Final report

Paramotor Transport Box

Paratroopers

European Project Semester

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Abstract

This project aims to design a box for transporting, protecting and storing a paramotor. After analysing existing market solutions, we developed a custom design that fulfils all the requirements set by our client and tutor, Tobias. Research and technical calculations were conducted on the paraglider's dimensions and weight, the structural stresses the box would endure, and the relevant aerodynamic and traffic regulations. The design was created using CAD software, ensuring full alignment with the client's specifications. This report presents the final design, the product we were able to construct, and suggestions for future improvements.

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1. Introduction

What is the project

The project involves creating an efficient transportation system or container for powered paragliders, aiming to simplify and enhance the user experience of paramotor transport. It will be carried out over four months with a budget of 1,000€.

Problem statement

When transporting their paramotors from home to the take-off area, pilots often have no choice but to use their car trunk. However, this method is neither efficient nor safe for such a bulky and valuable piece of equipment. Due to the large cage size and the motor's weight, carrying a powered paraglider without a dedicated transport system can be challenging, potentially leading to product damage or increased risk for the driver and passengers. Additionally, the lack of a proper storage system exposes the paramotor to the risk of damage when not in use, which compromises its durability and long-term performance.

1.1. Project background

What is EPS?

The EPS (European Project Semester) is a program available at 19 universities across 13 European countries, primarily designed for third-year engineering students but open to others. Established in 1994, EPS successfully equips students with essential skills for the global economy through interdisciplinary, industry-linked projects. Participants collaborate in international teams and attend cohort-based classes, enhancing both technical and intercultural competencies.

1.2. Team members

The team that will execute this project consists of four members, each coming from a different country and background.

Tom Geluk

Figure 1: Tom Geluk

I am Tom Geluk, a 20-year-old student from the Netherlands. Currently I am studying Engineering at HZ University of Applied Sciences, specializing in Product Engineering. Throughout the EPS project, I aim to broaden my overall knowledge of Engineering, while also improving my collaborative skills in an international setting.

Marino González Bravo

Figure 2: Marino González Bravo

My name is Marino González Bravo, I am currently 23 years old, and I am Spanish student.

I study mechanical engineering at the University of Valladolid, and this is my last year. Additionally, I am currently participating in an EPS project at Novia University of Applied Sciences in Vaasa, Finland. It has been a truly enriching experience, exploring mechanical engineering from a global perspective and applying my knowledge in an international project. Collaborating with people from diverse backgrounds and expertise has broadened my understanding and enhanced my problem-solving skills.

I am particularly interested in thermodynamics and propulsion systems, including internal combustion engines and reaction engines.

Jonas Stockmann

Figure 3: Jonas Stockmann

I am Jonas Stockmann, a currently 23-year-old student from Germany. I study mechanical engineering at Osnabrück University of applied Sciences, specialising in Production technology. I take part in the EPS to improve my collaborative skills in an international and unfamiliar environment, while also learning about other cultures and ways of living.

Mathis Besançon

Figure 4: Mathis Besançon

I am a 22-year-old French student studying in Packaging engineering in ESIREIMS engineer school of Reims Champagne-Ardenne university. I am participating in the EPS program because it offers a unique opportunity to work abroad with people from diverse nationalities and fields of study. This experience will allow me to become more open to new perspectives, improve my communication skills, and confidently share my ideas.

2. Research phase

Before designing the transport box, various types of research needs to be conducted. The findings from this research will be used to define all the requirements for the paramotor transport box.

2.1. The Sky Engine 110 S

The Sky Engine 110 S is a paramotor engine with a high performance due to its light weight. This engine has a two-stroke single cylinder that is liquid-cooled and has a 110c that delivers a power of 26 HP at 11200 rpm. Including the fluids this engine has a weight of 13.5 kg that makes this engine a perfect balance between power and portability. This is a great engine if you are looking for good performance and reliability.

The dimensions of a paramotor equipped with this engine can vary depending on the manufacturer and the chosen model. The paramotor transport box will be specifically designed for the Explorer 2 model (figure 2), which suits perfectly with the Sky Engine 110 S. The specifications of the Sky Engine 110 S mounted on the Explorer 2 can be found in table 9 (Sky Engines, sd).

Figure 5: Sky Engine 110 S with Explorer 2 model
Source: (Flymecc, sd)

Table 1: Specifications Sky Engine 110 S

ID	Specification	Details
1.	Engine model	Sky Engine 110S
2.	Engine type	Single-cylinder, two-stroke, liquid-cooled
3.	Displacement	110cc
4.	Power Output	26 HP at 11200 rpm
5.	Engine weight	13.5 kg (including fluids)
6.	Frame diameter	1400 mm (for a 125 cm propeller)
7.	Frame material	Stainless steel
8.	Total paramotor weight	Approx. 23 kg + 10 L fuel capacity

2.2. Existing solutions

Most existing solutions for transporting a paramotor rely on either a flat platform or a pair of support arms mounted onto the vehicle's tow hook serving as a base for securing the paramotor frame. These systems are available in two main forms: some are specifically designed and manufactured for this purpose by companies or private individuals, while others are adapted from generic cargo carriers or trays, which are modified to safely hold the paramotor. The most common solutions can be divided into three categories:

1. A skid paramotor carrier
2. A platform paramotor carrier
3. A homemade paramotor carrier

The primary goal of these setups is to provide a stable and secure means of transportation while ensuring easy loading and unloading. A well-designed system prevents excessive vibrations and movement during transit, which could otherwise cause damage to the paramotor or the vehicle.

Figure 6: A skid paramotor carrier
Source: (VikingPPG, sd)

Figure 8: A platform paramotor carrier
Source: (bad-fashion.com, sd)

Figure 7: An example of a platform paramotor carrier
Source: (ParamotorCarrier.com, sd)

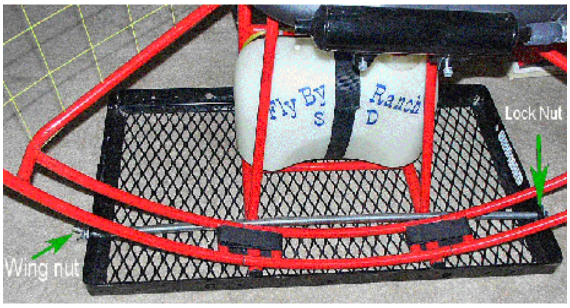

Figure 9: An example of a homemade carrier
Source: (Gudnason, sd)

Figure 10: A different example of a homemade carrier
Source: (Goin, 2019)

These transport solutions are composed of three fundamental components:

1. **A central support beam** – This serves as the main structural element, connecting the system to the tow hook and providing overall stability.
2. **A platform or two support arms** – These elements support the paramotor by either offering a flat surface for it to rest on or two arms that cradle the frame securely.
3. **A fixation system** – This mechanism, which may include straps, clamps, or custom brackets, ensures that the paramotor remains firmly in place, minimizing movement during transport.

Depending on the design, some solutions offer additional features such as tilting mechanisms for easier loading, quick-release systems for convenience, or adjustable components to accommodate different paramotor sizes and shapes.

3.1. Mounting mechanisms for the paramotor

The Sky Engine 110 S features two tubes on the lower part of the frame, designed to secure the paramotor to the transport box (see figure 8). This can be achieved using various methods, each presenting its own advantages.

Figure 11: The lower frame of the Sky Engine 110 S

1. **Ratchet straps**: quick and easy way to secure parts using adjustable straps with a ratcheting system. They provide a firm grip while still being easy to tighten or release when needed.

Figure 12: Example of a ratchet strap
Source: *(Fyndiq, sd)*

2. **Clamps**: A strong and reliable option for holding components in place. Clamps are great for semi-permanent mounts, offering a secure hold without requiring complex tools.

Figure 13: Example of a mounting clamp
Source: (MSC Direct, sd)

3. **Quick-release pins**: Perfect for situations where you need to attach or detach parts quickly. These pins lock components securely but can be removed in seconds.

Figure 14: Example of a quick release pin
Source: (NRC&XRC Store, sd)

4. **Pipe mounting brackets**: These are brackets specifically designed to hold pipes or tubes in place.

Figure 15: Example of a pipe mounting bracket
Source: (Thomann, sd)

5. **Pipe clamps**: Like the mounting brackets, pipe clamps secure the tubes on the frame to the transport box. These clamps wrap around the pipes and tighten them.

Figure 16: Example of a pipe clamp
Source: (Emiif, sd)

3.2. Mounting possibilities on tow hook

When transporting a paramotor with a car from A to B, there are two main options. One of them is mounting the paramotor to the tow hook of the car. The technology for transporting cargo on the tow hook is already well-established, primarily used for bike racks or universal cargo carriers. These carriers are securely mounted to the ball tow hitch, a standardized tow hook used on European cars (see figure 15). Usually, these mounting mechanisms consist of a clamp operated by a lever (see figure 14).

This research focuses only on the possibilities with European tow hooks. The earlier mentioned mounting mechanisms are sold separately, offering the flexibility to build a paramotor transport box around them. Figure 16 shows an example of a frame that can be mounted on a tow bar locking mechanism. A frame like this can provide a strong base for a paramotor transport box.

Figure 18: European tow hook
Source: (Eurotowbars, sd)

Figure 17: Tow bar locking mechanism
Source: *(Heck-Pack, sd)*

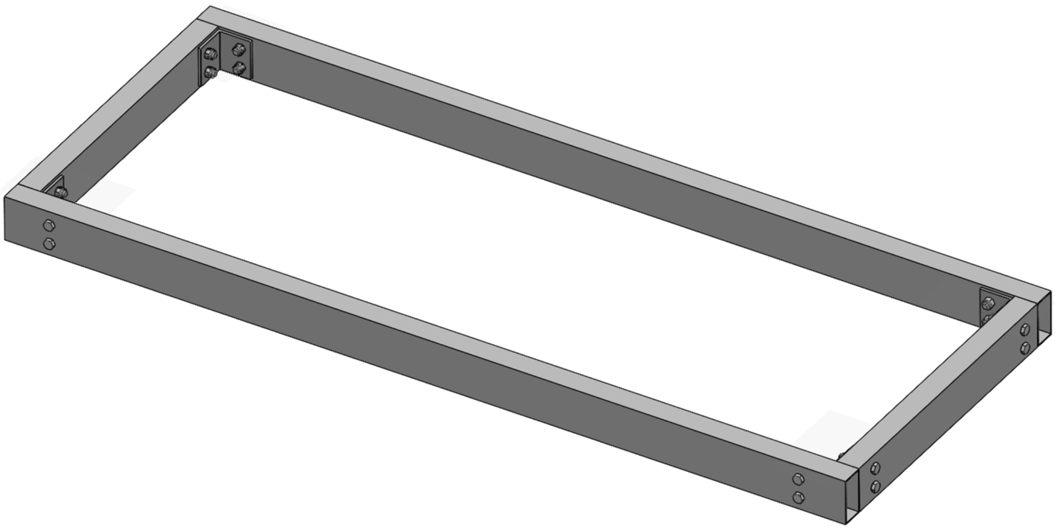

Figure 19: Example of a frame that can be mounted on a tow bar locking mechanism.

3.3. Tow hook dimensions

The distance between the top of the tow hook and the ground affects the height at which the paramotor transport box will be mounted. According to UNECE Regulation 55, the centre of the tow ball, when loaded to the vehicle's gross weight, must be between 350 mm and 420 mm from the ground. Figure 17 illustrates the difference in tow ball height between a loaded and an unloaded vehicle, as well as the mentioned dimension between the ground and the centre of the tow ball (Caravan and Motorhome Club, sd) (United Nations Economic Commission for Europe, 2010).

Figure 20: The tow bar height of a car when loaded
Source: (Towbarexpress, 2017)

3.4. Mounting possibilities on a trailer

Mounting a box on a trailer can be done using several methods. The most common approach is securing it with ratchet straps (see figure 18). Another option is a hook-and-rail system, which allows the box to slide easily into position. This solution is more commonly used in air freight transport. Alternatively, the box can be bolted to the trailer using brackets mounted on the trailer frame, providing a secure and stable attachment.

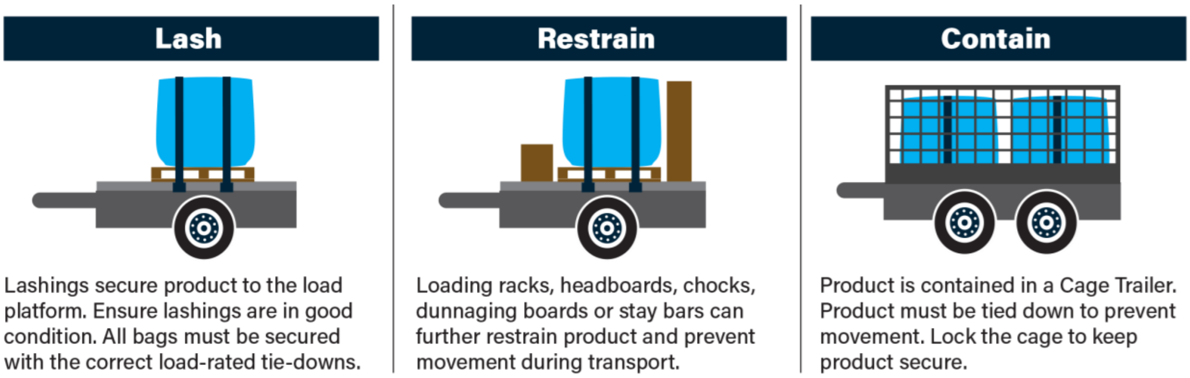

Figure 21: Guidelines for loading trailers
Source: (Ballance.co, sd)

3.5. Trailer dimensions

Trailers come in various sizes, since the Sky 110 S paramotor is relatively compact, the transport box will be compatible with most trailers. However, a minimum trailer bed area is required. The Sky 110 S has a width of approximately 1.4 meters and a depth of 0.6 meters. The trailer must exceed these dimensions by at least 0.2 meters on each side. This extra space is necessary to securely fasten the box using straps.

3.6. Regulations for transporting payload by car

In the document “driving in Finland” multiple regulations for transporting payloads by are listed. The most important regulations for our project are that the view of the driver should not be obstructed, the signal lights should not be blocked, the maximum weight of 750 kg for trailers not fitted with brakes or 3500 kg if they are fitted with brakes must not be exceeded. Furthermore, the load must not project beyond the body of the vehicle or its stowage space and the load must be secured so it cannot shift around and thus endanger traffic safety (Centre for Economic development, Transport and the Environment, 2020).

If the box is mounted on a tow hook, the maximum weight limit will be different because the load is primarily vertical instead of horizontal. This maximum weight varies depending on the type of car, but it is usually between 45 and 75 kg (Brink).

3.7. External factors

When designing a transport box that will be used outside of a car, it is essential to identify various external factors that would have some sort of effect on the transport box itself. Environmental conditions such as rain, humidity, temperature fluctuations and wind can impact the durability and functionality of the transport box.

Additionally, vibrations, shocks and debris may lead to wear and potential damage. Under-standing these external factors allows for the creation of a transport box that provides an optimal pro-tection, ensuring that the paramotor will stay in in one piece during transportation.

Rain and water in general

During transport of the paramotor from A to B, rain and water in general may accumulate on the box. Depending on the material, the formation of rust vital parts of the box is a possibility. Further-more, the box must protect the paramotor inside from water. This implies that the box must have an IPX-rating of at least IPX-4. The IP rating is an international standard to rate the degree of pro-tection of objects primarily against water and dust (see figure 19) (Gear, sd).

IPX-0	No protection
IPX-1	Protected against condensation or dripping water falling vertically.
IPX-2	Protected against spraying water when tilted up to 15 degrees vertically.
IPX-3	Protected against spraying water when tilted up to 60 degrees vertically.
IPX-4	Protected against splashing water from any angle.
IPX-5	Protected against low pressure water stream from any angle.
IPX-6	Protected against high pressure water stream from any angle.
IPX-7	Protected against water immersion. Immersion for 30 minutes at a depth of up to 1 meter.
IPX-8	Protected against continual water submersion in under water conditions.

Figure 22: IPX protection table
Source: *(Hypergear, sd)*

Structural integrity

During transportation vibrations and shocks can occur. The paramotor box should withstand these factors without damaging the paramotor nor the box itself. Besides that, the structure of the box must be strong enough at the mounting points to the vehicle or the cargo trailer.

Wind and aerodynamic drag

The paramotor transport box will be attached to the vehicle itself or to a cargo trailer. Both options have effect on the driving experience. Depending on the surface area of the box, wind and wind gusts can change the way the vehicle will behave during transportation. In addition, the transport box will have a certain amount of aerodynamic drag. This will increase the consumption of fuel (see figure 20). Both factors must be kept in mind when designing the transport box.

