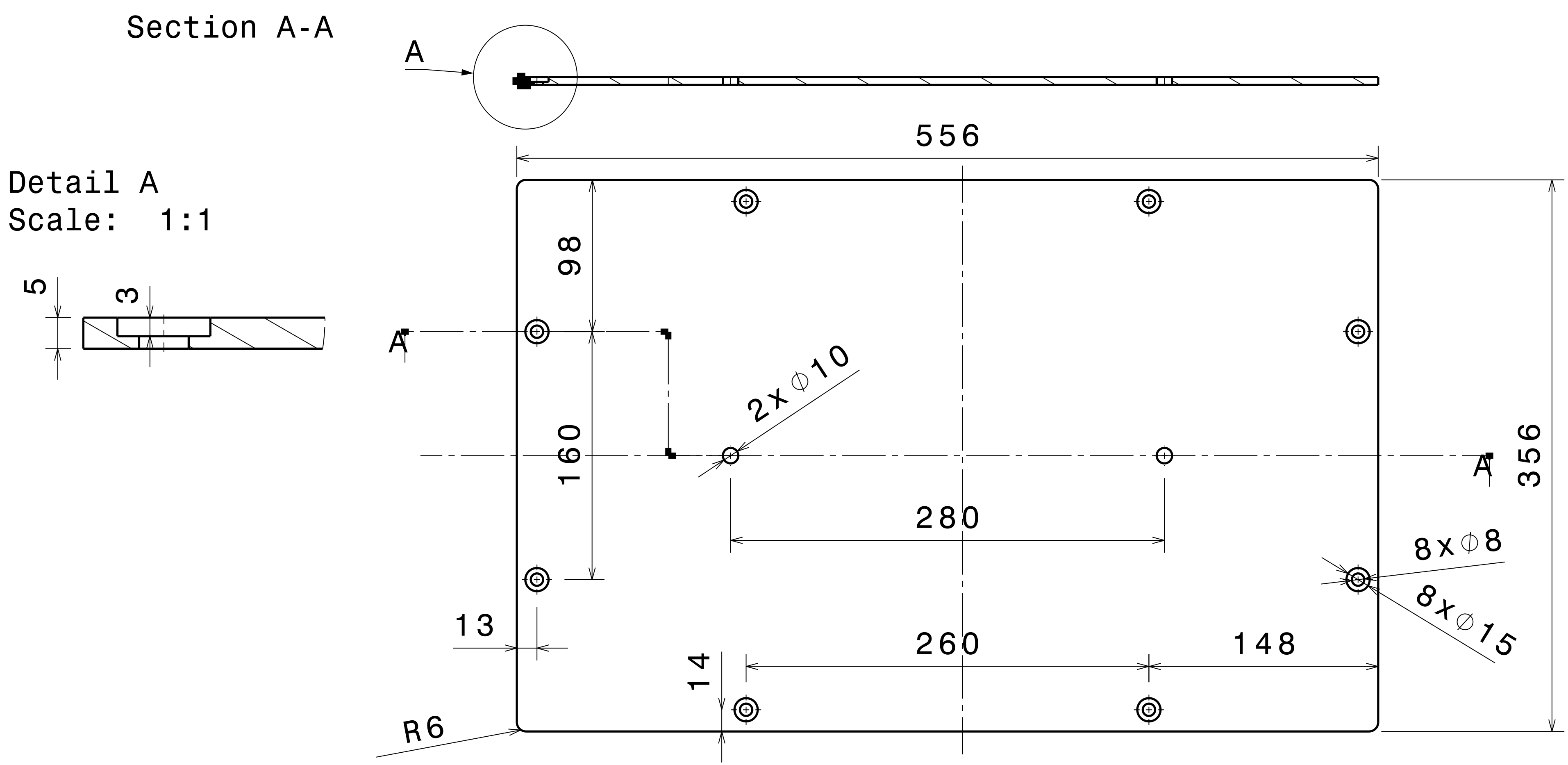
E-FOIL BOARD

SCALE:

