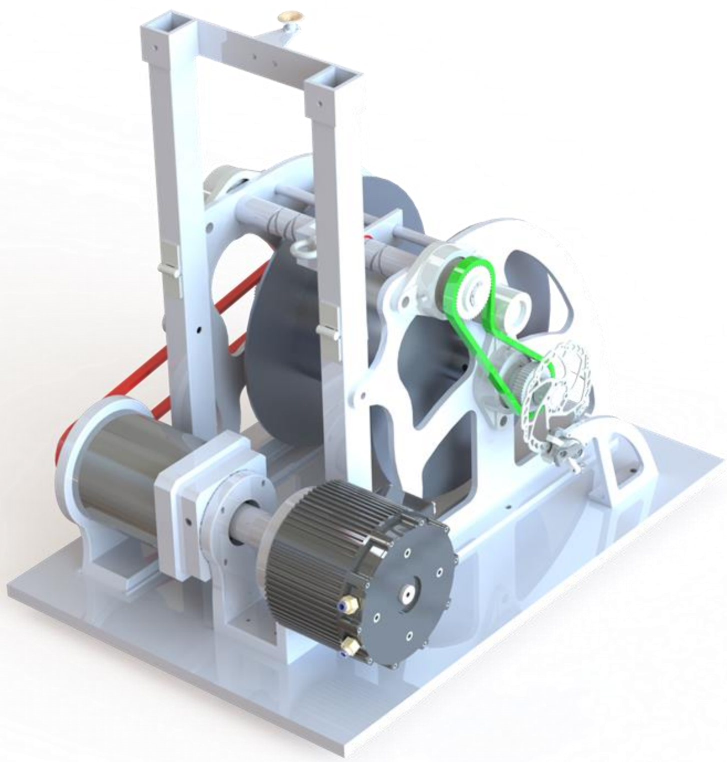
Final report

CombiWinch



Anaïs Bombardier

Thomas Donny

Rodrigo García

Sherifatu Issah

Supervisor: Tobias Ekfors

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Novia UAS

Abstract

The goal of this project is mainly to combine two methods of launching for paragliding.

Inspiring ourselves from existing devices such as the eWinch and the Parawinch, we designed a product fitting every requirement from the customer, our tutor Tobias.

Research and calculations were made about paragliding, materials, brakes, data, motor, electric systems, and environment. The design was then made on a CAD software answering every specification.

At the end of this report, we are presenting the final product we designed and thought about as well as every other auxiliary system and component.

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Acknowledgements

To start, we first wanted to acknowledge and thank the stakeholders in this project. Our tutor, Tobias Ekfors, is the person who decided on this project. As our reference, he always helps us when we have any questions or doubts and guided us throughout this project.

Next comes Roger Nylund who started the semester with us in a Teambuilding class and built the groups for this EPS project. While in class with him, he helped us break the ice, knowing everyone and also guided us a little at the start of the project.

Finally, we wanted to recognize the work and help of Philip Hollins during every week of this first part. The work we did in project management allowed us to learn how to build and conduct a project but also define roles within the team.

1. Introduction

In this little introduction will be a presentation of the background of this project. It started with the idea and hobby of our project's tutor, Tobias. As said, one of his hobbies is paragliding. Paragliding is an outdoor activity that requires equipment, wind, and most importantly altitude. But as you surely know, Finland is not renowned for its numerous mountains. In fact, the country is mostly flat. That brings the need of some method to compensate for the lack of relief to enjoy paragliding: Winches. Some already existing solutions are currently in use by Tobias and his paragliding club. These solutions are working perfectly but Tobias saw opportunities of improvement. That is where we come in, our goal will be to design and produce our own improved version of winch, and also combining two different methods in one, hence our team's name: CombiWinch.

1.1 Project background

The purpose of this report is to document the delivery of the EPS project entitled: CombiWinch.

The EPS (Erasmus Project Semester) is a program that gathers engineering students from different countries, nationalities, and culture into a project to work a whole semester. Ours is taking place at Novia University of Applied Sciences in Vaasa.

The aim of CombiWinch is to integrate the two possible modalities of paragliding launch into one device. The first method consists of towing the paraglider with the help of a motorized vehicle, like a car or an ATV. The second method is to use the force of a winch, which will give speed and force to the pilot through the cable/rope that will be attached to it.