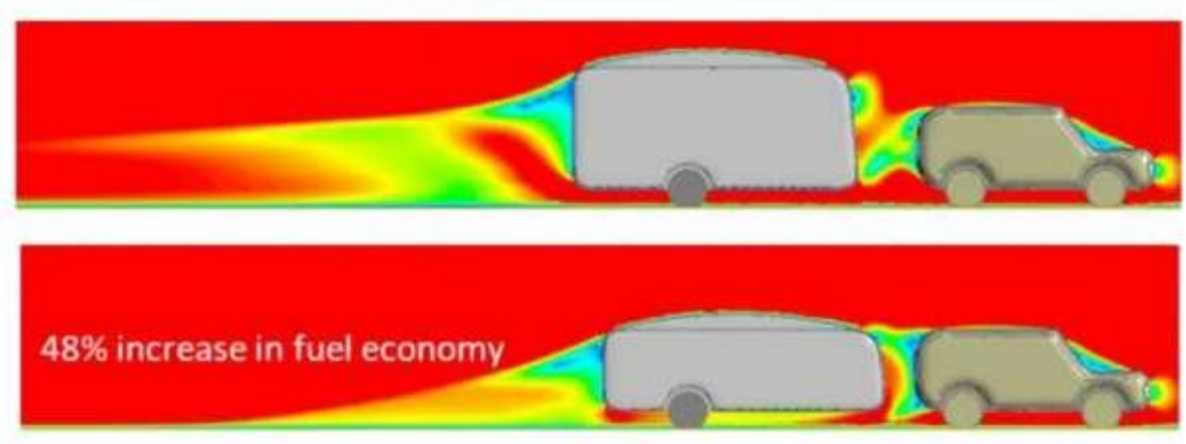

Figure 23: Example of aerodynamics on a caravan
Source: *(Mechanical Elements, sd)*

3.8. Table of requirements

The requirements for the transport box serve as the main guideline for the design phase of the project. All of the requirements are listed below in table 2. These requirements are categorized into three types:

1. Fixed requirement: These requirements must be fulfilled. If they are not met, the project is considered incomplete or has failed.
2. Wish requirement: These are non-essential features that are desirable. Including them enhances the quality and user experience of the project, but they are not mandatory.
3. Minimum requirement: These requirements define the lowest acceptable standard. They must be met for the project to be considered successful, but exceeding them will improve the overall quality.

Table 2: Table of requirements

List of requirements Paramotor transport box			
F - Fixed requirement W – Wish requirement M – Minimum requirement		Method according to Pahl/Beitz	
ID	**Prio**	**Description**	**Measurability**
1		Geometry	
1.1	F	The paramotor transport box must be large enough to fit the Sky Engine 110 S without being unnecessarily large.	Min 1400 x 800 x 1400
1.2	W	The paramotor transport box should have a way to reduce aerodynamic drag.	
1.3	M	The paramotor transport box must protect the paramotor from water and dust.	At least IPX-4
1.4	F	The paramotor transport box must be as lightweight as possible, without compromising structural integrity.	Max 75 kg
1.5	F	The paramotor transport box must have a water drainage port	
2		Structural integrity	
2.1	F	The base of the paramotor transport box must support the weight of the paramotor and the box.	
2.2	W	The paramotor can be started when still mounted on the transport box	
2.3	F	The paramotor transport box should withstand the dynamic load when transporting from A to B	
3		Ergonomics	
3.1	W	The paramotor transport box must help the user to get his paramotor on his back.	
3.2	F	The paramotor transport box must be easy to use and does not need exceptional strong force	

3.3	F	The paramotor transport box does not have sharp corners	
3.4	W	The paramotor transport box can be operated by one person	
3.5	F	The paramotor should be easily mounted into the box	
4		Mobility	
4.1	F	The paramotor transport box must have the option to be transported on (retractable) castor wheels.	
4.2	F	The paramotor transport box can be lifted using straps or any kind of lifting device	
4.3	F	The paramotor transport box can be transported by car or trailer	
5		Mounting	
5.1	F	The paramotor should stay in one place during transportation and does not loosen over time	
5.2	F	The paramotor transport box can be locked	
6		Cost	
6.1	F	The paramotor transport box must be cheap to produce	Max €1000,-
7		Manufacturing	
7.1	F	The paramotor transport box should be as easy to assemble	
7.2	W	The manufacturing should only require common household tools that most people typically have at home should be used	
8		Sustainability	
8.1	F	The paramotor box must have a long lifetime	At least 10 years
9		Regulations	
9.1	F	The paramotor transport box should follow the transportation regulations	

4. Design phase

After establishing a table of requirements, possible working solutions for transporting the paramotor can be developed. These solutions will be compared and evaluated, after which one concept will be selected for further development.

4.1. Brainstorming and sketches

There are many possibilities when it comes to designing a paramotor transport box. Some early brainstorming and sketching have shown that the method of mounting the box has significant influence on its overall design. For this reason, the design process focused primarily on three possible mounting options. The first option is mounting the box on a trailer. The second involves attaching it to a tow hook. The third is a hybrid solution that accommodates both mounting methods (see figure 24 to 26).

These three concepts are explained in more detail on the following pages.

Figure 25: Concept 1

Figure 24: Concept 2

Figure 26: Concept 3

Concept 1: Trailer mount

This concept was designed to fit only on a trailer (see figure 27 and 28). It consists of a plywood box mounted on top of an aluminium frame. To unload the paramotor, a side panel can be opened using two hinges. Inside the door and the floor of the box, two rails are mounted, along which a carriage is installed. The paramotor is secured on top of this carriage, allowing it to slide out of the box onto the folded-out door. To support the weight of the paramotor and the door, two aluminium profiles can be slid out from the main frame. These profiles help prevent the door from bending downward under load. For easier mobility during storage, the box is equipped with retractable caster wheels at each corner.

Figure 28: Concept 1

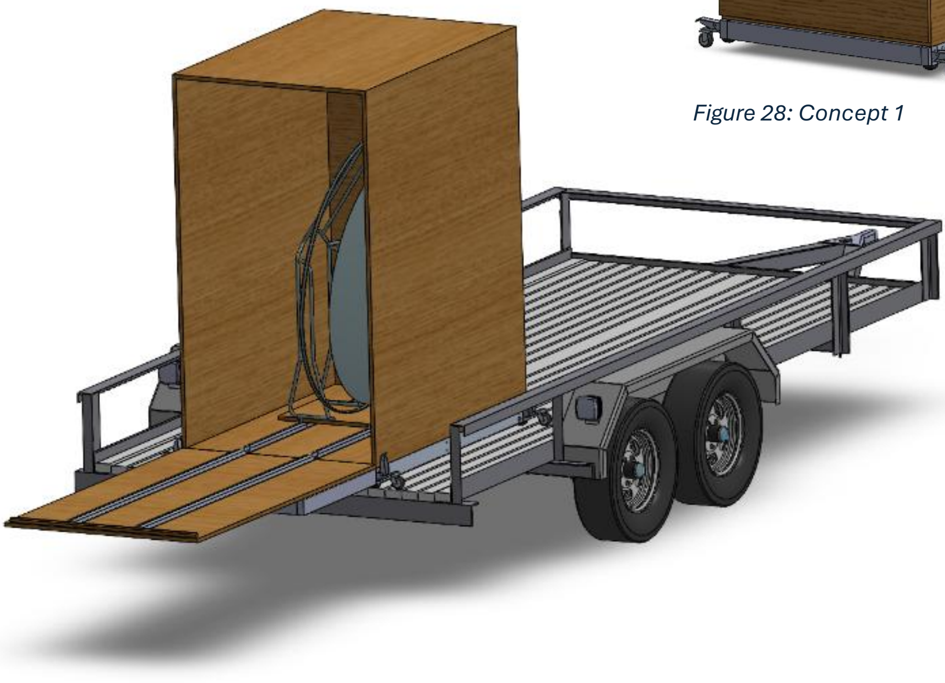

Figure 27: Concept 1 mounted on a trailer

Concept 2: Tow hook mount

This concept is designed to be mounted on a car's tow hook (see figure 29 and 30). Unlike concept 1, it does not require a complex sliding system to unload the paramotor. Unloading is simplified by sliding the back panel out of the box. By removing this panel, the user has enough room to strap the paramotor onto their back. After unloading, the back panel can be easily put back into place. This concept uses the same design principle for the bottom frame. It consists out of four rectangular aluminium profiles, with caster wheels attached at each corner.

Figure 30: Concept 2

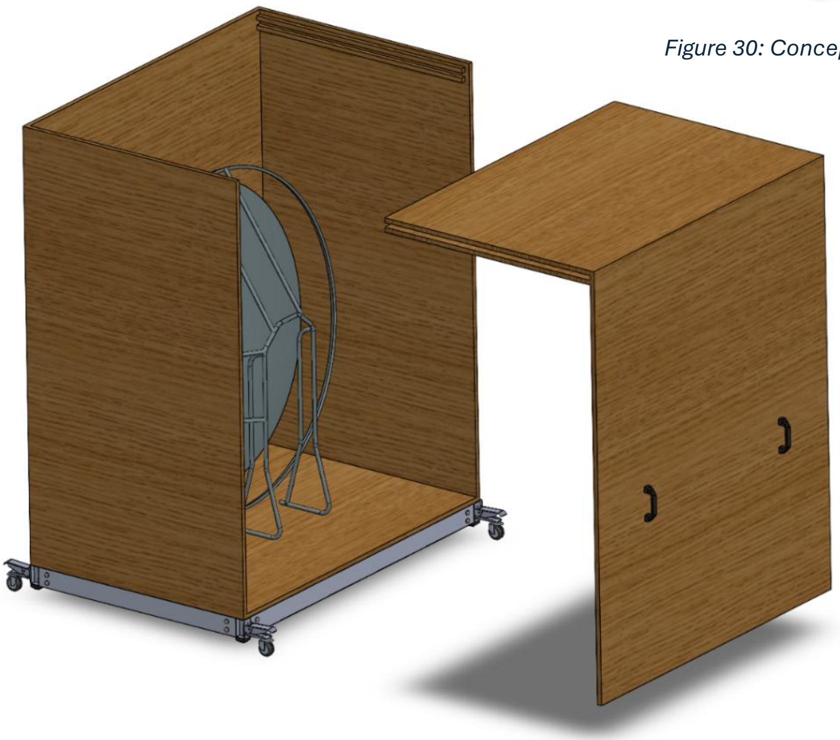

Figure 29: Concept 2 with opened door

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Concept 3: Trailer and tow hook mount

This concept offers two mounting options: it can be attached either to a trailer or directly to the tow hook of a car (see figure 31 and 32). The box features a more rounded shape to improve aerodynamics when mounted behind a vehicle. Similar to Concept 1, it utilizes the same sliding system for loading and unloading the paramotor. However, a key difference is the smaller door size. Since the paramotor requires only 1000 mm to be fully removed from the box, the door has been reduced to minimize stress on the sliding aluminium profiles. Additionally, a second door is integrated on the top, allowing the paramotor to be completely extracted when needed.

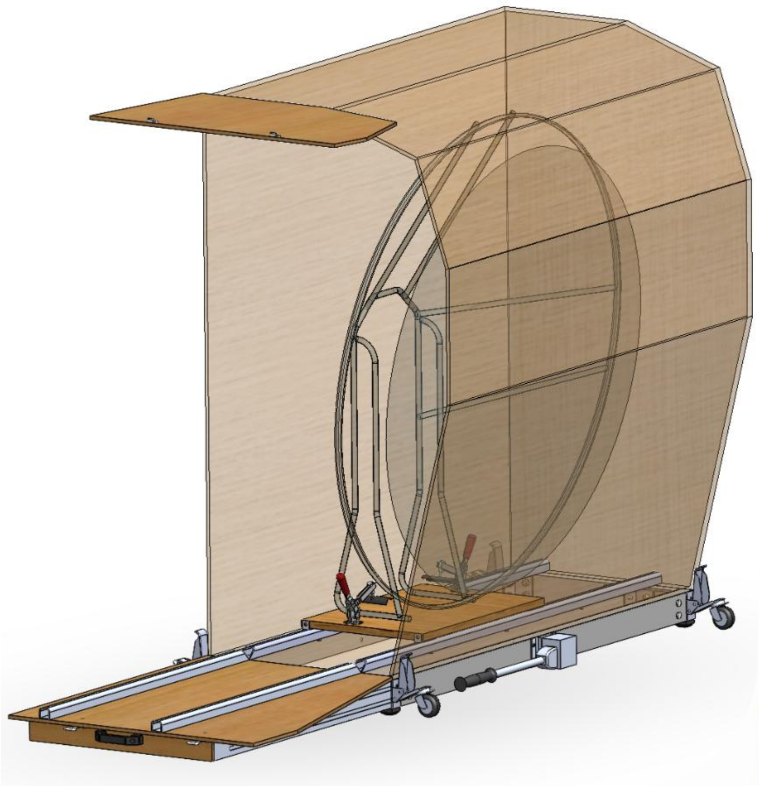

Figure 31: Concept 3 with open doors

Figure 32: Concept 3

4.2. Concept comparison and project redefinition

After a thorough evaluation of the initial design concepts, a decision was made to narrow the focus of the project. While all three mounting options offer viable approaches, certain practical constraints and safety considerations have led to a redefinition of the project scope.

Tow Hook Mount: Not Pursued

The tow hook mounting option will not be further developed. Although it offers a compact and convenient solution, several challenges make it impractical within the context of this project:

Regulatory Compliance: Mounting a large box to a tow hook requires strict adherence to road safety regulations, many of which are difficult to meet given the current design and resources.

Aerodynamic Drawbacks: The paramotor's size increases the frontal surface area significantly when mounted directly behind the vehicle, leading to substantial aerodynamic drag (see figure 33 and 34). This can negatively affect fuel efficiency and vehicle stability.

Structural Concerns: The increased wind resistance demands a more robust and complex structural design, which would be difficult to implement without exceeding the tow hook's weight limit or compromising safety.

Due to these limitations, the tow hook mount, despite its simplified unloading process, will not be further considered in the development phase.

Figure 34: Tow hook mount: side view

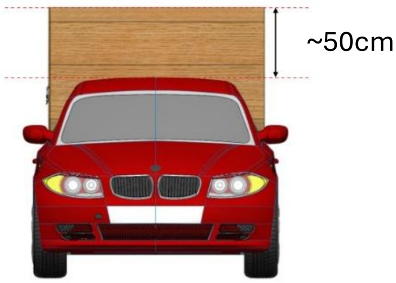

Figure 33: Tow hook mount: front view

Trailer Mount: Selected for Further Development

The trailer-mounted concept has been selected for continued development (see figure 35). Although it introduces higher aerodynamic drag compared to the tow hook version, since the box is positioned more openly behind the towing vehicle, it provides several key advantages:

- **Structural Support**: The trailer distributes the resulting forces evenly across the entire bottom surface of the box. This reduces structural stress and allows for a more straightforward construction, as the load does not only rest on the tow hook.
- **Weight Accommodation**: Unlike the tow hook, trailers can handle greater loads, meaning the design does not need to be restricted by the weight limitations typically associated with vehicle-mounted accessories.
- **Secure Fixation**: The box can be effectively secured to the trailer using tensioning straps. This ensures stability during transport and eliminates the risk of tipping or falling over.
- **Functional Loading System**: The trailer-mounted design features a fold-down door with integrated rails and a sliding carriage, simplifying the loading and unloading process for the paramotor.

In summary, the trailer mount strikes the most practical balance between functionality, safety, and structural feasibility. The design process will therefore continue with this concept as the basis for the final transport solution.

Figure 35: Selected concept for further development

4.3. **Final** design

The final design consists of two parts: an aluminium frame and a wooden box (see figures 36 and 37). To get access to the paramotor, the box has a door that folds down and rests on a drawer system. With this drawer system the paramotor can be unloaded easily. Furthermore, wheels will be added on the outside of the box to improve the moveability of the box while storing it. Additionally, the box can be secured on the trailer using tensioning straps.