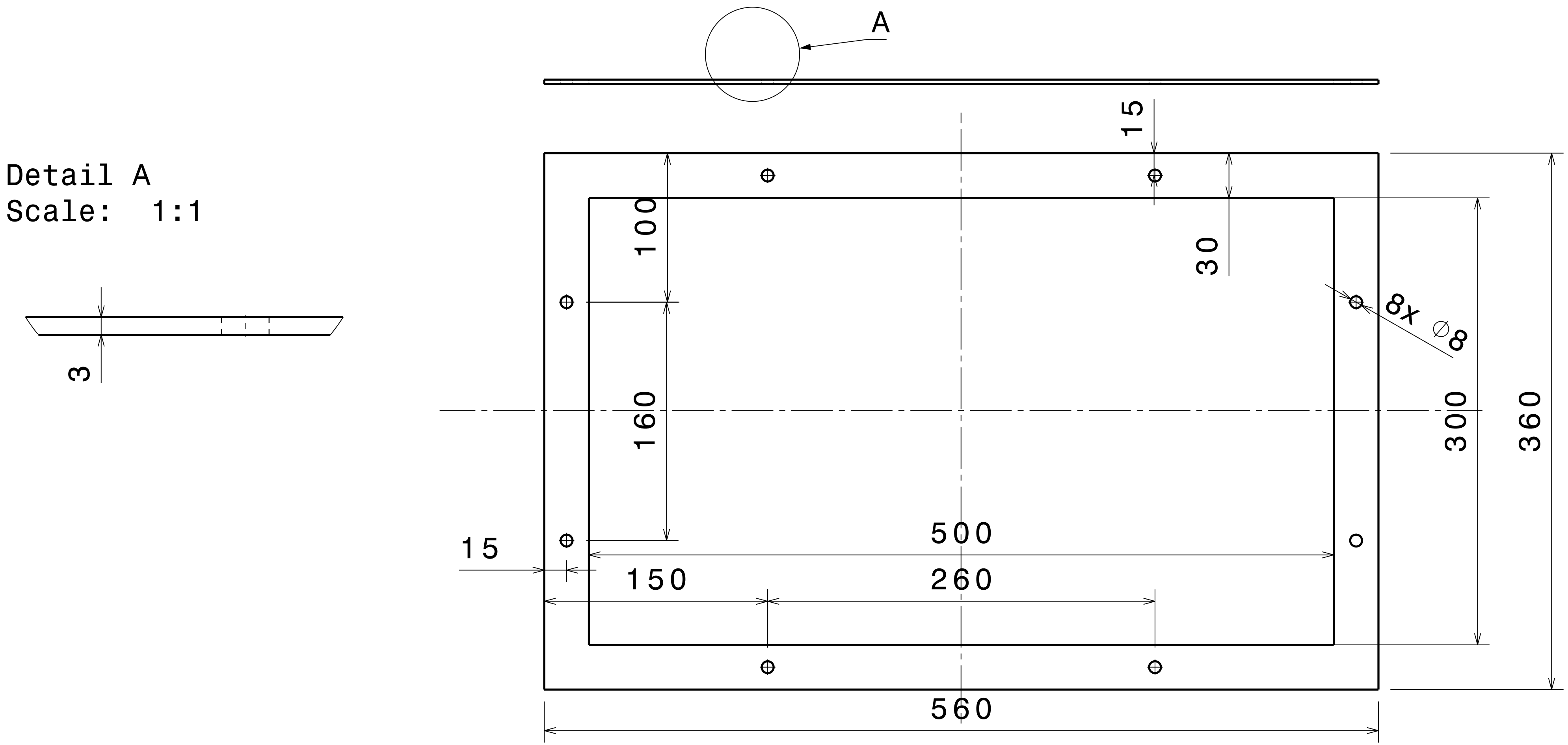
Balloon 2

Overall drawing 3

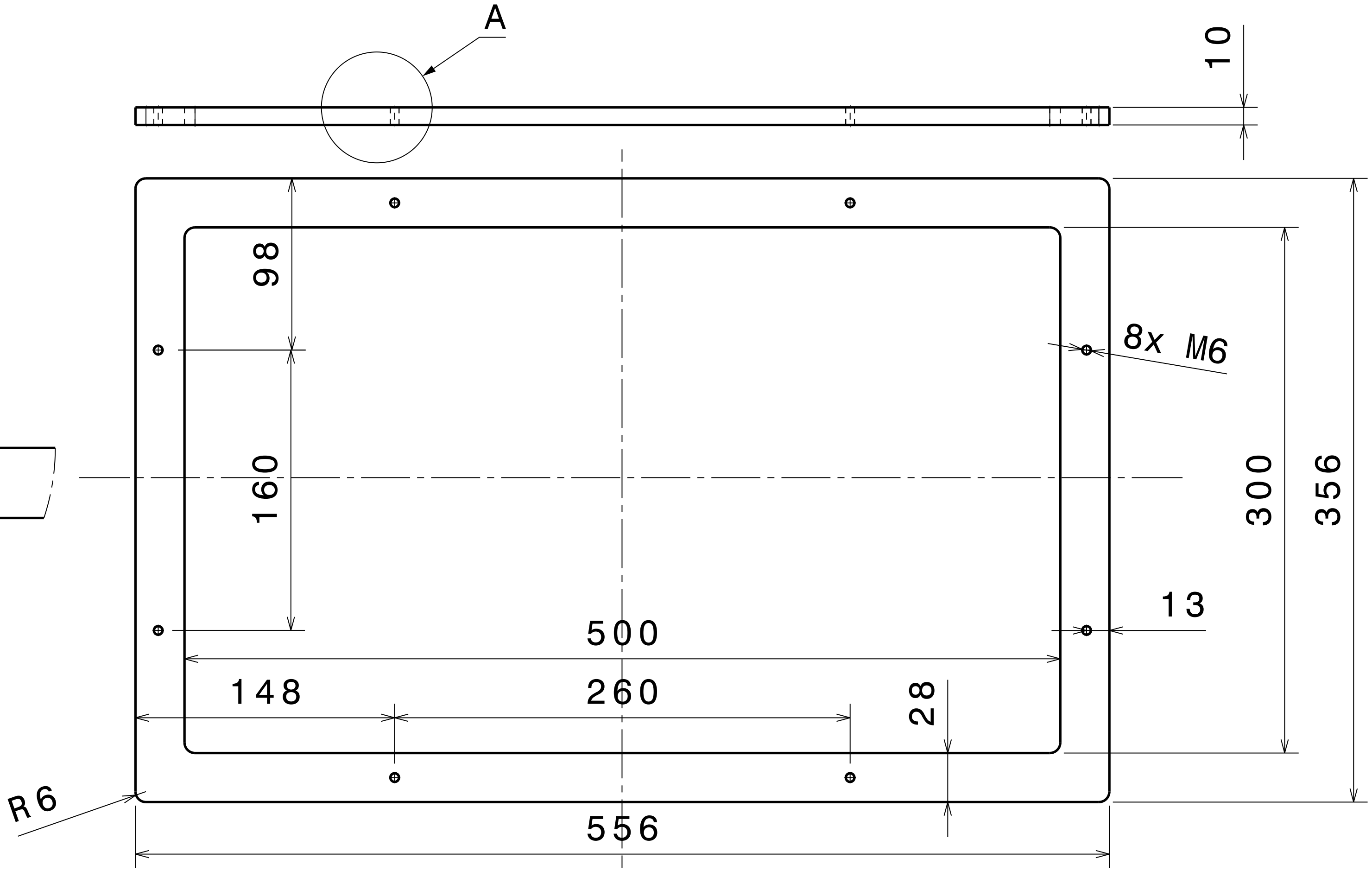
SHEET 6/12



DESIGNED BY: Ocean Mates DATE: Spring semester 2025		COVER
SIZE A4		BATTERY CASE LID
SCALE 1:4		Balloon 7 — SHEET 7/12



DESIGNED BY: Ocean Mates DATE: Spring semester 2025	RUBBER
SIZE A4	BATTERY CASE LID
SCALE 1:4	Balloon 8
SHEET 8/12	