The project will also try to improve the braking solutions that the commercial options for these devices are using now, while trying to reduce the high price of this product.

1.2 Team members

For this project, the team consists of four members, from different countries and different degrees and backgrounds.

Anaïs Bombardier

Figure 1: Anaïs Bombardier

I come from France, my name is Anaïs Bombardier, and I am 21 years old. My journey into my studies started after high school when I decided to go to a bigger city than where I am from in the south-west of France to learn about material sciences. It was only a two-year degree that really pleased me and made me like practical aspects of studies. Think, design, and build different objects in varied materials really appealed to me.

It was after that I decided to specialize into packaging engineering and for that I needed to go far in the north of France at Reims where funnily I was born. With both my schools, I learned a lot about materials, process, design, etc. My skills are mostly present and good in technical aspect thanks to my previous experience in school, building furniture. For my learning experience in my current school, I was able to discover and get better at designing and know the processes of packaging.

I had a first experience in a small company while doing my two-year degree, my main mission was to imagine another process line to be able to produce another type of wine crate since the company is fabricating wine crate to transport wine bottles in the region, Bordeaux region in the south-west of France. It brought me a lot in terms of first genuine experience in the working world.

Lastly, I am interested in a lot of things, since I am quite a curious person mostly about cultures. Learning new languages and new cultures by traveling are things that I appreciate a lot as well as reading in my native language or some foreign ones.

Being invested in social and student life is also important, and I took this opportunity in my current school as I am the secretary of one of the associations doing arts and cultural activities such as shows and small trips.

With my practical vision and detailed oriented mindset, I believe my contribution to the team will be beneficial in this project.

Thomas Donny

Figure 2: Thomas Donny

My name is Thomas Donny, I am currently 21 years old, and I am a French student.

I study Mechanical Engineering at the National Engineers School of Tarbes, in the department of Hautes-Pyrenees. My major consists of five years after the High School diploma in 2020. During these five years, we have the chance to do one and half year of internships, and one semester of international mobility.

During my studies, I gathered some experience in many different CAD software, but the main one was Catia. I also have skills in CNC lathe and milling machining, and some in welding, foundry, ALM and metrology.

In 2023 I did my first internship in a small company called Effigear/Cavalerie based in Maclas in France. They are designing and manufacturing gearboxes for mountain bikes and the mountain bikes that incorporate them.

My job during this 2-month internship was to help design their newest carbon fibre frame E-Mountain Bike. I used a CAD software called TopSolid7 which was quite practical.

This e-MTB was integrated with the first-of-a-kind Smart E-Bike System, an innovation combining a gearbox and an electric motor, that they design in partnership with Valeo.

Last year, I had the chance to do my second internship in a bigger company called Latesys (formally called Latécoère Services) based in Sainte-Foy-d'Aigrefeuille (31) and specialised in the design and manufacture of production, assembly and test equipment offering integrated functions at the request of industrial and to guarantee high added value.

During this 6-month internship, I had three main projects I worked on, all of them were Computer Aided Design on Catia. The first and most important one was the design and development of an assembly line for a heavy payload partially reusable space launcher. The second one was the design and development of assembly-line tools for a light payload space launcher. And the last one was the design and development of assembly-line tools for a high-altitude surveillance drone.

Rodrigo García

Figure 3: Rodrigo García

I come from Valladolid, Spain, a city with a rich history and vibrant culture. Currently, I am in the final stages of my studies in industrial electronics and automation at the University of Valladolid. It has been quite the journey, diving into circuits and automation systems while navigating the challenges of university life.

On top of that, I am currently involved in an EPS project at Novia University of Applied Sciences in Vaasa, Finland. It has been an enlightening experience, delving into industrial automation from an international perspective, and applying my knowledge in the topic in an international project, collaborating with people from all over the world with experience and background in many other fields.

As for the future, I am enthusiastic about pursuing a career in the automotive industry. Whether that involves further academic pursuits with a master's degree or diving straight into the workforce remains to be seen. What is certain is my enthusiasm for the automotive world, where I hope to make a meaningful impact.

During my time at the University of Valladolid, I have been actively involved in a Formula Student team for the past three years. My role has primarily focused on the battery and electronics side, and I even had the opportunity to manage the department for a year. It has been a valuable experience, teaching me the importance of teamwork and project management. Also, it has shown me the importance of the dedication and motivation of a team towards a common goal, and the satisfaction that produces watching a whole team of students achieving their dreams and goals.