Figure 36: Final design

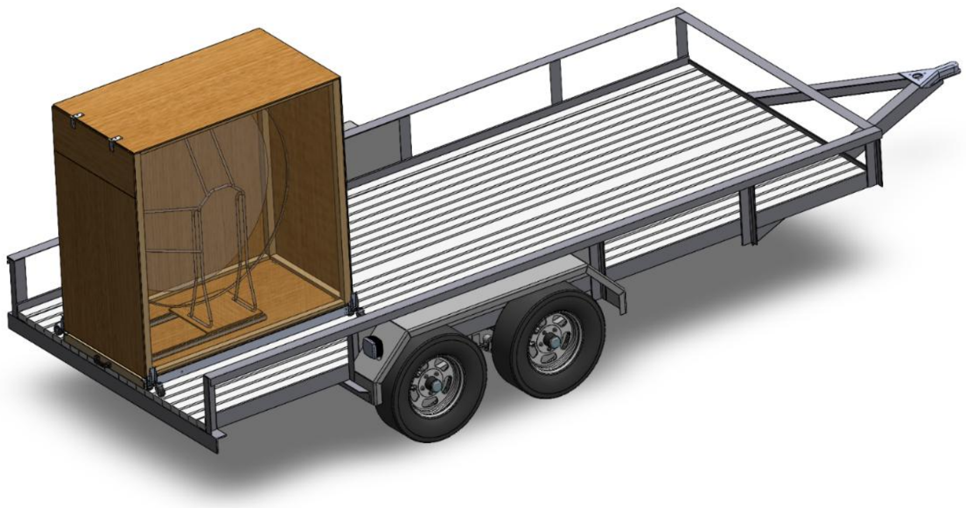

Figure 37: Final design mounted on a trailer

4.4. **Frame** design

The aluminium frame of the paramotor transport box is constructed from four rectangular tubes: two with a length of 1500 mm and two measuring 750 mm. This configuration results in a overall dimension of 1500 mm by 830 mm. The four profiles are connected using corner brackets at each corner (see figure 38 and 40). Each profile is securely fastened with M8 bolts and torque-prevailing nuts on the opposite side (see figure 39). On each profile of 750 mm there are two additional corner brackets are mounted that allow the wooden floor to be attached to the frame.

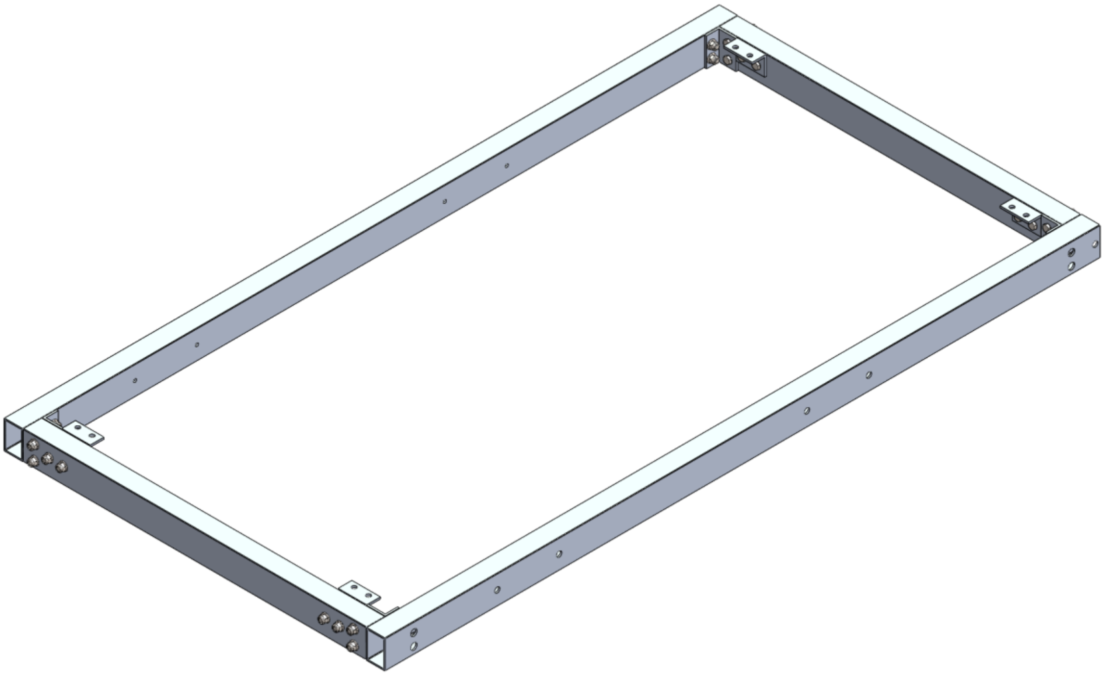

Figure 39: Aluminium frame

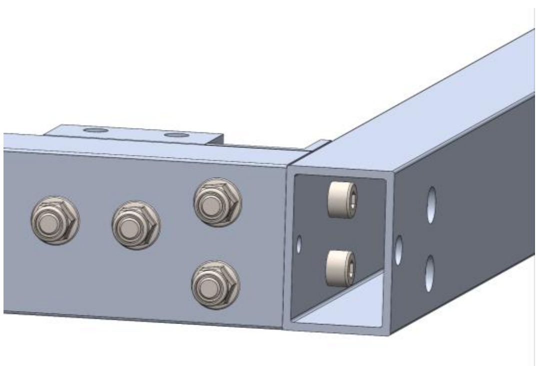

Figure 40: Frame corner - outside

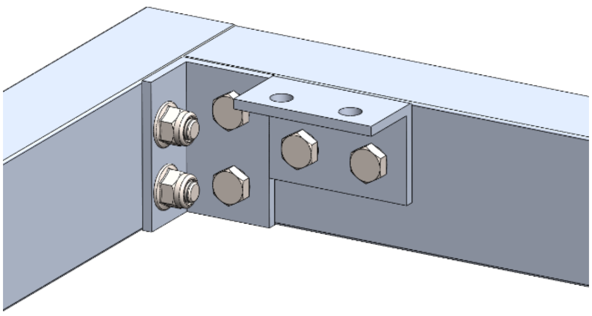

Figure 38: Frame corner - Inside

4.5. **Drawer** design

To support the door and the weight of the paramotor during loading and unloading, two aluminium corner profiles can be extended out of the rectangular tubing (see figure 41). These profiles are held in place by 3D printed brackets (see figure 42 and 43), which distribute the load from the profiles into the surrounding structure. To prevent the drawer from extending beyond their range, an M6 bolt is installed at the end of each profile. This bolt will function as a mechanical end stop against the brackets. To minimize torsional deformation, the two profiles are connected by a wooden plank. In order to pull the drawer out, a handle will be added onto the wooden plank.

Figure 41: Drawer

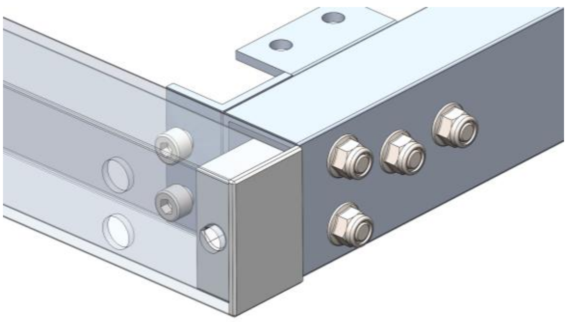

Figure 43: Sliding mechanism end cap

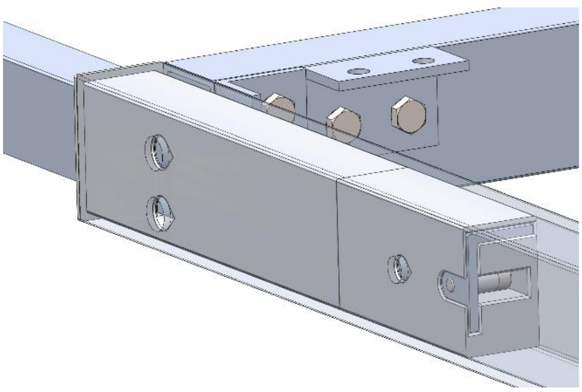

Figure 42: See through view of the sliding mechanism

Calculations

Structural Analysis

We are going to do the structural calculations for an aluminium bar with an L profile with measures 40.30.4

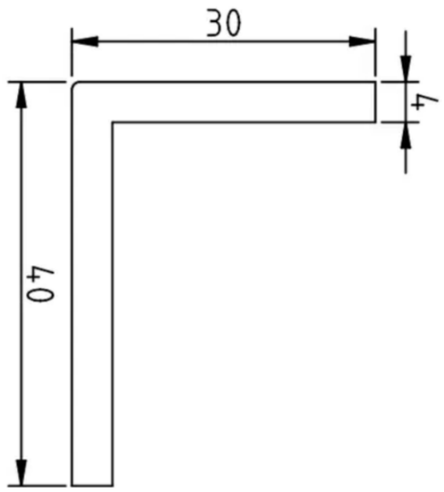

Figure 44: Dimensions L-profile

To start, we are going to calculate the gravity centre and the inertia of the profile.

For the calculation of the gravity centre, we are going to divide the profile into two different rectangles, one of 30 by 4 mm and the other of 36 by 4 mm. We are going to locate the axis in the bottom left corner using x for the horizontal axis and y for the vertical axis. The first thing we are going to calculate are the areas of the rectangles and their gravity centres positions.

$$A_1 = 30 \cdot 4 = 120mm^2;\ \ A_2 = 36 \cdot 4 = 144mm^2$$

$$x_1 = 15\ mm;\ \ y_1 = 38\ mm$$

$$x_2 = 2mm;\ \ y_2 = 18mm$$

Now we are going to calculate the area momentum for each rectangle in each axis by multiplying the area of the rectangle by the distance to the coordinate origin in each axis.

$$A_{x1} = 120 \cdot 15 = 1800\ mm^3;\ A_{y1} = 120 \cdot 38 = 4560\ mm^3$$

$$A_{x2} = 144 \cdot 2 = 288\ mm^3;\ A_{y1} = 144 \cdot 18 = 2592\ mm^3$$

Now we are going to add everything and get the total area of the profile and the total area momentum for each axis.

$$A_T = 120 + 144 = 264\ mm^2$$

$$A_{xT} = 1800 + 288 = 2088\ mm^3;\ A_{yT} = 4560 + 2592 = 7152\ mm^3$$

Finally for the calculation of the coordinates of the centre of gravity we divide each total area momentum by the total area of the profile

$$\bar{x} = \frac{2088}{264} = 7.91\ mm;\ \bar{y} = \frac{7152}{264} = 27.09\ mm$$

$$GC(7.91, 27.09)$$

Now that we have the position of the gravity centre, we are going to calculate the inertia of the profile by using Steiner Theorem. First, we are going to calculate the inertia of the rectangles and then the total inertia.

$$I_{x1} = \frac{b \cdot h^3}{12} = \frac{30 \cdot 4^3}{12} = 160\ mm^4$$

$$I_{y1} = \frac{b^3 \cdot h}{12} = \frac{30^3 \cdot 4}{12} = 9000\ mm^4$$

$$I_{x2} = \frac{b \cdot h^3}{12} = \frac{4 \cdot 36^3}{12} = 15552\ mm^4$$

$$I_{y2} = \frac{b^3 \cdot h}{12} = \frac{4^3 \cdot 36}{12} = 192\ mm^4$$

$$I_x = 160 + 120(38 - 27.09)^2 + 15552 + 144(27.09 - 18)^2 = 41893.8\ mm^4$$

$$I_y = 9000 + 120(15 - 7.91)^2 + 192 + 144(7.91 - 2)^2 = 20253.8\ mm^4$$

As we could have imagined, the inertia axis dominant is the x one.

Now that we have the inertia of the profile and the gravity centre of the profile, we can begin with the structural analysis of the aluminium bar with an L profile. The case we are going to study is a bar that is embedded in one of its endings and at the other end it has a punctual force applied. The bar we are going to study at is 1100 mm long, but in reality, is a 1500 mm that goes inside other profile and can be taken out up to 1100 mm, so this means we are going to study the worst scenario possible. To continue with this line of thought, the paramotor weights around 30 kg and this weight could be considered as a distributed force in the platform, but we are going to simplify it to a punctual force in each of the two bars that will also make it a worst scenario and the final security consideration is instead of using a 15 kg force for each bar we are going to use a 20 kg force. With these security considerations we compensate for the fact that the calculus is not the most accurate.

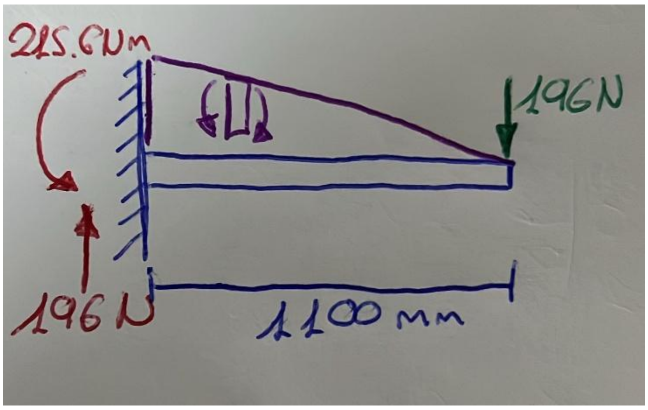

Figure 45: Free body diagram L-profile

$$F = 9.8\ \frac{m}{s^2} \cdot 20\ kg = 196\ N$$

$$M = 196\ N \cdot 1{,}1\ m = 215.8\ Nm$$

We can appreciate that the most critical ponit of the bar is in the enbedment where the momentum is maximun.

$$\sigma_{xx}^{max} = \frac{N}{A} \pm \frac{M}{I} y^{max} = \frac{215.6\ Nm}{4.189 \cdot 10^{-8}\ m^4} \cdot 27.09 \cdot 10^{-3} m = 139.4\ MPa$$

This is the maximun shear stress that the bar needs to resist and now we are going to calculate the maximun bending in the ending of the bar.

For this calculation we need to know that the elastic modulus of the aluminum is E = 69 GPa

$$W = \frac{F \cdot L^3}{3 \cdot E \cdot I} = \frac{196\ \cdot 1.1^3}{3 \cdot 69 \cdot 10^9 \cdot 4.189 \cdot 10^{-8}} = 0.0301\ m$$

The bending of the bar can be up to 30.1 mm.

4.6. **Railing system** design

To enable the smooth transfer of the paramotor from inside the box to the door, functioning as a loading platform, a rail system must be securely mounted to the box floor. This system must ensure both high stability and effortless motion during operation. To meet these criteria, a dual-rail configuration was selected, as a single rail would not provide the required balance or support. The two parallel rails will support a sliding carriage onto which the paramotor is fixed.

A sliding door gear rail system was chosen as it meets all functional requirements and can be easily attached to the floor structure (see figure 46 and 47). The corresponding wheel sets were selected to match the chosen rail type, with two-wheel sets per rail. Specifically, the system utilizes a 2-meter aluminium hanging rail from FIXIT, along with the compatible hanging wheel sets. These wheel sets also include end stops that are fixed at the ends of the rails to prevent overtravel (see figure 48).

Figure 47: Aluminium sliding profile
Source: (IKH, sd)

Figure 46: Wheel set for a sliding door rail system
Source: (IKH, sd)

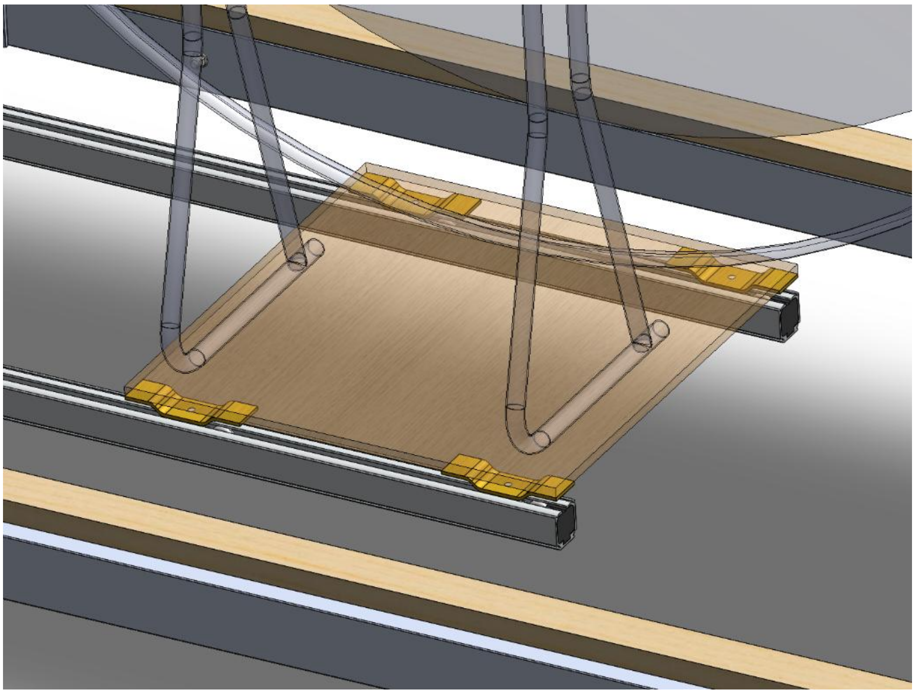

Figure 48: See through view of the carriage railing system

To accommodate the opening motion of the door, the rails are divided into four segments: two mounted on the box floor and two on the inner side of the door (see figure 49). To allow the door to close without obstruction, the rail ends near the hinge area are cut at a 45° angle (see figure 50). Although this cut introduces a small gap between the floor and door rails, it does not hinder the movement of the carriage, as each wheel set includes two pairs of wheels spaced far enough apart to bridge the discontinuity.