Detail A
Scale: 1:1

DESIGNED BY: Ocean Mates

DATE: Spring semester 2025

PLANK

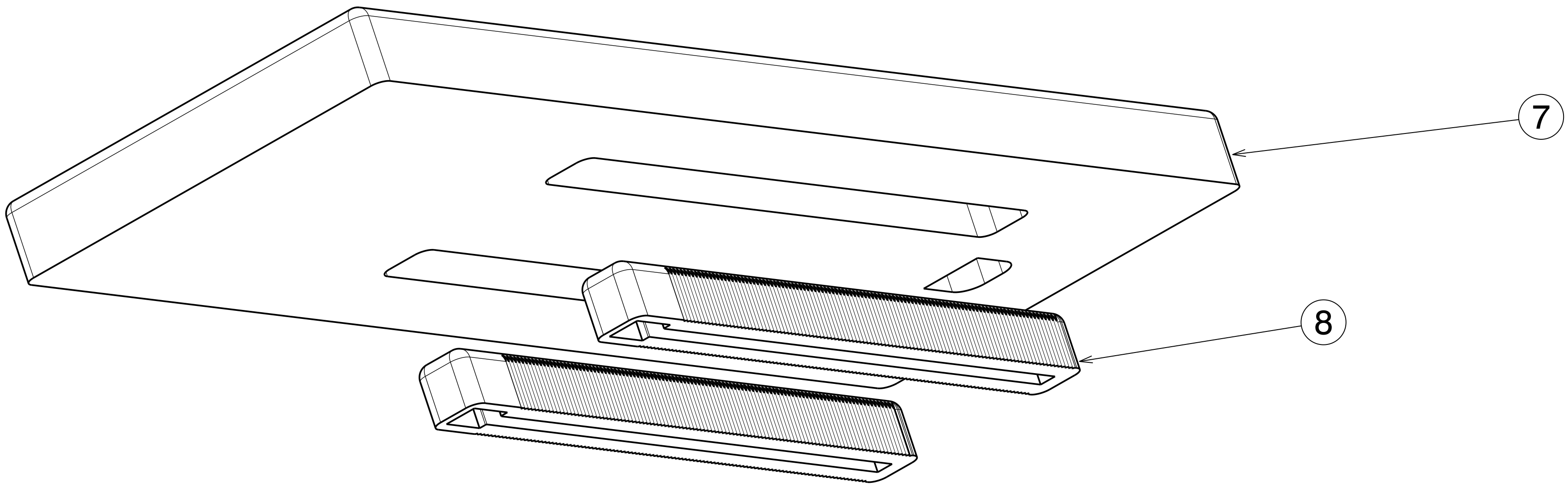
SIZE: A4

BATTERY CASE LID

SCALE: 1:4

Balloon 9

SHEET 9/12



Nº PIECES	NAME	BALLON	SHEET	MATERIAL
2	Track	11	12	ONNYX
1	Reinforcement	10	11	XPS