Outside of academia, I have also gained experience in the catering and restaurant business, where I have honed my people skills and adaptability in challenging environments.

In summary, my journey thus far has been marked by an academic rigour, international experiences, and a passion for the automotive industry. As I prepare to embark on the next stage of my career, I am eager to apply my skills and knowledge to make a positive contribution in the field.

Sherifatu Issah

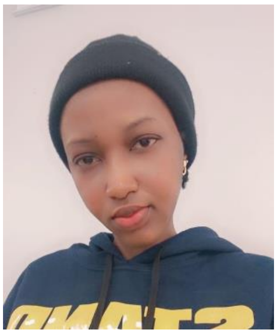


Figure 4: Sherifatu Issah

My name is Sherifatu Issah, and I am a Ghanaian living in Accra. I am currently pursuing a degree in Agricultural Engineering at the University for Development Studies (UDS). It is a four-year course, and I am in my final year, set to complete my studies this year after finishing my thesis. My experience in agricultural engineering has expanded my knowledge and passion for improving agricultural production and implementing policies to support the agriculture sector in my country.

The EPS is my first opportunity to study abroad. I chose EPS and Finland because it offers me a chance to hone my talents and skills of communication areas that are lacking at my home university and learn more about Finnish culture and the beautiful land. Working as a group to discuss our ideas and address the challenges on the project is enriching.

The team: Our team is composed of four members coming from three different countries, diversity is a what make a good team. We meet each other at the start of the semester, and we will be doing the project together which will make us learn about each other. Meeting and collaborating with new classmates will make us grow in a lot of various aspects.

2. Previous research and calculations

Before starting to design or to find any component for our version of this device, we had to investigate the types of solutions or approaches used in current commercial models. This way, we could avoid repeating mistakes that some companies in this field have already experienced. Additionally, we need to gather important data before beginning calculations so that we have a clear understanding of the results and data required.

2.1 Benchmarking on towing devices

Firstly, to start this project, scheduling and organizing were the first thing to do to know where to begin. The second step is the benchmarking phase which means researching and looking into the topic to learn more about it. In that way, our goal to combine two devices is easier and more constructed.

In order for a paraglider to be launched in the air while starting at the ground, airspeed needs to be of at least around 10 to 15 km/h and an average air speed of 30 km/h is recommended for a safe flight. What is important to note is that if the airspeed is stronger, the paraglider go up faster in the sky due to the increased lift force.

For a launch, the rope needs to be already unwound while the paragliding pilot place himself at the end. And according to the requirement, the rope that will be used with the CombiWinch needs to enable a minimum of one thousand metres of flight altitude. So, for future launches with our design, a big space will be required for the best towing.

During the flight, the rope will be wound to help air going into the paraglider canvas and lifting him up. When the height wanted is reached, the cable will be dropped for the paraglider to have a free flight.

2.2 Existing devices

Before looking for a solution to the topic, research was made about the existing and currently used devices. Two of them were most of our concern, we took every information possible on how it works and what we want ours to look like.

The first one, the eWinch, is an electric winch allowing one pilot to launch and tow himself up.

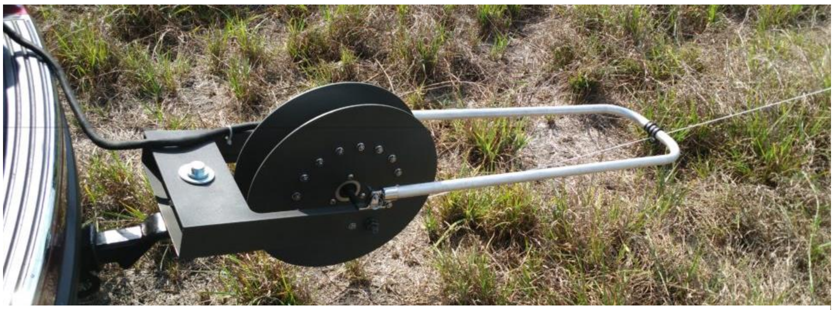


Figure 5: eWinch.