The final rail length was determined based on the size of the carriage platform, which measures 400×400 mm. With this configuration, each floor rail segment is cut to 945.4 mm, leaving the remaining 1,054.6 mm of the 2-meter rail for the door segment. This setup ensures the paramotor can be fully extended outside the box during loading and unloading operations.

To secure the carriage during transport, a simple pin-and-hole locking mechanism can be integrated into the rail system (see figure 51). A small pin placed just in front of the wheel set, when aligned with a pre-drilled hole in the rail, will prevent unwanted sliding movement, locking the carriage in its resting position inside the box. This ensures safe and stable transport of the paramotor under dynamic driving conditions.

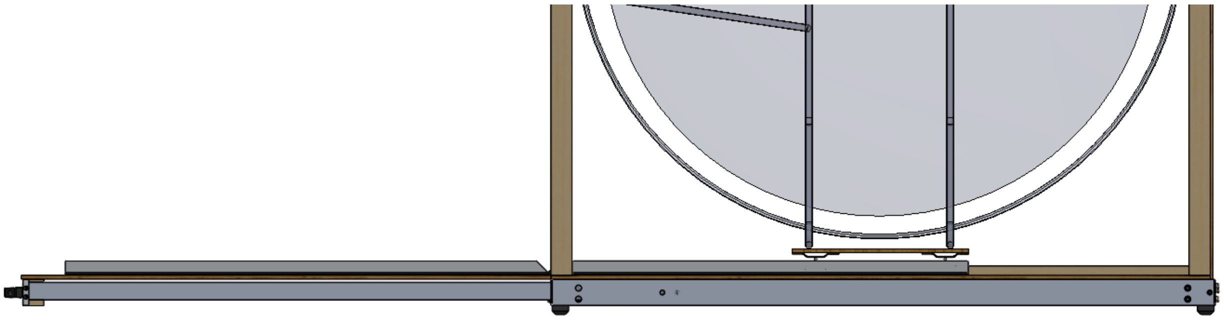

Figure 49: Side view of the railing system

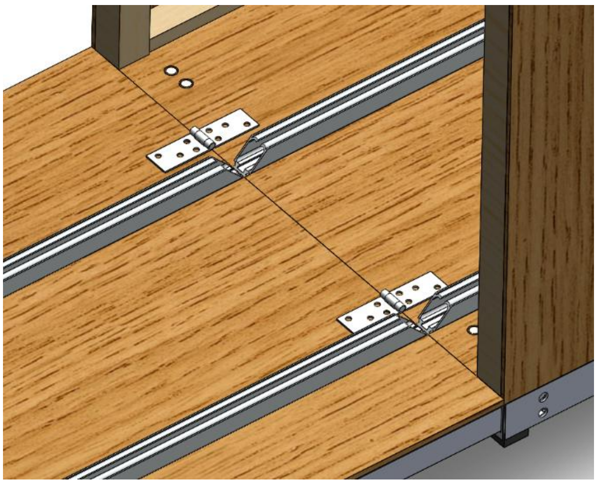

Figure 50: Close up of the hinge area

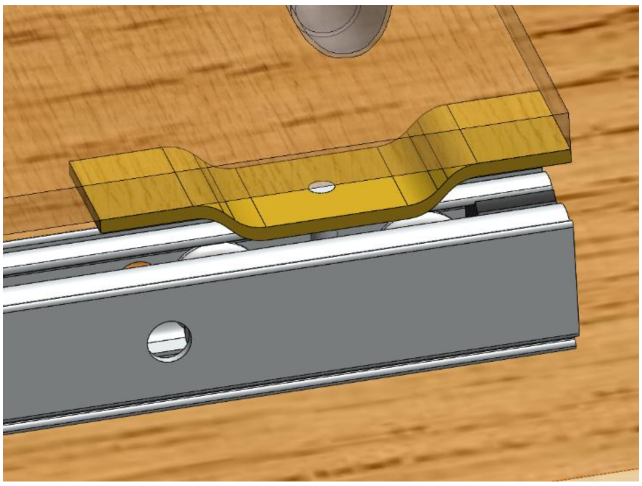

Figure 51: Pin-and-hole locking mechanism

4.7. **Fixation system** design

As the paramotor rests on a wooden carriage during transport, it is exposed to vibrations that may occur while driving. These vibrations pose a risk of the paramotor slipping or falling from the platform, potentially resulting in damage to both the equipment and the transport box. To mitigate this risk, the paramotor must be reliably secured to the carriage (see figure 52). However, ease of use remains a crucial requirement: the fixation system must allow the user to mount and lock the paramotor quickly and effortlessly, ideally without needing to remove it from their back during loading and using only their shoulders to lift it into position.

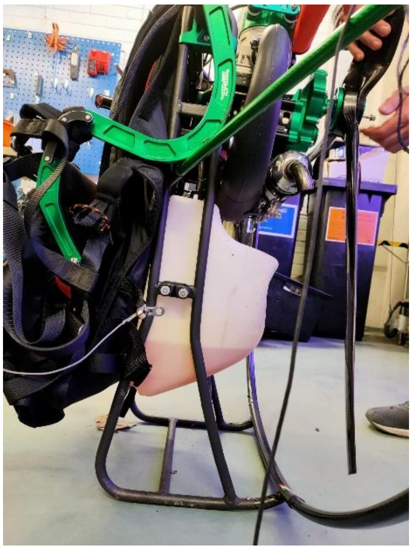

Figure 52: Side view of the paramotor

Initial solutions considered the use of commercially available components such as clamps, clips, ratchet straps, or locking pins, options identified during the research phase of the project.

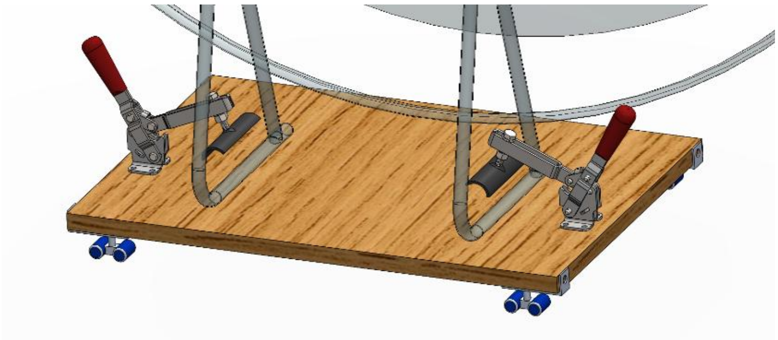

Figure 53: Possible clamping solution 1

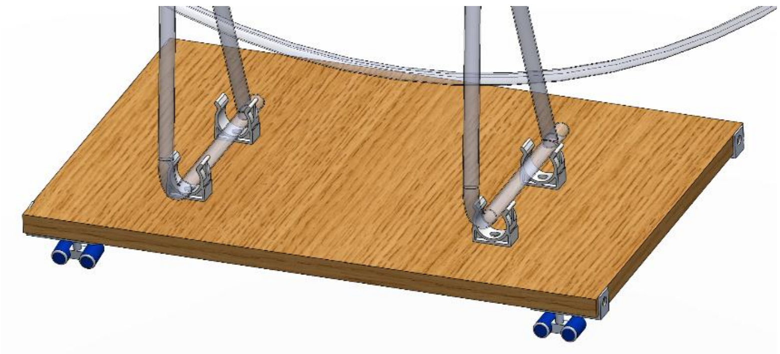

Figure 54: Possible clamping solution 2

While these components are easy to install and widely accessible, they present a critical limitation during the loading process. Because the user's visibility and control are limited while positioning the paramotor on the carriage, they may inadvertently miss the fixation point, placing the frame beside the clamp or outside the clip's range. In such cases, the user would need to readjust the load manually while carrying it, which is neither comfortable nor safe.

This limitation led to an additional design requirement: the fixation system must not obstruct the surface of the carriage in any way that would force the user to precisely align the paramotor during loading.

A more effective solution, therefore, involves integrating the fixation system directly into the design of the wooden carriage itself (see figure 55 to 57). By machining or shaping a dedicated slot into the carriage platform, the user can simply slide the paramotor into the correct position, even if the initial placement is slightly off. This passive guidance ensures correct alignment without the need for visual precision.

To secure the paramotor once positioned, a secondary locking mechanism can then be engaged. Various options are under consideration, such as quick-release clamps, threaded screw clamps, or clip-based systems inspired by buckle mechanisms. These components could be custom-designed and produced via 3D printing to ensure a precise fit and ease of use.

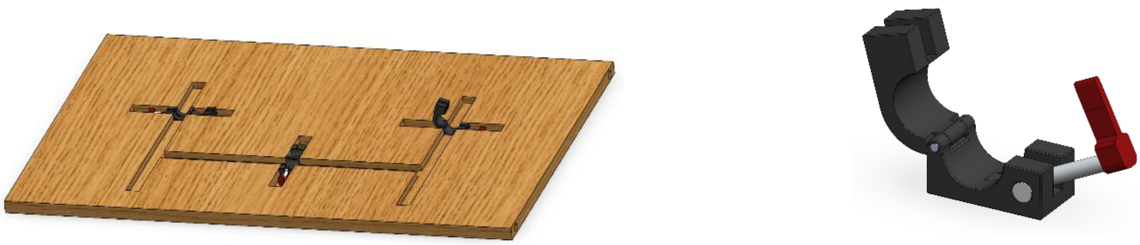

Figure 55: Possible clamping solution 3

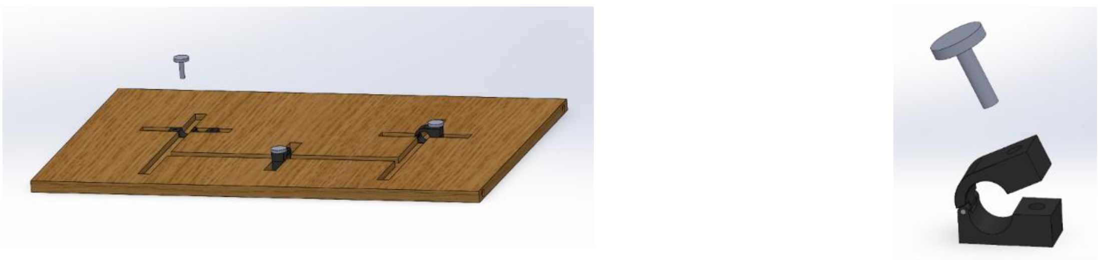

Figure 56: Possible clamping solution 4

Figure 57: Possible clamping solution 5

4.8. **Box** design

The box consists of 6,5mm wooden sheets on the outside (see figure 58). A frame of 48mm x 48mm square wooden beams and 21mm x 48mm rectangular wooden beams supports the wooden sheets. The sheets are made of film plywood to resist water buildup inside the material. The beams are used to give the sheets more stability and to make it easier to fix the upper part of the box to the baseplate, which contains the sliding system and the mounting mechanism for the box.

Figure 58: Side view of the box

4.9. Other components

- Wheels
  - Retractable wheels from Bennington manufacturing Company LLC will be used. They are constructed to carry up to 317,5 kg (700 pound) and offer a sufficient amount of lift from the ground compared to other models that were found.

Figure 59: Retractable caster wheels

- Pads
  - Pads made of rubber will be added to the bottom of the frame to protect the aluminium from corrosive damage. In addition, it will increase the friction between box and the ground its standing on.

- Hinges
  - Hinges are used to fix the upper and lower door to the box, and to keep its functionality. They were bought from Stark-Suomi. They were chosen to be the simplest in design so they could be found in every DIY-shop.

Figure 60: Hinges

- Door lock
  - The doors will be held closed using Toggle Latch Clamps attaching to the upper and lower door with each one part of the Clamp. The clamping force between the parts of the clamp will make it impossible for the doors to open.

Figure 61: Door lock

- Tensioning Straps
  - To safely transport the box on the trailer, tensioning straps to secure the box will be needed. To guide the tensioning straps Tie-down rings will be added to the top of the box.

https://uk.misumi-ec.com/vona2/detail/221005334785/?ppc_key-word=&gad_source=5&gad_campaignid=21975264381&gclid=EAIaIQobChMIpa6btqun-jQMVvhCiAx1e5zXrEAAYASAAEgIvuPD_BwE

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5. Production phase

In the last phase, a final concept has been selected for production. This production phase will focus on all aspects related to the manufacturing of the paramotor transport box. It includes the bill of materials and a step by step production description.

5.1. Bill of materials

In the bill of materials all the parts of the paramotor transport box can be found. In addition, a cost estimation is done. The bill of materials can be seen in table 3.

Table 3: Bill of materials

Quantity	Part	Supplier	Cost in €
1	Rectangular aluminium profile 60x40x3 mm – 6 m	Hartman	109,72
1	L shaped aluminium profile 40x30x4 – 6 m	Hartman	51,63
2	Hanging wheel rail – 2 m	IKH	63,00
2	Door hanging wheel set	IKH	52,00
1	Square wood beam 48x48 - 8,4m	Byggmax	12,33
1	Rectangular wood beam 21x48 – 20,4m	Stark	13,83
1	Wood plate 9x1500x3000 mm	Stark	103,95
2	Wood plate 6,5x1500x3000 mm	Stark	207,90
4	Hinge 38 mm	Stark	13,20
14	Corner bracket 60x60x40 mm	K Rauta	9,66
1	PROF T25 countersink screw 5x25 mm (200 pack)	K Rauta	8,95
1	PROF T25 domehead screw 5x30 mm (200 pack)	K Rauta	10,58
16	DIN 931 M8x60	K Rauta	3,04
8	DIN 933 M8x40	K Rauta	1,04
8	DIN 912 M8x20	Puuilo	5,99
4	DIN 912 M6x20	Puuilo	4,99

32	DIN985 M8 Torque-prevailing nut	K Rauta	1,6
4	DIN985 M6 Torque-prevailing nut	K Rauta	0,12
1	Toggle Clamp - Latch Type	Misumi	12,36
Total			685,89

5.2. Production

3D printing the sliding mechanism parts

To ensure the L-profiles would slide smoothly and align correctly inside the rectangular tubes we designed, and 3D printed a set of custom plastic guides (see figure 62 and 63). These pieces were made to fit snugly between the inner surfaces of the rectangular profile and the outer edges of the L-profile, reducing play and preventing metal-on-metal friction.

By using PLA for the printed components, we were able to achieve both precision and low friction, while also adding a slight damping effect that improves the overall feel of the sliding mechanism. The guides also help maintain parallel alignment throughout the drawer's movement, which is essential for long-term durability and performance.

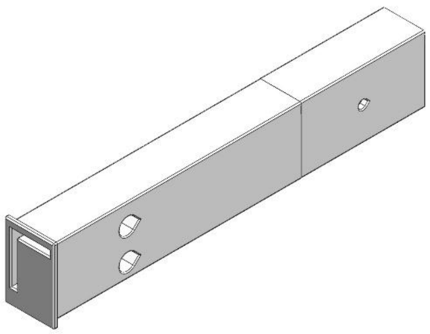

Figure 63: Custom plastic guides for the L-profiles

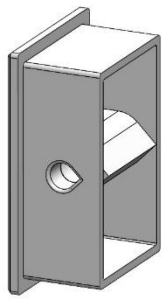

Figure 62: Plastic end cap

Cut aluminium profiles to size

In order to construct both the main frame and the internal drawer structure, we used a total of 6 meters of a 60x40x3 mm rectangular aluminum profile and another 6 meters of a 40x30x4 mm L-shaped aluminum profile. Additionally, we relied on a 3D printer to produce custom components that would support and reinforce the final assembly.

We began the process by carefully measuring and cutting the aluminum profiles to the required dimensions (see figure 64. From the rectangular profile, we cut two bars measuring 1500 mm in length and two additional bars of 720 mm. These would form the outer perimeter of the box. The L-profile was cut into two 1200 mm bars, which were later used to support the drawer guides. The leftover sections of the L-profile were repurposed efficiently: we cut them into eight small corner pieces, which serve as internal reinforcements to connect the frame segments securely at right angles.

To ensure accuracy and clean cuts, we used a precision sawing machine. This allowed us to maintain tight tolerances, which are essential when working with aluminum structures, especially when the components need to fit together precisely without gaps or misalignments.

Figure 64: Cutting process of the aluminium profiles

Drill the holes

Once the pieces were cut, we moved on to drilling. Using a CNC drilling machine, we carefully positioned and drilled the necessary holes in the aluminum profiles (see figure 65). The CNC ensured consistent spacing and alignment for the bolt holes, which is critical for a square and sturdy frame. These holes would later allow us to bolt the frame together, ensuring both strength and modularity, in case disassembly is required in the future.

This initial phase laid the groundwork for the rest of the building. By focusing on precise cuts and accurate drilling from the beginning, we ensured that the structure would be solid and dimensionally accurate, minimizing issues in the later stages of the project.