DESIGNED BY: Ocean Mates

DATE: Spring semester 2025

STRUT ATTACHMENT

SIZE A4

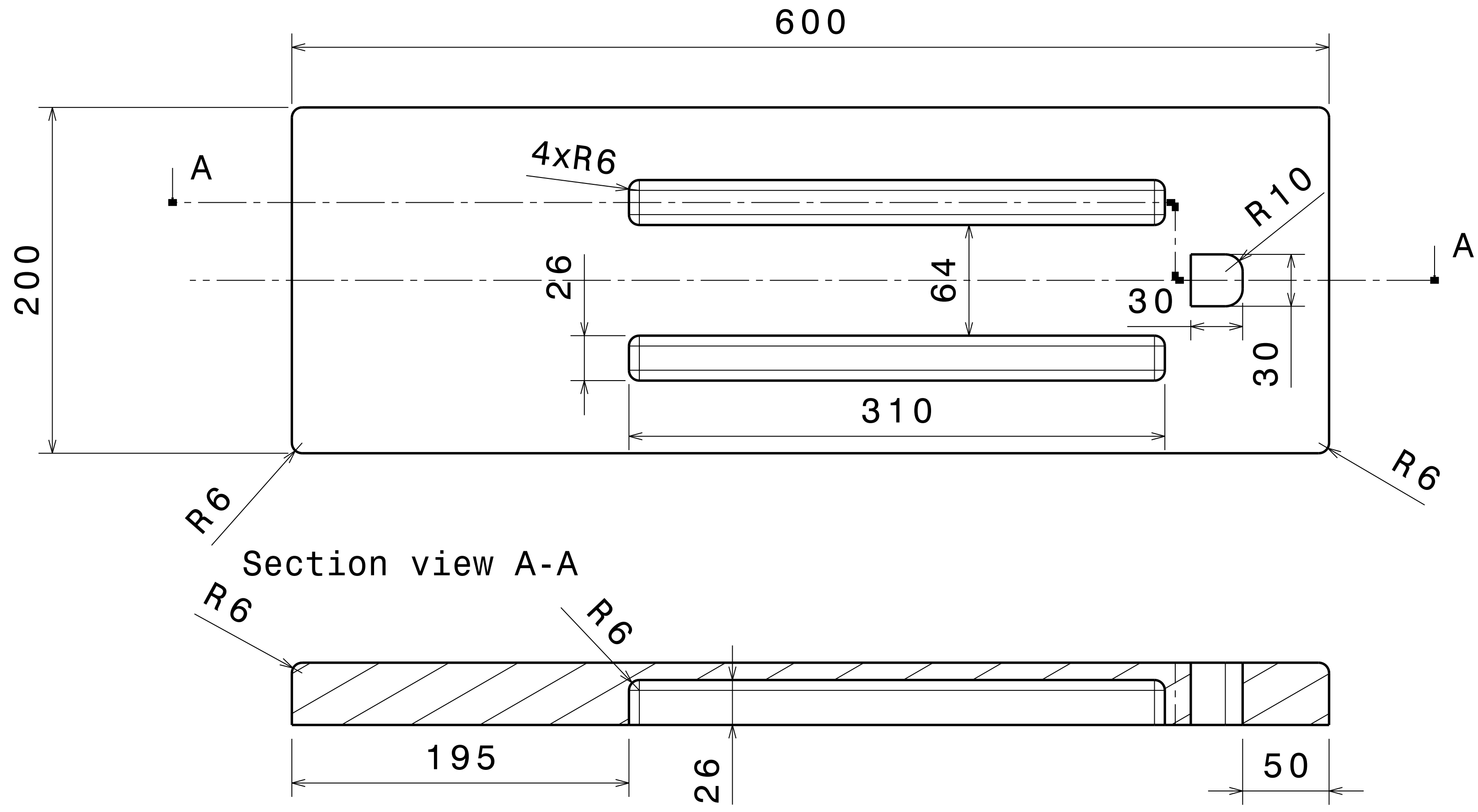
E-FOIL BOARD

SCALE

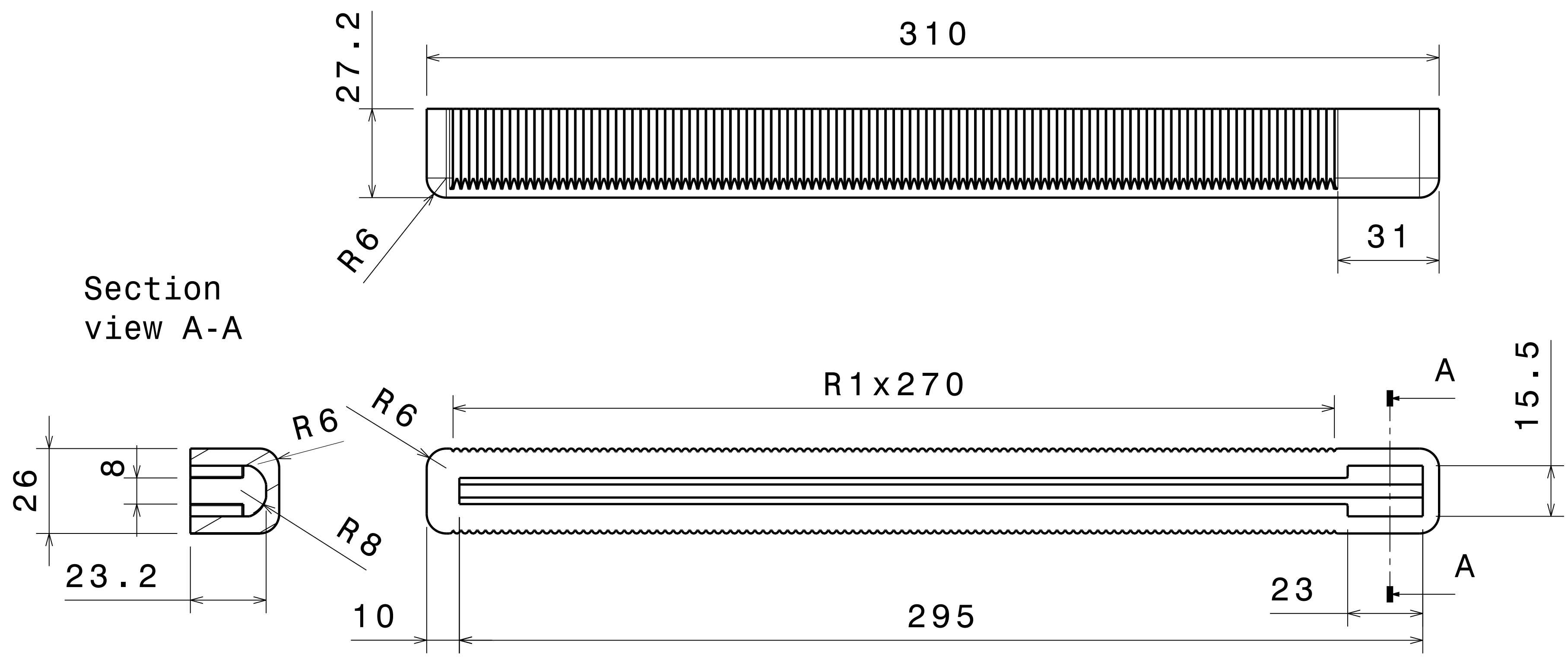
Balloon 3

Overall drawing 4

SHEET 10/12



DESIGNED BY: Ocean Mates DATE: Spring semester 2025		REINFORCEMENT
SIZE A4		STRUT ATTACHMENT
SCALE 1:4	WEIGHT (kg)	Balloon 10 — SHEET 11/12



DESIGNED BY: Ocean Mates DATE: Spring semester 2025	TRACK	
SIZE A4	STRUT ATTACHMENT	
SCALE 1:2	Balloon 11	SHEET 12/12

F Budget

After the conducted research and the chosen materials, it was time to set up the budget. This section explains, why and how the budget was made up. All prices and costs are included with VAT and valid by march 2025.

Because of the chosen board size of 120 x 70 x 15 cm resulting into 126 litres of volume, we needed to build a suitable foam core. At the local hardware store EPS plates measure 120 cm in length, 60 cm in width and 5 cm in depth each, were available. To achieve the designed measurements and have a safety space on the outside for the CNC machine, we calculated with 11 plates of EPS, cost 41,5 kroners each AB, 2025. To reinforce the strut area, we calculated with one single plate of XPS foam, where 2 cm wide tracks get inserted into. For attaching the foams we put the PU glue, which came alongside delivery cost, and a needed foam gun into the budget. The price per hour for using the CNC machine at the Fellasverkstedet is 199 kroners.Fellesverkstedet, n.d. To estimate the right duration was not that easy because it depends on many detail factors, so we calculated with 4,5 hours for the whole milling process.