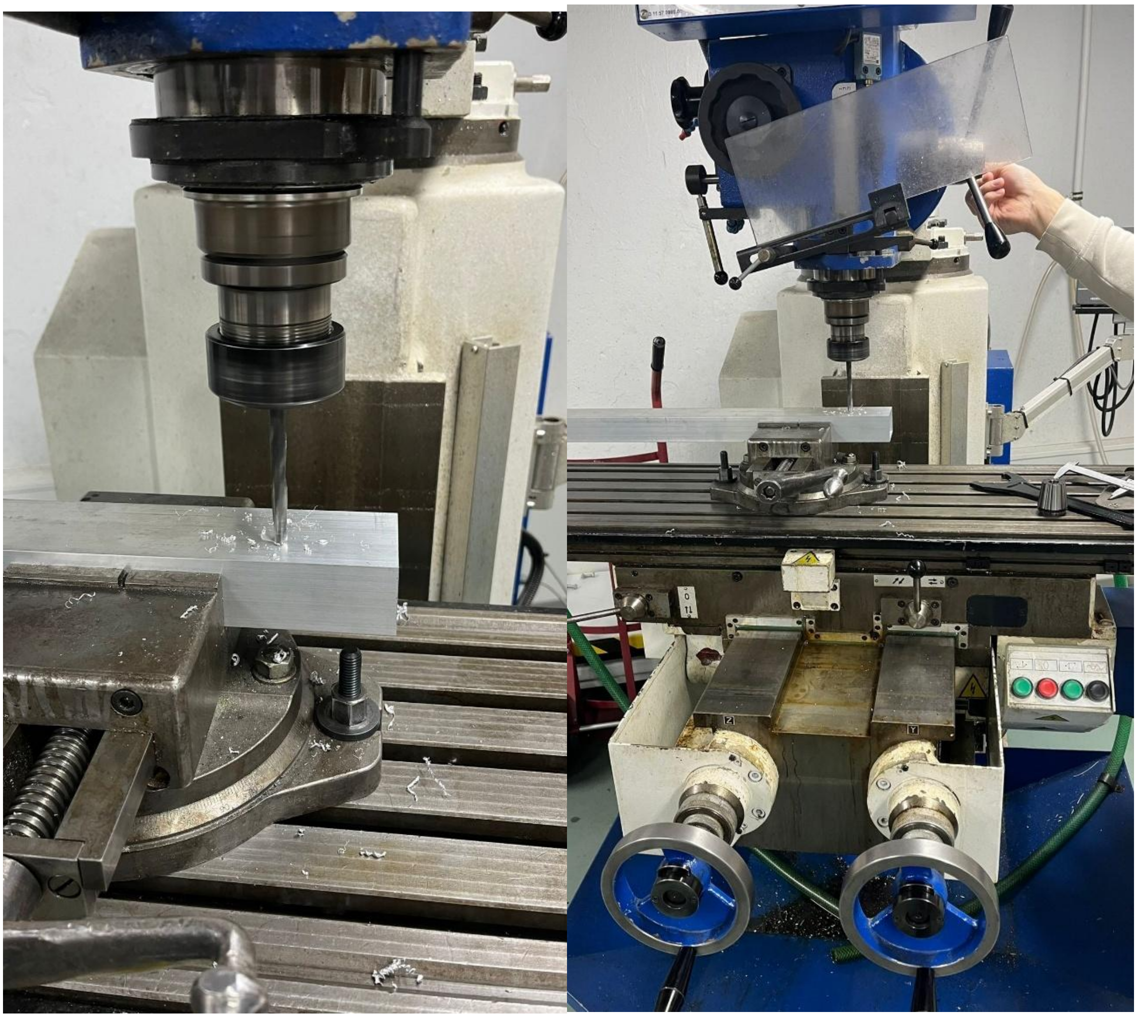

Figure 65: Drilling process

Assembling the frame

Once all the components had been precisely cut and drilled, the final step of this phase was the assembly. With all parts prepared to exact dimensions, the process of putting everything together was straightforward, but still required attention to detail to ensure structural integrity and alignment.

We began by aligning the rectangular profiles and securing them with bolts through the pre-drilled holes, using the custom corner brackets to reinforce each joint (see figure 66). These brackets, cut earlier from the leftover L-profile sections, played a key role in maintaining right angles and preventing any flex or twisting in the frame.

After assembling the main frame, we inserted the L-profiles into their corresponding slots, guided by the 3D-printed plastic inserts we had fabricated. These inserts ensured a smooth and stable fit, reducing friction and keeping the profiles aligned throughout the drawer's motion. The result was a sturdy, square frame with a fully functional sliding drawer mechanism, ready for the next stage of the building.

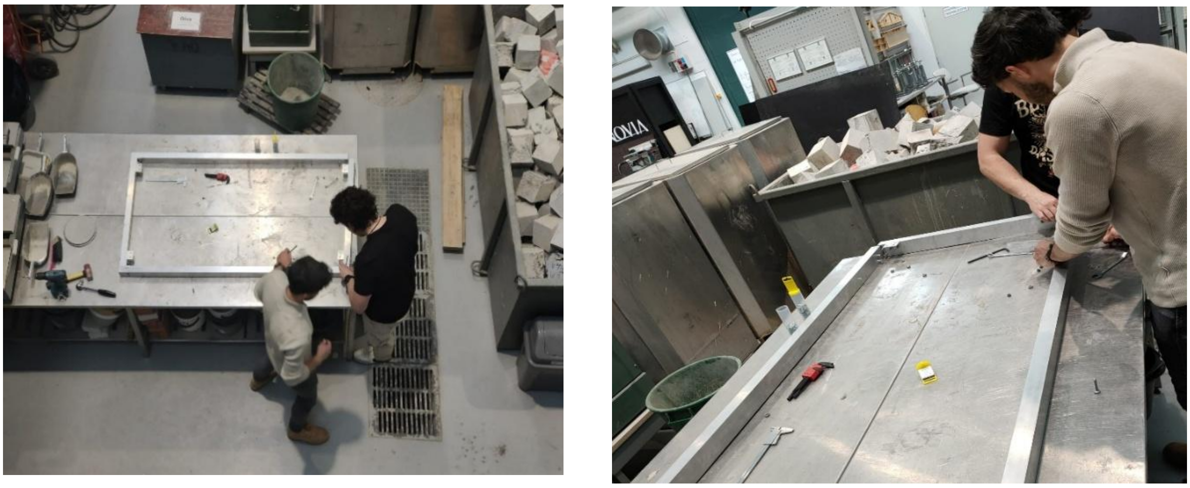

Figure 66: Manufacturing the aluminium frame

Cutting the wood to size

As for the wood components, we decided to order the panels pre-cut to the exact dimensions required for the project. This approach saved us considerable time and effort during the build, ensuring that the panels fit perfectly within the aluminum frame from the start.

Once the custom-sized panels arrived, we performed some minor finishing work to achieve a flawless fit. Using a handsaw, we carefully trimmed any small excesses or uneven edges. Then, we smoothed the surfaces and edges with sandpaper to eliminate roughness and ensure a clean, professional appearance. These final adjustments allowed the wood panels to integrate seamlessly into the frame, providing both structural support and an attractive finish to the box.

In the case of the wooden beams, the process was quite similar to that of the aluminum bars. We ordered the beams pre-cut to the required width but took responsibility for cutting them to the exact lengths needed for the project (see figure 67). Unlike the aluminum profiles, where we used a sawing machine for precision, this time we opted to cut the wooden beams manually with a handsaw.

Using a handsaw gave us more control over the cuts for these pieces, allowing us to adjust lengths carefully and make any small modifications on the spot. Although it required a bit more physical effort, this approach was practical and efficient for working with wood, especially given the relatively straightforward dimensions involved.

Figure 67: Cutting the wood

Assembling the box

Once all the components were prepared, we proceeded to assemble the box (see figure 68 to 70). We began by constructing the main structure using the wooden beams, which we joined together with L-shaped metal plates and screws for added stability and strength. After the frame was securely assembled, we attached the wooden panels by screwing them onto the structure, then bolted the panels to the aluminum frame to create a solid and integrated enclosure.

Next, we connected the two aluminum L-profiles with a leftover piece of wooden beam, which we repurposed to serve as a sturdy handle. For the door, we installed hinges to attach it firmly to the box, allowing smooth opening and closing.

To optimize functionality, we decided to divide the door into two sections: a larger 1200 mm door that opens downward, and a smaller 300 mm door that opens upward. Although we did not have enough time to fully complete the project, the remaining tasks are straightforward: installing the rail system for the sliding drawer, fitting the door lock mechanism, and attaching the wheels to enable mobility.

Figure 69: Assembling the aluminium frame

Figure 68: Mounting the floor

Figure 70: Assembling the wooden box

6. Conclusion

The development of the Paramotor Transport Box has involved a comprehensive design process, from idea and concept generation to construction and final assembly. Through careful evaluation of multiple transporting options, it became clear that the trailer mounted concept offered the best fit for the scope of the project. It addressed key concerns to road safety regulations, structural integrity and load capacity while still allowing for ease of use and transport.

The final design integrates a robust aluminium frame for the baseplate with a plywood enclosure above, completed by a two-part door and a sliding carriage system for efficient loading and unloading, additional features such as retractable castor wheels and support struts, enhance both mobility and stability, making the box suitable for multiple storage and transportation scenarios.

Throughout the project attention was given not only to functional performance but also manufacturability and user safety as well as keeping a DIY-character to it to make it reproduceable using the blog where the design and manufacturing process is further documented. The resulting transport box is a balanced solution that meets the specific requirements of paramotor pilots and can be adapted or scaled for similar models or applications.

In conclusion, this project demonstrates the effectiveness of iterative design, practical engineering solutions, user-centred and international teamwork in developing a specialized transport system that is both functional and feasible for real-world use.

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A. Appendices

A1. Team management

A1.1. Belbin & leadership test results

Belbin Test

Before starting the project, a Belbin test was performed to get a better understanding of the potential strengths and weaknesses of our team. The Belbin test, developed by Dr Meredith Belbin in the 1970s, is a tool designed to assess how individuals contribute to a team. It helps to identify and control individual differences to improve collaboration, effectiveness, and overall performance. (Belbin, sd)

The result of a Belbin test provides a team role profile, showing in which of the nine Belbin Team Roles they are strong or weak. A common way to visualize these results is through a star diagram, which maps the individual's scores across the nine Team Roles. Table 2 shows the nine Belbin Team Roles with their contribution and allowable weaknesses.

Table 4: The nine Belbin team roles
Source: (PrePearl Training Development, sd)

Team Role	Contribution	Allowable Weaknesses
Plant	Creative, imaginative, free-thinking. Generates ideas and solves difficult problems.	Ignores incidentals. Too preoccupied to communicate effectively.
Resource Investigator	Outgoing, enthusiastic, communicative. Explores opportunities and develops contacts.	Over-optimistic. Loses interest once initial enthusiasm has passed.
Co-ordinator	Mature, confident, identifies talent. Clarifies goals. Delegates effectively.	Can be seen as manipulative. Offloads own share of the work.
Shaper	Challenging, dynamic, thrives on pressure. Has the drive and courage to overcome obstacles.	Prone to provocation. Offends people's feelings.
Monitor Evaluator	Sober, strategic and discerning. Sees all options and judges accurately.	Lacks drive and ability to inspire others. Can be overly critical.
Teamworker	Co-operative, perceptive and diplomatic. Listens and averts friction.	Indecisive in crunch situations. Avoids confrontation.
Implementer	Practical, reliable, efficient. Turns ideas into actions and organises work that needs to be done.	Somewhat inflexible. Slow to respond to new possibilities.
Completer Finisher	Painstaking, conscientious, anxious. Searches out errors. Polishes and perfects.	Inclined to worry unduly. Reluctant to delegate.
Specialist	Single-minded, self-starting, dedicated. Provides knowledge and skills in rare supply.	Contributes only on a narrow front. Dwells on technicalities.

Figure 1 shows a star diagram with the results of each individual Belbin test.

A key finding is that our team consists of both well-rounded team members and some team members with a stronger representation in specific roles. If we look at the roles our team has, we have a strong representation in the Implementer, Shaper, Plant, and Team worker roles. However, the Monitor Evaluator and Resource Investigator roles are less well represented. This could lead to some problems in either the research phase or the designing phase of the project.

To tackle this, our team should be aware of these gaps and actively work together compensate for these less represented roles. This implies encouraging open discussions, seeking feedback, and ensuring that decisions are carefully evaluated from different perspectives. Through supporting each other and sharing responsibilities, we can strengthen these weaker roles over time and create an even more well-rounded team.

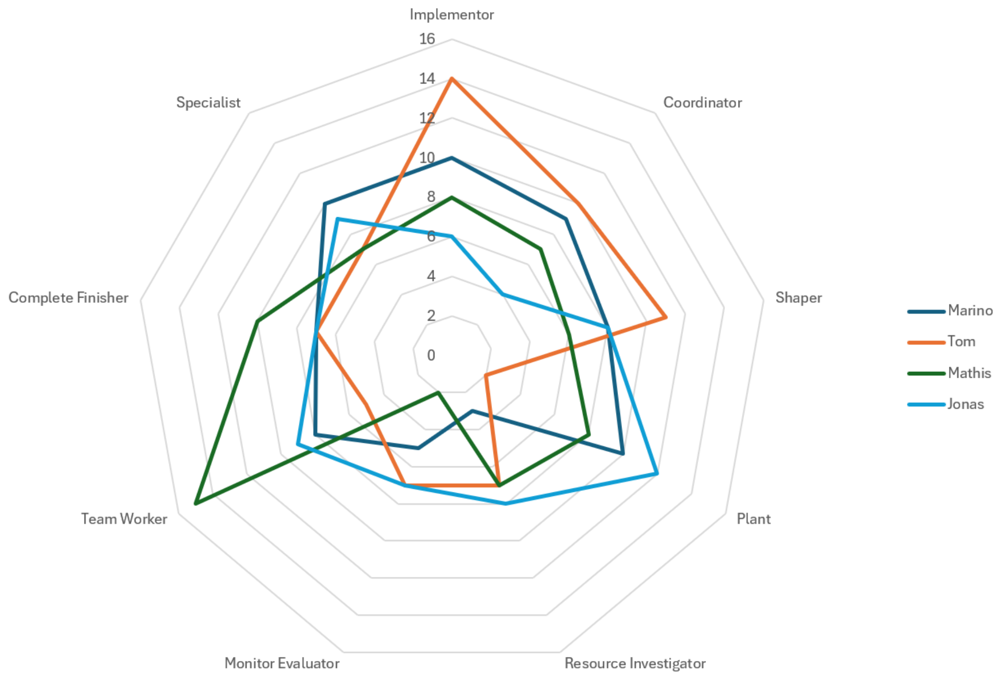

Figure 71: Belbin test results

Leadership test

In addition to the Belbin test, our team has also conducted a Leadership Skills Test. This test assesses an individual's strengths across five key leadership competencies. Just like the Belbin test, the results are presented in a Star diagram. The results of our Leadership Skills Test can be found below in figure 2.

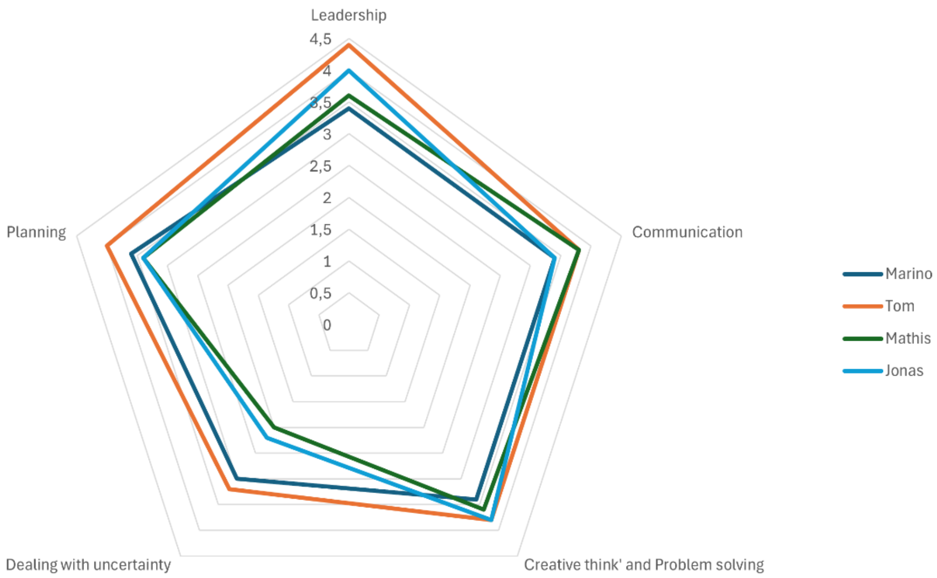

Figure 72: Leadership test results

A1.2. Hofstede country comparison

Our team is internationally diverse, which indicates that there will be cultural differences among team members. To better understand these differences, our team has used the Hofstede Country Comparison tool. This tool, based on the research of Professor Geert Hofstede, is a model designed to analyze how national culture influences workplace values. It helps organizations understand cultural differences and improve communication, management, and cooperation across cultures (The Culture Factor, sd).

The Hofstede Comparison tool compares the working culture of different countries on six dimensions:

1. Power distance
2. Individualism
3. Motivation towards achievement and succes
4. Uncertainty avoidance
5. Long term orientation
6. Indulgence

Figure 3 shows the results of the cultural differences between the nationalities of our team members. The cultural differences in each dimension are analysed in the text below.

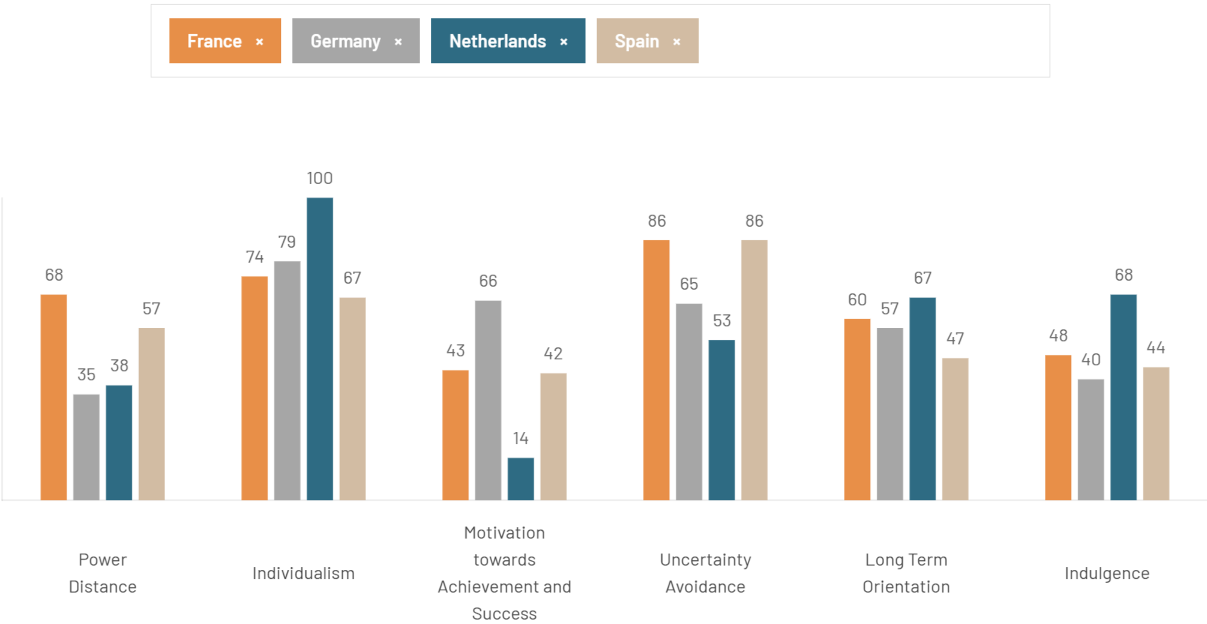

Figure 73: Hofstede test results
Source: (The Culture Factor, sd)

Power distance

The Spanish and French societies are more hierarchical than the German and Dutch ones. That means they're more content with the opinion of their superior and pay them more respect while the German and Dutch people tend to question what they're being told.

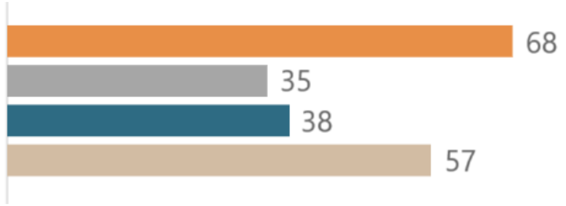

Figure 74: Power distance
Source: (The Culture Factor, sd)

Individualism

All nationalities in this group are quite individualistic, meaning they keep more to themselves and have a bigger focus on self actualization. Promotion in these societies is mostly done on merit.

Figure 75: Individualism
Source: (The Culture Factor, sd)

Motivation towards achievement and success

The Dutch society is focused heavily on having a good work-life-balance and making everyone feel included. Frech and Spanish societies also have a greater focus on quality of life and taking care of one another. Meanwhile in German society work is an essential part of their culture and a lot of self-esteem is derived from their tasks.

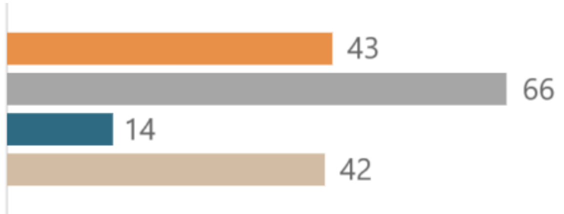

Figure 76: Motivation towards achievement and success
Source: (The Culture Factor, sd)

Uncertainty avoidance

French and Spanish people don't like uncertainty, it is important to them to know what they're supposed to do and to have rules which they can follow. Dutch and German societies allow for a bit more uncertainty, but security and precision are important elements.

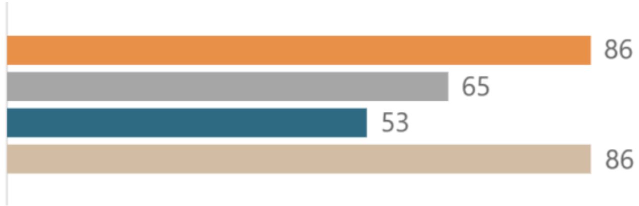

Figure 77: Uncertainty avoidance
Source: (The Culture Factor, sd)

Long term orientation

Dutch, German and French societies are more pragmatic in nature, meaning that to them the truth depends on the context, situation and time. The Spanish on the other hand prefer quick results and living in the moment.

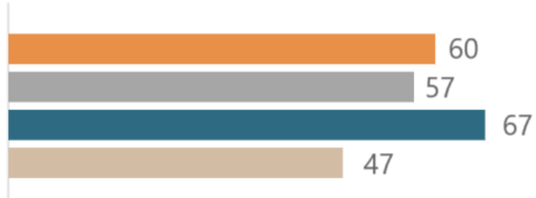

Figure 78: Long term orientation
Source: (The Culture Factor, sd)

Indulgence

French, German and Spanish cultures show more restraint in their actions. Whereas Dutch culture is more indulgent and impulsive.

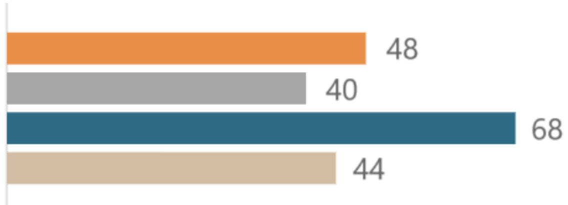

Figure 79: Indulgence
Source: (The Culture Factor, sd)

A2. Scope management

A2.1. Project aims and objectives

Project Aim

The aim of this project is to design, develop, and test a transport box for a paramotor. It must be safe, lightweight, durable, and easy to use, ensuring efficient transport and protection. A structured approach ensures timely delivery and quality results.

Project Objectives

To achieve this, the project focuses on:

1. Identifying Needs
   - Researching existing transport solutions.
   - Analysing Sky Engine 110 S specifications.
   - Defining key criteria: weight, dimensions, materials.
2. Developing the Box
   - Brainstorming and creating sketches.
   - Evaluating materials and using CAD software for 3D models.
3. Manufacturing and Assembly
   - Selecting components and building a prototype.
   - Assembling and verifying functionality.
4. Testing and Validation
   - Conducting durability tests.
   - Ensuring compatibility with transport methods.
   - Fixing design flaws.
5. Documentation and Presentation
   - Preparing technical documentation.
   - Tracking progress with WBS and Gantt chart.
   - Delivering a report and presentation.

This ensures the final product meets safety, efficiency, and usability standards while staying on schedule.

A2.2. Work Breakdown Structure (WBS)

The Work Breakdown Structure (WBS) is a key tool in project management that helps break down a complex project into smaller, more manageable tasks. By organizing the project into structured levels, the WBS allows the team to plan efficiently, assign responsibilities, and monitor progress effectively. A well-defined WBS ensures that no critical aspect of the project is overlooked and provides a clear roadmap for the team to follow.

Method Used to Create the WBS

To construct the WBS for this project, we used a collaborative brainstorming approach. Our goal was to generate a comprehensive and structured breakdown of the tasks required to design, build, and test the Paramotor Transport Box. The method followed these key steps:

1. Individual Idea Generation: Each team member started by independently writing down ideas, sketches, and key terms related to the project on Post-it notes. These ideas covered various aspects such as research, design, manufacturing, assembly, testing, and project management.

2. Grouping and Organizing: Once all ideas were written down, we placed the Post-its on a large surface, such as a whiteboard or table. This allowed us to visually sort and cluster similar ideas together, identifying logical groups of tasks and sub-tasks (see figure 10 and 11).

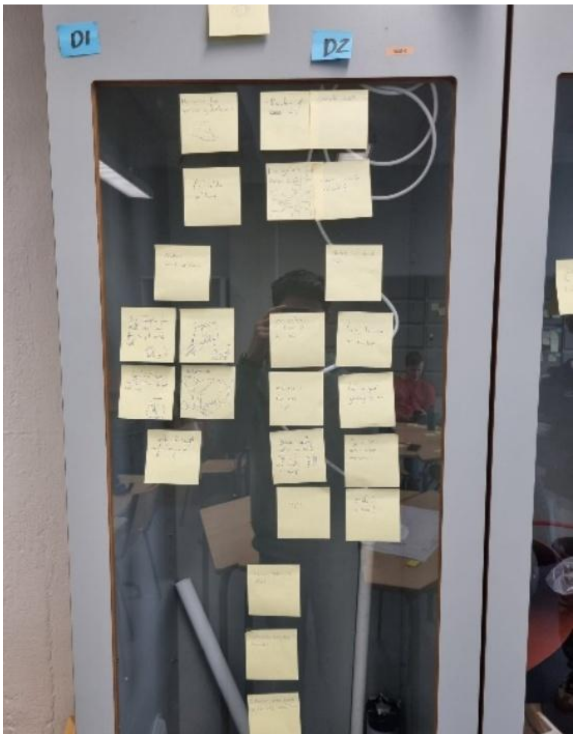

Figure 81: Post-its for deliverable 1 and 2

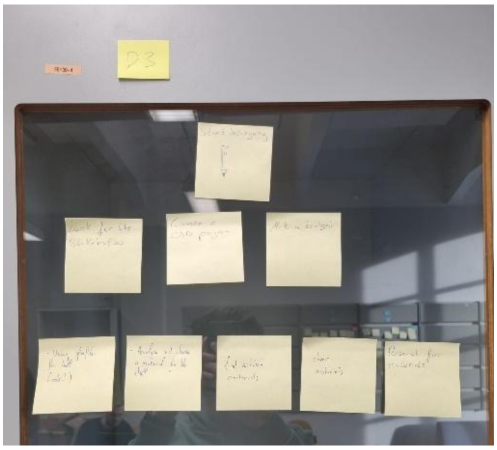

Figure 80: Post-its for deliverable 3

3. Refining the Structure: After forming initial groups, we discussed the relationships between tasks, refined their hierarchy, and ensured all essential steps were included. Some tasks were merged, while others were split into smaller, more manageable components.
4. Finalizing the WBS: Once the structure made sense, we translated the Post-it notes into a formal WBS diagram, ensuring that it followed a clear hierarchical organization with deliverables, phases, tasks, and sub-tasks.

This brainstorming technique allowed us to capture diverse perspectives, ensure a well-organized workflow, and create a WBS that accurately represents the project's scope.

Project Breakdown and Deliverables

The WBS for the Paramotor Transport Box project is structured around five major deliverables, each corresponding to a key phase of the project. Within each deliverable, specific tasks and subtasks are organized to ensure a logical and efficient workflow.

Each task in the WBS is labelled with a unique identifier (e.g., T.3.1, T.4.1) to facilitate tracking. This systematic breakdown ensures a structured approach to project execution, minimizing risks and improving efficiency.

1. **D1 – EPS Documentation**
   This deliverable covers all the reports, presentations, and communication materials related to the project:
   - Writing and validating the midterm and final reports.
   - Preparing, practicing, and delivering presentations.
   - Creating an internet blog to document progress and share insights.
   - Developing guides and documentation for paramotor enthusiasts.

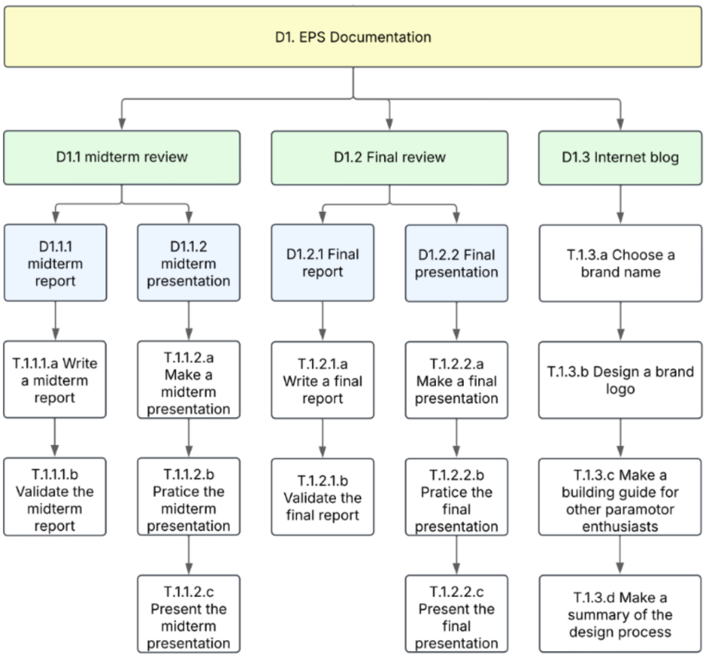

Figure 82: D1: EPS documentation

2. **D2 – Management Documentation**
   This phase ensures the project is well-structured and progresses smoothly:
   - Setting up and maintaining the WBS and Gantt chart.
   - Tracking project progress and adjusting plans if necessary.
   - Establishing a stakeholder register and risk matrix.
   - Conducting leadership and teamwork assessments.

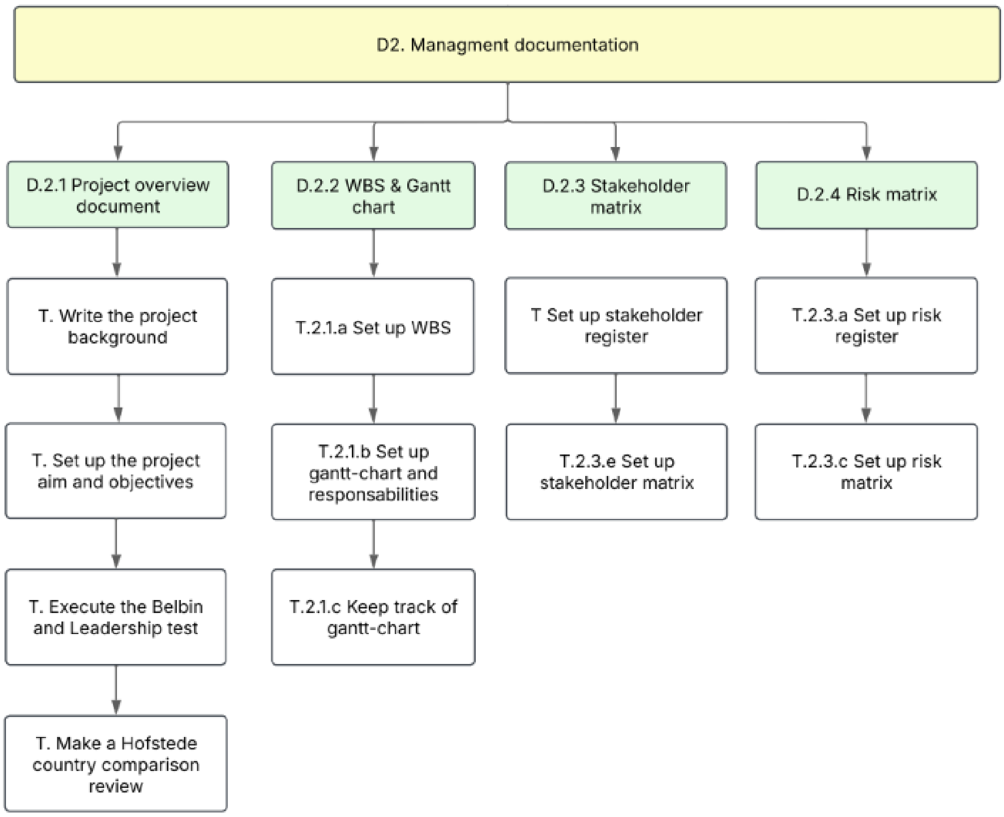

Figure 83: D2: Management documentation

3. **D3 – Table of Requirements**
   This deliverable defines the specifications and constraints for the Paramotor Transport Box to ensure it meets the necessary criteria:
   - Researching existing solutions and best practices.
   - Analysing the Sky Engine 110 S specifications.
   - Identifying different mounting mechanisms (trailer, tow hook, etc.).
   - Investigating regulations for payload transport.