For the laminating process we calculated with 2 rolls of 5 square meter fibreglass fabric weave for 598 kronersBiltema, 2025a. It was assumed that the board is a rectangular block. Therefore, the calculated area is 2,25 square meters. To put 3 layers of fibreglass cloth, at least 6,75 square meters were needed. For the same price, two pieces of one square meter carbon fibre fabric covering two square meters were chosen for the last layer.

To calculate the right amount of Epoxy was difficult because we had no experience with it before as a reference. As a result of the research one litre of epoxy resin results in a layer thickness of 1 mm per square metre. If assumed that the coating area is a rectangle, the formula would be length x width x layer-thickness x specific weight of epoxy resin divided by 1000 to get the needed amount in kilograms (B.V, 2025). With a layer thickness of 1 mm we got an amount of 0,924 kg. To coat the whole board with a minimum of 3 layers, the needed epoxy would roughly be 5,5 kg. This would have required 3 cans of laminating epoxy cost 549 kroners each(Biltema, 2025b). Because of the board's shape, which is not a complete rectangle, we decided to put only 2 cans of epoxy into the budget. Through the research we found useful tools that had been used frequently for the laminating process. For example, to coat the epoxy, we included a filler set, consist of 4 different putty knives, nitrile gloves to protect the skin, masking tape and painting protective paper to not mess up the working space.

The battery case was calculated with a 5 m long and 5 mm thick nitrile O-ring-cord which was the best in stock at the online shop. For the lid, a 148 mm long wooden plate and the small plastic air vents were put into the budget. All costs are displayed in 5 the budget.