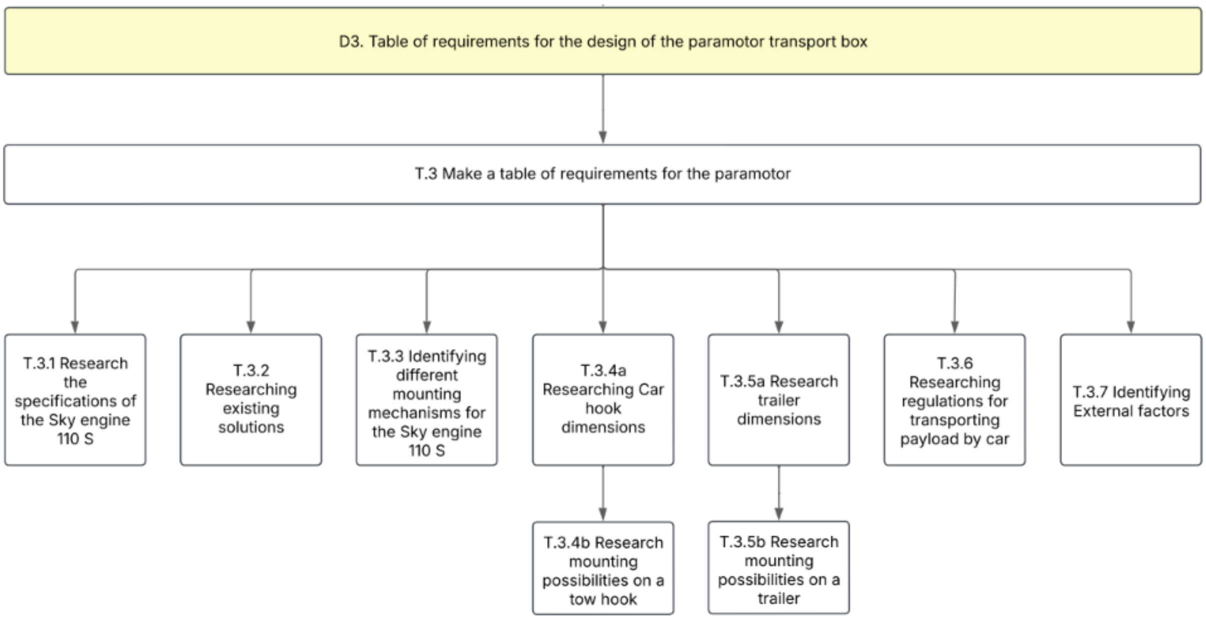

Figure 84: D3: Table of requirements for the design of the paramotor transport box

4. **D4 – Transport Box Design**
This phase focuses on the development of the transport box:

- Brainstorming and sketching initial design concepts.
- Comparing different design solutions and selecting the most suitable one.
- Choosing the right materials and components for construction.
- Creating CAD models, technical drawings, and structural calculations.
- Building a small-scale prototype to test feasibility.

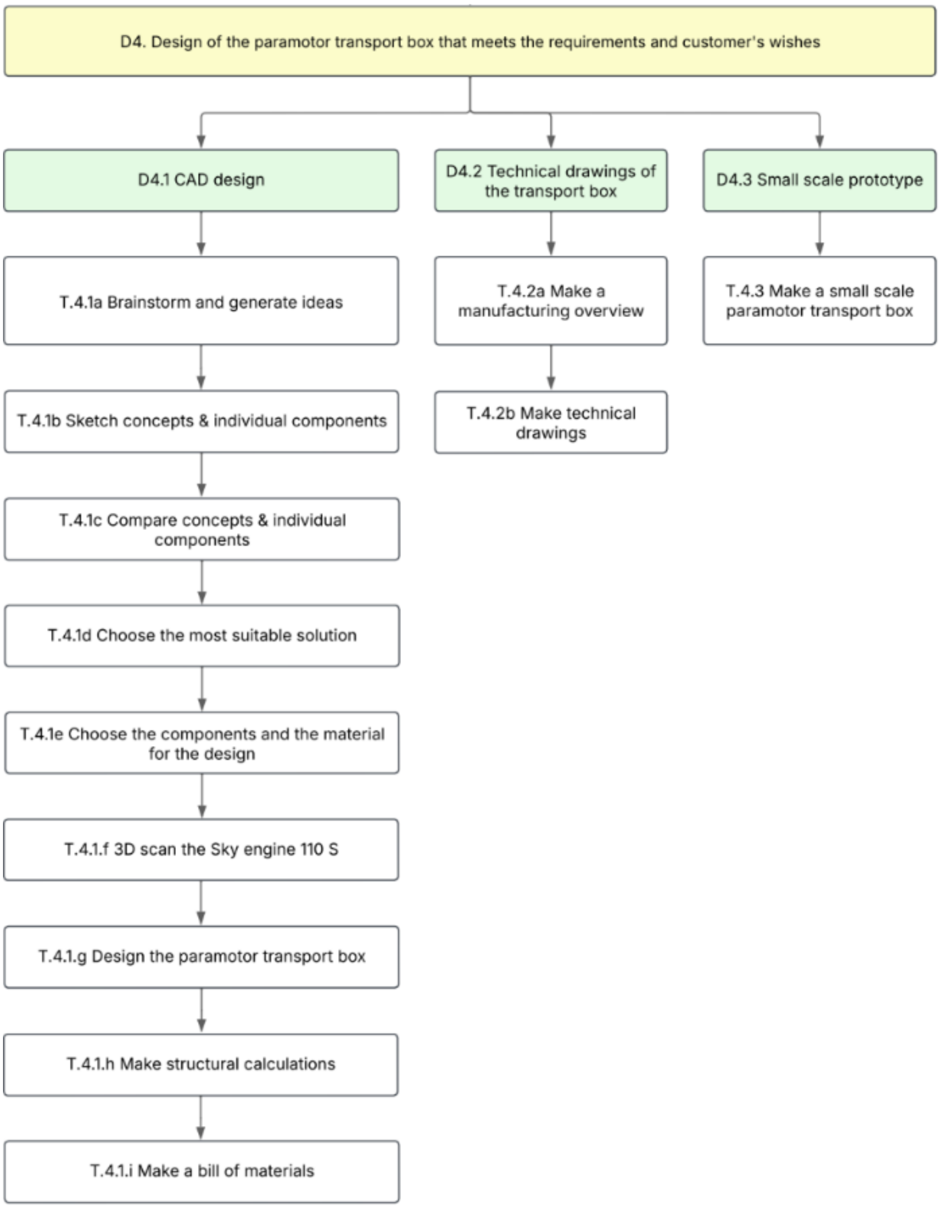

Figure 85: D4: Transport box design

5. **D5 – Final Product**
   The last phase involves the actual construction, testing, and validation of the transport box:
   - Ordering and manufacturing the necessary parts.
   - Assembling the transport box and verifying its dimensions.
   - Conducting various tests to ensure:
     - It fits the Sky Engine 110 S properly.
     - It can be securely mounted on a trailer and a tow hook.
     - It meets all functional and safety requirements.

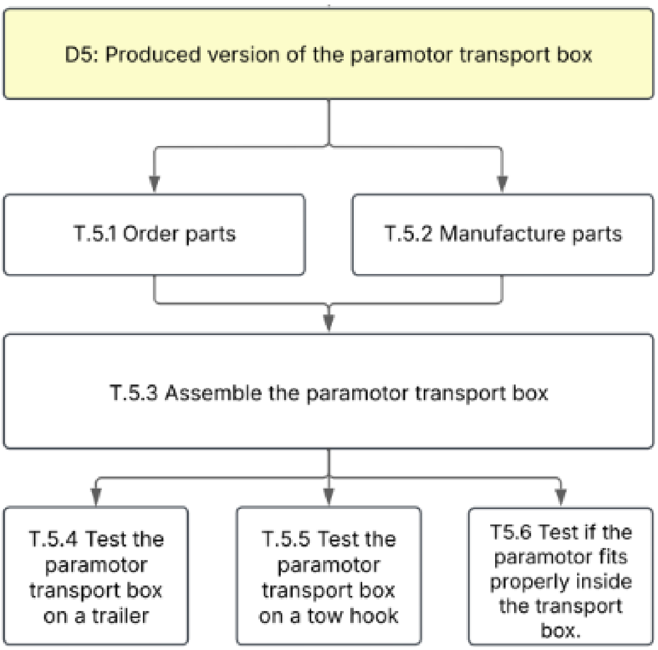

Figure 86: D5: Final product

Conclusion

The WBS provided a clear structure for the Paramotor Transport Box project, breaking it down into well-defined tasks and deliverables. This structured approach helped us organize the workflow efficiently and served as the foundation for time management.

Using the WBS, we developed the Gantt chart, which schedules tasks, sets deadlines, and tracks progress. In the next section, we will explore how this timeline was structured to ensure an efficient project execution.

A3. Time management

A3.1. Project schedule

Time Management

After defining the Work Breakdown Structure (WBS), the next step was to establish a clear timeline for the project. Using the WBS as a foundation, we developed a Gantt chart to plan, schedule, and track the execution of each task. This tool allows us to visualize task dependencies, manage deadlines, and ensure an even distribution of workload over the project timeline.

Project Timeline and Key Phases

The project spans a total of 15 weeks, starting on February 10, 2025, and concluding on May 19, 2025. The Gantt chart is structured into several key phases, ensuring a logical progression from research to final assembly:

1. Research & Requirement Analysis (Weeks 1-4)
    - Investigating existing solutions and best practices.
    - Defining project specifications and regulatory constraints.
2. Design & Development (Weeks 4-11)
    - Brainstorming ideas and creating initial sketches.
    - Developing CAD models, technical drawings, and small-scale prototypes.
    - Performing structural calculations and material selection.
3. Production & Assembly (Weeks 12-13)
    - Ordering materials and components.
    - Manufacturing and assembling the Paramotor Transport Box.
    - Conducting functional tests and making adjustments.
4. Testing & Validation (Weeks 12-13)
    - Verifying design specifications.
    - Ensuring compatibility with mounting mechanisms.
    - Addressing potential improvements.
5. Documentation & Presentation (Weeks 7-15)
    - Completing the final report and preparing the final presentation.
    - Publishing the final documentation and project summary.

Gantt Chart Placement

The Gantt chart visually represents this timeline, showing task durations, dependencies, and milestones. It helps the team coordinate efforts efficiently, ensuring timely completion of each phase (see table 3 and 4 below).

By aligning the WBS with the Gantt chart, we have established a structured approach to managing both task execution and time allocation, reducing the risk of delays and ensuring smooth project progression.

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Table 5: Gantt chart 1

Paramotor Transport Box

Paratroopers

	Project Start Date	2/10/2025 (lundi)		Display Week	1	
	Project Lead	5/20/2025 (mardi)				

WBS	TASK	LEAD	START	END	DAYS	% DONE
D1	**EPS Documentation**		lun 2/10/25	mar 5/20/25	100	
D1.1	**Midterm review**		lun 2/10/25	mar 3/25/25	44	
D1.1.1	Midterm report		lun 2/10/25	sam 3/15/25	34	
T.1.1.a	Write a midterm report	Everyone	lun 2/10/25	lun 3/10/25	29	100%
T.1.1.b	Validate the midterm report	Tom	mar 3/11/25	sam 3/15/25	5	100%
D1.1.2	Midterm presentation		dim 3/16/25	mar 3/25/25	10	
T.1.1.2.a	Make a midterm presentation	Everyone	dim 3/16/25	jeu 3/20/25	5	100%
T.1.1.2.b	Pratice the midterm presentation	Everyone	ven 3/21/25	lun 3/24/25	4	100%
T.1.1.2.c	Present the midterm presentation	Everyone	mar 3/25/25	mar 3/25/25	1	100%
D1.2	**Final review**		mer 3/26/25	mar 5/20/25	56	
D1.2.1	Final report		mer 3/26/25	lun 5/05/25	41	
T.1.2.1.a	Write a final report	Everyone	mer 3/26/25	mer 4/30/25	36	0%
T.1.2.1.b	Validate the final report	Tom	jeu 5/01/25	lun 5/05/25	5	0%
D1.2.2	Final presentation		mar 5/06/25	mar 5/20/25	15	
T.1.2.2.a	Make a final presentation	Everyone	mar 5/06/25	lun 5/12/25	7	0%
T.1.2.2.b	Pratice the final presentation	Everyone	mar 5/13/25	lun 5/19/25	7	0%
T.1.2.2.c	Present the final presentation	Everyone	mar 5/20/25	mar 5/20/25	1	0%
D1.3	**Internet blog**		lun 2/10/25	mar 5/20/25	100	
T.1.3.a	Choose a brand name	Everyone	lun 2/10/25	lun 2/10/25	1	100%
T.1.3.b	Design a brand logo	Mathis	mar 2/11/25	sam 2/15/25	5	100%
T.1.3.c	Make a building guide	Everyone	sam 5/10/25	lun 5/19/25	10	0%
T.1.3.d	Make a summary of the design process	Everyone	mar 4/29/25	jeu 5/08/25	10	0%
D2	**Managment documentation**		lun 2/10/25	mar 5/20/25	100	
D.2.1	**Project overview**		lun 2/10/25	lun 2/24/25	15	
T.2.1.a	Write the project background	Everyone	lun 2/10/25	mar 2/11/25	2	100%
T.2.1.b	Set up the project aim and objectives	Everyone	mer 2/12/25	jeu 2/13/25	2	100%
T.2.1.c	Execute the Belbin and Leardership test	Everyone	lun 2/10/25	mar 2/11/25	2	100%
T.2.1.d	Make a Hofstede country comparison review	Everyone	lun 2/10/25	mar 2/11/25	2	100%
D.2.2	**WBS & Gantt chart**		lun 2/10/25	mar 5/20/25	100	
T.2.1.a	Set up WBS	Tom & Mathis	lun 2/10/25	dim 2/16/25	7	100%
T.2.1.b	Set up gantt-chart and responsabilities	Mathis	lun 2/17/25	dim 2/23/25	7	100%
T.2..1.c	Keep track of gantt-chart	Everyone	lun 2/24/25	mar 5/20/25	86	37%
D.2.3	**Stakeholder matrix**		ven 2/14/25	mar 2/18/25	5	
T.2.3.a	Set up stakeholder register	Everyone	ven 2/14/25	dim 2/16/25	3	100%
T.2.3.b	Set up stakeholder matrix	Everyone	lun 2/17/25	mar 2/18/25	2	100%
D.2.4	**Risk matrix**		ven 2/14/25	mar 2/18/25	5	
T.2.3.a	Set up risk register	Everyone	ven 2/14/25	dim 2/16/25	3	100%
T.2.3.c	Set up risk matrix	Everyone	lun 2/17/25	mar 2/18/25	2	100%
D3	**Table of requirements for the design of the paramotor transport box**		lun 2/10/25	ven 3/07/25	26	
T.3	Make a table of requirements for the paramotor	Everyone	lun 2/10/25	ven 3/07/25	26	100%
T.3.1	Research the specifications of the Sky engine 110s	Marino	lun 2/10/25	ven 2/14/25	5	100%
T.3.2	Researching existing solutions	Mathis	lun 2/10/25	mer 2/12/25	3	100%
T.3.3	Identifying diffrent mounting mechanisms for the Sky Engine 110s	Tom	lun 2/10/25	mer 2/12/25	3	100%
T.3.4.a	Researching car hook dimensions	Jonas	lun 2/10/25	mar 2/11/25	2	100%
T.3.4.b	Research mounting possibilities on a tow hook	Tom	mer 2/12/25	ven 2/14/25	3	100%
T.3.5.a	Research trailer dimensions	Jonas	lun 2/10/25	mar 2/11/25	2	100%
T.3.5.b	Research mounting possibilities on a trailer	Marino	mer 2/12/25	ven 2/14/25	3	100%
T.3.6	Researching regulations for transporting payload by car	Jonas	lun 2/10/25	mar 2/11/25	2	100%
T.3.7	Identifying external factors	Tom	lun 2/10/25	mer 2/12/25	3	100%

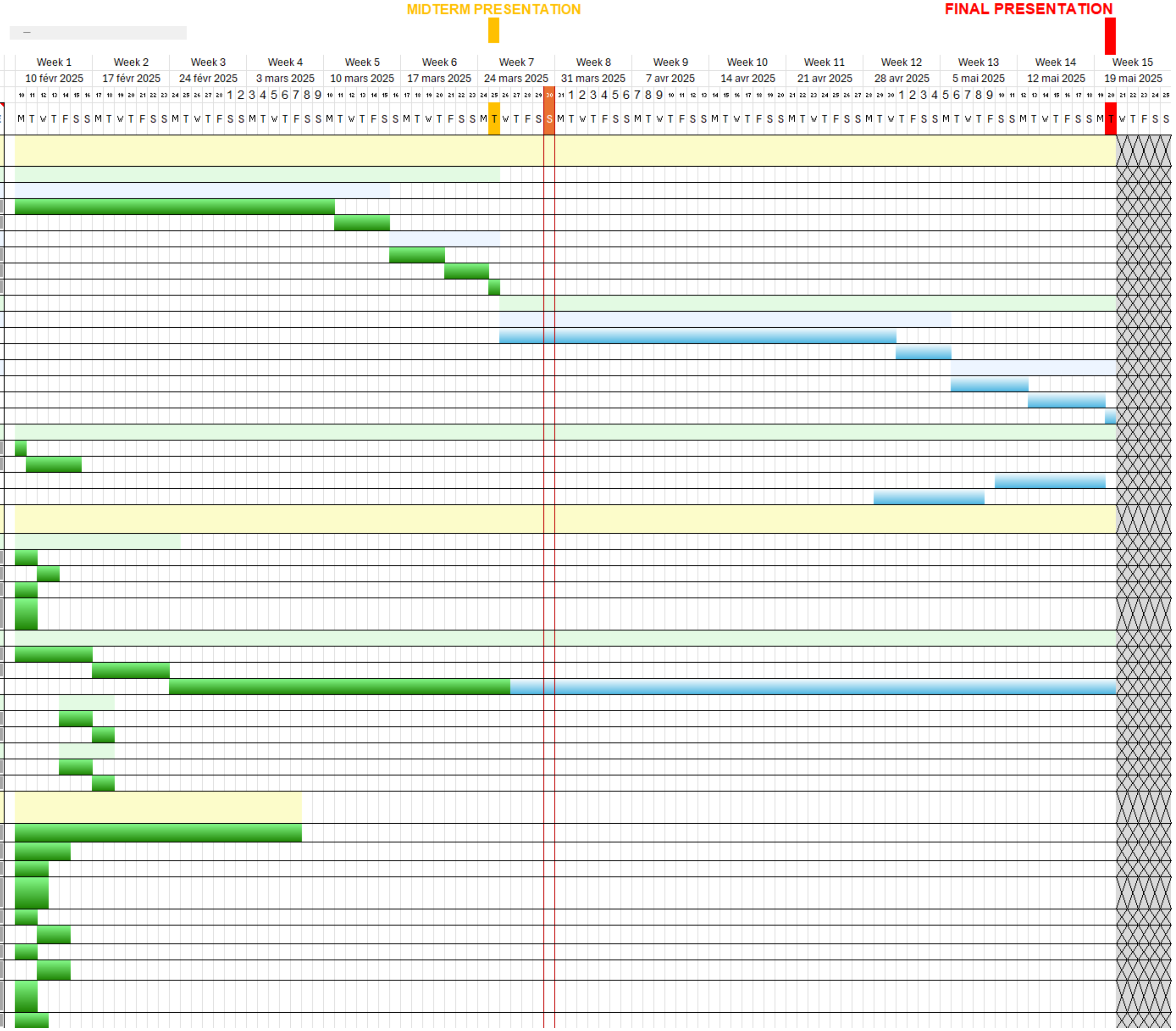


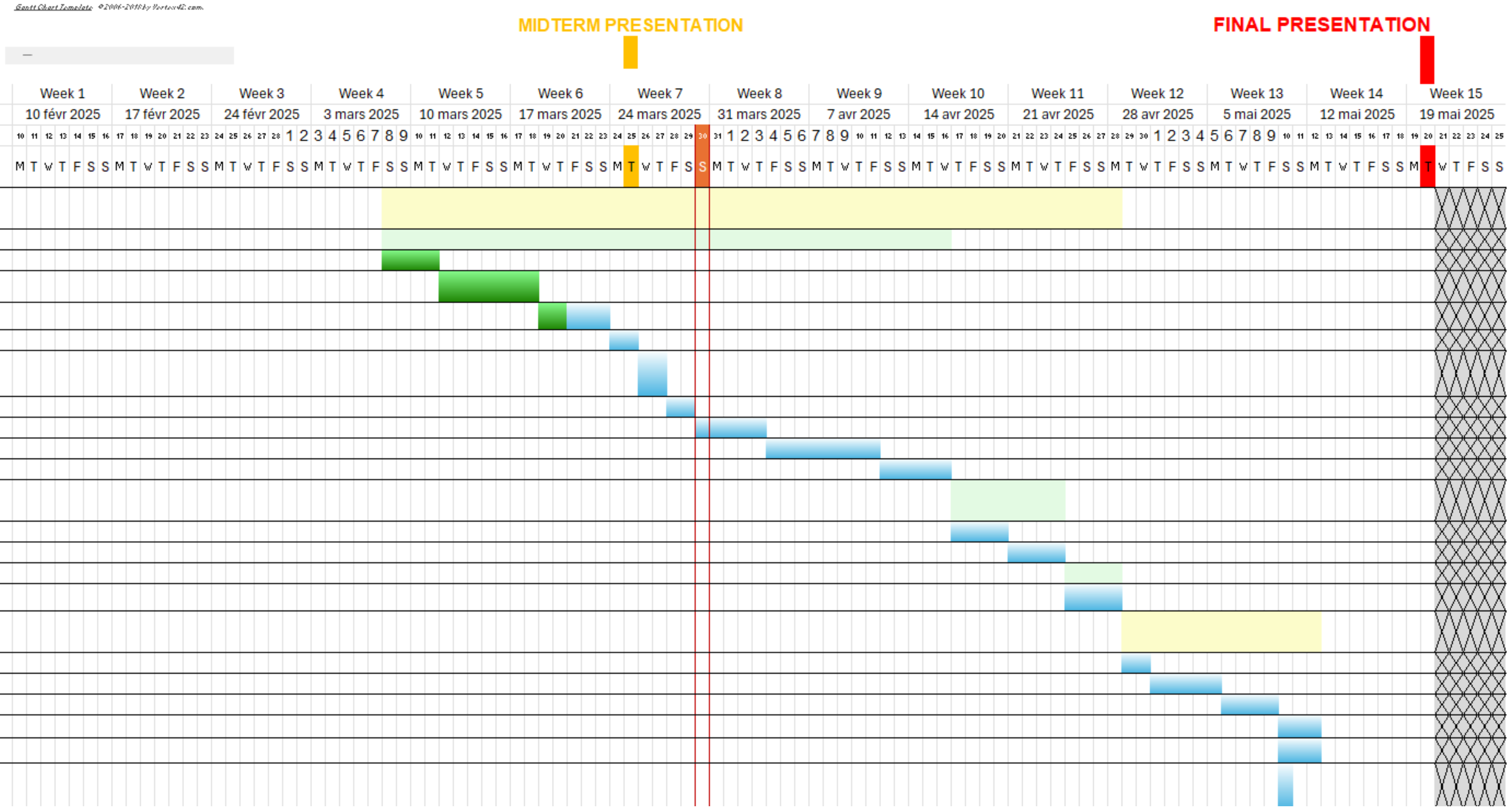
Table 6: Gantt Chart 2

Paramotor Transport Box

Paratroopers

Project Start Date: 2/10/2025 (lundi)
Project Lead: 5/20/2025 (mardi)
Display Week: 1

WBS	TASK	LEAD	START	END	DAYS	% DONE
D.4	**Design of the paramotor transport box that meets the requirements and customer's wishes**		sam 3/08/25	lun 4/28/25	52	
D.4.1	**CAD design**		sam 3/08/25	mer 4/16/25	40	
T.4.1.a	Brainstrom and generate ideas	Everyone	sam 3/08/25	mar 3/11/25	4	100%
T.4.1.b	Sketch concepts & individual components	Everyone	mer 3/12/25	mar 3/18/25	7	100%
T.4.1.c	Compare concepts & individual components	Everyone	mer 3/19/25	dim 3/23/25	5	50%
T.4.1.d	Choose the most suitable solution	Everyone	lun 3/24/25	mar 3/25/25	2	0%
T.4.1.e	Choose the components and the material for the design	Mathis	mer 3/26/25	jeu 3/27/25	2	0%
T.4.1.f	3D scan the Sky engine 110 S	Jonas	ven 3/28/25	sam 3/29/25	2	0%
T.4.1.g	Make structural calculations	Marino	dim 3/30/25	jeu 4/03/25	5	0%
T.4.1.h	Design the paramotor transport box	Everyone	ven 4/04/25	ven 4/11/25	8	0%
T.4.1.i	Make a bill of materials	Tom	sam 4/12/25	mer 4/16/25	5	0%
D.4.2	**Technical drawings of the transport box**		jeu 4/17/25	jeu 4/24/25	8	
T.4.2.a	Make a manufacturing overview	Tom	jeu 4/17/25	dim 4/20/25	4	0%
T.4.2.b	Make technical drawings	Everyone	lun 4/21/25	jeu 4/24/25	4	0%
D.4.3	**Small scale prototype**		ven 4/25/25	lun 4/28/25	4	
T.4.3.a	Make a small scale paramotor transport box	Tom	ven 4/25/25	lun 4/28/25	4	0%
D5	**Produced version of the paramotor transport box**		mar 4/29/25	lun 5/12/25	14	
T.5.1	Order parts	Jonas	mar 4/29/25	mer 4/30/25	2	0%
T.5.2	Manufacture parts	Everyone	jeu 5/01/25	lun 5/05/25	5	0%
T.5.3	Assemble the paramotor transport box	Everyone	mar 5/06/25	ven 5/09/25	4	0%
T.5.4	Test the paramotor transport box on a trailer	Everyone	sam 5/10/25	lun 5/12/25	3	0%
T.5.5	Test the paramotor transport box on a tow hook	Everyone	sam 5/10/25	lun 5/12/25	3	0%
T.5.6	Test if the paramotor fits properly inside the transport box	Everyone	sam 5/10/25	sam 5/10/25	1	0%



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A3.2. Stakeholder identification and analysis

During the project, our team will work with various stakeholders. Before starting the project, it is crucial to identify all stakeholders, analyse their interests, and determine the best communication approach for each. Below is a list of the stakeholders our team will be working with.

1. Tobias Ekfors
2. Novia UAS
3. Novia Technobotnia staff
4. Transport regulations
5. Sky Engines
6. Other Project teams
7. Project team members

A3.3. Stakeholder register

Table 5 shows the stakeholder register, outlining how we communicate with each stakeholder, their preferred communication type, and their stake in the project. Table 6 shows their influence and power in relation to their interest in the project.

Table 7: Stakeholder register

Stakeholder register

Date of last review: 13-03-2025

ID	Title/role	Communication types	Communication vehicles	Stake in project	Contact
1	Project coach & Customer	Direct communication, weekly meetings	MS Teams, Emails	Manage closely	tobias.ekfors@novia.fi
2	Project supervisor	Formal reports	Emails	Meet their needs	Studentservices@novia.fi
3	Responsable for use of machinery in production phase	On-site communication, instructions	Emails, informal discussion	Keep into account	/
4	Has effect on the design of the box	Regulatory documents	Government guidelines	Meet their needs	/
5	Has effect on the design of the box	Decision making	Technical specification sheets	Meet their needs	/
6	Give possible useful feedback	Informal discussions	Shared documents	Keep informed	/
7	Executing the project	Online discussions, direct communication, meetings	Whatsapp group, MS teams		Jonas: stockmann.jonas@edu.novia.fi Tom: tom.geluk@edu.novia.fi Mathis: mathis.besancon@edu.novia.fi Marino: marino.gonzalezbravo@edu.novia.fi

Table 8: Stakeholder matrix

Stakeholder matrix

Date of last review: 13-03-2025

		Interest of stakeholder		
		Low interest	Medium interest	High interest
Influence and power	High stake	ID 4 ID 5		ID 1 ID 7
	Medium stake			ID 2
	Low stake	ID 3	ID 6	

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A4. Risk management

A4.1. Risk identification and analysis

When executing a project, it is essential to identify all possible "what-if" events that have either negative (threads) and positive (opportunities) effect on the project. Table 7 shows all the possible risks that can happen during the project.

Table 9: Possible risks during the project

ID	Risk
1	Over-engineering
2	Not enough budget
3	Limited time
4	Communication between stakeholders
5	Material supply
6	Deviation from schedule

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A4.2. Risk register and mitigation

Only identifying risks is not enough for a project to operate successfully. It is also important to identify the impact of the risk on the project and how the team can respond to the risk when it happens. Table 8 shows the impact of each risk and what the response of our team will be. In addition, the risk owner can be seen.

Table 10: Risk register

Risk register

Date of last review: 13-03-2025

ID	Description of risk	Impact	Risk response	Risk level	Risk owner
1	Over-engineering	Not having results on time	Regularly review design requirements to avoid unnecessary complexity.		Project team
2	Not enough budget	Not being able to produce the product	Monitor expenses and adjust scope as needed to stay within budget.		Project team
3	Limited time	Not having results on time	Prioritize the most essential tasks and stick to the schedule.		Project team
4	Communication between stakeholders	Not coming up with the right solution	Have clear communication and regular updates for all interested stakeholders.		Project team
5	Material supply	Not being able to produce the product	Begin early with sourcing and purchasing the materials required for production		Project team
6	Deviation from the schedule	Not having results on time	Track progress closely and adjust resources to stay on schedule.		Project team

By assessing the impact of each risk, it is now possible to estimate its likelihood of occuring. A common for visualizing both the probability and consequences of risks is a risk matrix. This matrix helps prioritize risks by highlighting those that pose the greatest threat and require close monitoring. The matrix also shows lower-risk factors that need less attention. Table 9 shows the risk matrix for our project.

Table 11: Risk matrix

Risk matrix

Date of last review: 13-03-2025

		Consequences				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelyhood	Certain			ID 6		
	Likely					
	Moderate			ID 2	ID 3 ID 5	
	Unlikely			ID 1		
	Rare			ID 4		

A5. Quality assurance and closure

In the planning stages weekly meetings were held to discuss the customers wishes and new ideas to fulfil them. In the design phase choices were discussed to adhere to the customers wishes and to keep the project feasible. Through testing of the core functionalities with the finished prototype the quality will be controlled and assured.

A6. Closure

The last part of the Project is the closure. This involves handing over the product and the project documentation. Finally, the assessment of the project will be discussed.

A6.1. Instructions for report compilation

As the report should be easy to read the template of rules for writing a report from Novia UAS is to be followed. The rules in the template consider several aspects.

- The disposition of the report. The report should include:
  - A title page
  - An abstract, describing the project
  - A table of contents
  - (A list of figures and/or tables)
  - (A table of appendices)
  - (Word explanations)
  - (Preface)
  - Introduction
  - Purpose and problem statement
  - Theoretical starting points
  - Theoretical background
  - Previous research/ similar studies
  - Methods and procedures
  - Results and interpretation of the results
  - Critical examination and discussion
  - Reference list
  - Appendices
- The format and style of the report.
  - The font Calibri or Calibri light should be used for headings
  - Font size should be 11 or 12
  - Line spacing should be 1-1,5
  - Page numbering begins with the introductory chapter and continues including the reference list
  - The report should have margins of 3 cm on the left and 2,5 on the right, top and bottom
  - Formulas must be numbered consecutively and included in the text according to normal writing rules
  - Material that is to extensive to include in the running text but still important for the work and its credibility shall be included in the appendices.
- The source referencing.
  - Source material needs to be accompanied by a source reference, unless the information is generally known

A6.2. Project evaluation/assessment criteria

Discussing the grading of the project will be the final part of the project. By following the marking scheme it is ensured that the grading system is the same and fair for everyone. The criteria on which the report will be graded and their impact are as follows.

1. The individual oral presentation
2. The professional content of the report
3. The communicational value of the report

A7. social media

In the context of an international and multidisciplinary project like PARATROOPERS, social media plays a key role in shaping the project's public presence, connecting with the broader community, and documenting each step of our design and engineering process.

To ensure this, a dedicated communication strategy was developed and managed by the team's communication coordinator. The Instagram page @Team_Paratroopers was created as the central hub for project updates, team introductions, product insights, and build progress. This page not only showcases our technical achievements but also reflects the collaborative spirit of our diverse and motivated team.

The main goals of our social media strategy are:

- To share the story behind the development of our transport solution for paramotor pilots.
- To visually communicate the evolution of our prototype from sketches to final build.
- To highlight the work, roles, and international perspectives of each team member.
- To engage with an audience of engineers, students, paramotor enthusiasts, and other EPS project teams.

Our approach emphasizes clarity, consistency, and visual appeal. Each post is carefully crafted to blend technical depth with accessible language, supported by photos, videos, and design visuals. In doing so, we aim to make the engineering process understandable and inspiring to a wider audience, while reinforcing the educational value of the EPS experience.

TEAM_PARATROOPERS