Budget calculation foil board

			all prices include VAT			
Material	Measures	Quantity	Price/piece in kr	Price/piece in €	Total kr	Total €
Polysterol foam	5*60*120cm	11	41,5	3,57 €	kr 456,50	€ 39,26
fiberglass cloth	300/m^2, 5m^2	2	299	25,71 €	kr 598,00	€ 51,43
carbon fiber	200g/m^2, 1m^2	2	299	25,71 €	kr 598,00	€ 51,43
Epoxy resin	1,5l laminating epoxy	2	549	47,21 €	kr 1 098,00	€ 94,43
Nitrin gloves	size L, 50pcs	1	199	17,11 €	kr 199,00	€ 17,11
filler set	4 parts	1	22,9	1,97 €	kr 22,90	€ 1,97
masking tape	38mm	1	29,9	2,57 €	kr 29,90	€ 2,57
painting protective paper	1m-1,2m	1	84,9	7,30 €	kr 84,90	€ 7,30
air vent	15,55x17mm	2	136,85	11,77 €	kr 273,70	€ 23,54
PU-glue	850ml	1	280	24,08 €	kr 280,00	€ 24,08
plastic rails set	2cm thick	4	180	15,48 €	kr 720,00	€ 61,92
nitrile o-ring cord	5mm diameter, 5m length	1	331,19	28,48 €	kr 331,19	€ 28,48
PU foam gun		1	206	17,72 €	kr 206,00	€ 17,72
wood plate	36x148mm	1	45,95	3,95 €	kr 45,95	€ 3,95
XPS foam	50x5851185mm	1	258,21	22,21 €	kr 258,21	€ 22,21
use of CNC machine	4,5 hours	4,5	199	17,11 €	kr 895,50	€ 77,01
delivery		1	199	17,11 €	kr 199,00	€ 17,11
buffer	10 %				kr 629,68	€ 54,15
					kr 6 926,43	€ 595,67

Figure 5: Budget calculation

After everything had been summed up, the calculated cost of the final product were 6296,75 kroners. Then a buffer of 10 percent were added to the amount, resulting into 6926,43 kroners. With this budget, we applied to the department of finance, who approved it and gave us an overall budget of 7000 kroners.

Compare estimated budget with real costs of the project

In figure 6 our estimated budget is displayed against our final costs. In the end, we ended up 1176,09 kroners over the calculated budget. There are different reasons for this. Some things got adjusted in terms of quantity or measures, compared to the estimated budget and other things were changed completely.

To start with the foams, the XPS was used as planned and for the EPS we found a way of adjusting the plates that we could save 3 plates. The carbon fibre as well as the filler set were used as planned, on top of that were we able to use at least half a square metre of carbon in the next layer. As we decided to make the fibreglass layers out of one complete piece instead of using the overlapping parts on the side, we needed one extra roll of fibreglass cloth.

First of all, the delivery time of more than 2 weeks of the planned PU glue was checked too late, as the building phase had been already scheduled. As a result the foam pieces were glued together with epoxy, planned for coating, which also made the planned PU foam gun unnecessary. Secondly, because of the decision with the fibreglass, more epoxy was needed, that is why we first bought one can more and eventually we bought two extra. This calculation was not well done. A total of five cans were bought, from which four cans got eventually used. Lastly, the calculation was too tight. Due to a lack of experience, the mixture of epoxy was sometimes overdosed and therefore not used, resulting into a waste of material. This counts as well for using too much epoxy and dropping it on the working area. Those possible issues needed to be calculated as a buffer into the epoxy-resin calculation.

The use of the CNC machine was difficult to predict, even tough an employee of the "Fellasverkstedet" gave us an approximate duration. Furthermore because of material decisions, like using an aluminium and a polycarbonate plate, the using time got extended. This explains why the wooden plate of the budget was not purchased. Also the mandatory purchase of the used milling tool was not taken into account. Overall the use of the CNC machine was 1352,8 kroners higher than expected.

The air vent is a little bit more expensive because the model got changed. The o-ring cord was calculated with a length of 5m because back then, it was the only available size of the square model. The 2m option reduced the price by 71,21 kroners.

The fibreglass filler was needed to fill the holes, caused by the CNC machine, which was not expect while making the budget.

Things changed, compared to the calculated budget. In order to cut the costs, nitrile gloves, masking tape, the plastic rails set and the painting protective paper were not purchased. For the paper, newspaper was used and the tracks were 3D printed in the Ocean Lab. The rest was also used from the Ocean Lab. The screws with the plain washers and the grip mat were missing in the estimated budget because they have been put into the buffer.

In the end, it stands out that the budget was not well done. It was handed in too early and with too much missing parts, that were either not considered or not decided yet. The plan was to put these undecided things into the buffer. Because this cannot include that many things, the 10 percent buffer of the estimated budget was way to small for the materials that really have been purchased afterwards.

			expected	actual	expected	actual	expected		actual	
Material	expected quantity	actual quantity	Price/piece in kr	Price/piece in kr	Price/piece in €	Price/piece in €	Total kr	Total €	Total kr	Total €
Polysterol foam	11	9	41,5	41,5	3,57 €	3,57 €	kr 456,50	€ 39,26	kr 373,50	€ 32,12
fiberglass cloth	2	3	299	299	25,71 €	25,71 €	kr 598,00	€ 51,43	kr 897,00	€ 77,14
carbon fiber	2	2	299	299	25,71 €	25,71 €	kr 598,00	€ 51,43	kr 598,00	€ 51,43
Epoxy resin	2	5	549	549	47,21 €	47,21 €	kr 1 098,00	€ 94,43	kr 2 745,00	€ 236,07
XPS foam	1	1	258,21	179	22,21 €	15,39 €	kr 258,21	€ 22,21	kr 179,00	€ 15,39
use of CNC machine	4,5	1	199	1247,8	17,11 €	107,31 €	kr 895,50	€ 77,01	kr 1 247,80	€ 107,31
filler set	1	1	22,9	22,9	1,97 €	1,97 €	kr 22,90	€ 1,97	kr 22,90	€ 1,97
fiberglass filler	0	1	199	199	17,11 €	17,11 €	kr 0,00	€ -	kr 199,00	€ 17,11
aluminium packs	0	1	39,9	39,9	3,43 €	3,43 €	kr 0,00	€ -	kr 39,90	€ 3,43
biltema shopping bag	0	1	15	15	1,29 €	1,29 €	kr 0,00	€ -	kr 15,00	€ 1,29
air vent	2	2	136,85	149,58	11,77 €	12,86 €	kr 273,70	€ 23,54	kr 299,16	€ 25,73
nitrile o-ring cord	1	1	331,19	259,98	28,48 €	22,36 €	kr 331,19	€ 28,48	kr 259,98	€ 22,36
screws	0	1	106,25	106,25	9,14 €	9,14 €	kr 0,00	€ -	kr 106,25	€ 9,14
plain washers	0	1	24,6	24,6	2,12 €	2,12 €	kr 0,00	€ -	kr 24,60	€ 2,12
Aluminium plate	0	1	240	240	20,64 €	20,64 €	kr 0,00	€ -	kr 240,00	€ 20,64
cut aluminium plate	0	1	100	100	8,60 €	8,60 €	kr 0,00	€ -	kr 100,00	€ 8,60
Divs Milling tool	0	1	535	535	46,01 €	46,01 €	kr 0,00	€ -	kr 535,00	€ 46,01
Oppstart CNC	0	1	125	125	10,75 €	10,75 €	kr 0,00	€ -	kr 125,00	€ 10,75
Puzzle EVA mat	0	1	169	169	14,53 €	14,53 €	kr 0,00	€ -	kr 169,00	€ 14,53
Nitrin gloves	1	0	199	199	17,11 €	17,11 €	kr 199,00	€ 17,11	kr 0,00	€ -
masking tape	1	0	29,9	29,9	2,57 €	2,57 €	kr 29,90	€ 2,57	kr 0,00	€ -
painting protective paper	1	0	84,9	84,9	7,30 €	7,30 €	kr 84,90	€ 7,30	kr 0,00	€ -
plastic rails set	4	0	180	180	15,48 €	15,48 €	kr 720,00	€ 61,92	kr 0,00	€ -
PU-glue	1	0	280	280	24,08 €	24,08 €	kr 280,00	€ 24,08	kr 0,00	€ -
PU foam gun	1	0	206	206	17,72 €	17,72 €	kr 206,00	€ 17,72	kr 0,00	€ -
wood plate	1	0	45,95	45,95	3,95 €	3,95 €	kr 45,95	€ 3,95	kr 0,00	€ -
delivery	1	0	199	199	17,11 €	17,11 €	kr 199,00	€ 17,11	kr 0,00	€ -
							kr 6 296,75		**kr 8 176,09**	
						Difference:	**-kr 1 879,34**	**-€ 161,62**		

Figure 6: Expected cost,visible in column 8 (expected) and the eventual costs,displayed in column 10 (actual)

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