Supplied by an electric motor and remote controller, the winch does not need a lot of people in order to use it. Furthermore, it can be attached to any vehicle like seen on the figure, only a small mounting is needed. The size of this one gives the possibility to have a rope of around 1300 metres long and there is a rotation angle thanks to the mounting on the vehicle. But this also the disadvantage that it is not doable to have a 360° rotation. Finally, the guider is a small hole just guiding the rope straight into the drum. With the design it has, there is a high probability of wear.

The second winch studied is the Parawinch. It has the same functions as every other one.

Figure 6: Parawinch.

What is innovative is mostly the guider which can have a rotation at 360° permitting to avoid any problems during the winding. In addition, there is a mechanism to distribute the rope evenly on the drum. The outer shell has a safety purpose while being nicely designed while the upper part of the winch is composed of the arms. These are foldable in the aim of being more compact and easier to transport anywhere.

2.3 Materials

In the existing towing devices for paragliding, most of construction is done with metals. Mostly aluminium, especially for the parts that need to support some kind of forces. For some other parts, plastic is used, like the mounting of the electronics, for example. For the rope, most of the time synthetic materials are used, with a multi-braid array, to give the rope more resistance to tensile efforts. Some of the best ropes are made of Kevlar a synthesised polymer related to aramids that resist a lot to forces and winds.

Figure 7: Kevlar material (aramid)

For the prototype of our CombiWinch, we aim to print it with a 3D printer after having done the design. A 3D printer is a device that creates a physical object from a digital design with printing layers of polymers chosen whether being the material, aspect or colour influencing the choice. The polymer is heated to reach his glass-transition temperature (Tg) and be just under his melting temperature to be a lot more flexible and adjustable.

Figure 8: 3D printer.

As of the materials used, there are a lot, but some are more common. Since in this project, and as a younger generation's team, we try to be sensitive to the ecological point of view, we searched ways of including this aspect in the building prototype phase.

As a result, the best polymer possible for 3D printing and being quite environmentally friendly would-be PLA (Polylactic acid) coming from condensation of lactic acid. It is a recyclable polymer. Most importantly, PLA is the most widely used plastic filament material in 3D printing, due to its low melting point, high strength, low thermal expansion, and good layer adhesion.

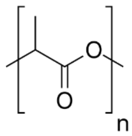


Figure 9: PLA molecule.

2.4 Brake

For our purpose we need a way of regulating the speed of the rope to ensure safe flight. First of all, we took a look at already existing solutions. The solution that our client wanted us to improve was using a drum brake, others were using hydraulic power. Let us dive deeper in the diverse types of brakes we could use, and which ones are our current choices.

2.4.1 Drum Brake

The first method we considered is the drum brake. Drum brakes are really common nowadays, they are used in all sorts of vehicles going from the kids' bike, all the way to transport vehicles such as trucks.

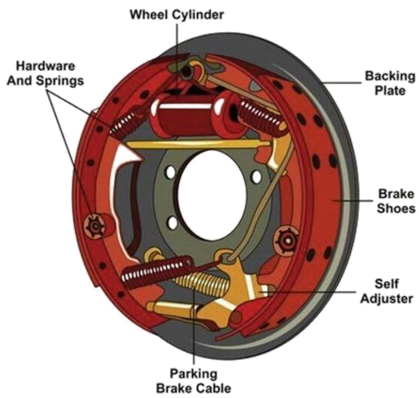


Figure 10: Drum brake.

The brake is composed of three main components that will impact the braking power of said brake. The first one is the brake drum, which is not represented on this scheme. It plays a crucial role in stopping as it is the wear part fixed to the spinning axle. Applying friction to it will allow the axle to slow down and then stop. That is where the brake shoes come in. They are these big circular shaped pads in red. These are composed of a brake lining, the exterior layer that will rub against the drum. It has to be highly resistant to heat and wear and have a high friction coefficient in order to deliver the most braking power. And last but not least, the hardware and springs will control the expansion of the brake shoes onto the brake drum. These will adjust automatically to match the lining wear over the use of the brake and deliver a constant control over said brake.

Advantages of drum brakes:

- They are pretty cheap.
- Slightly lower maintenance rate than disc brakes.

Disadvantages of drum brakes:

- Pretty complex design.
- Thermal expansion causes the brake drum to expand in diameter resulting in a need for more input of force.
- The lining's friction material might change properties under heat, which can result in a loss of friction. If overheated, the lining becomes glazed, reducing even more the friction.

2.4.2 Centrifugal Brake

Centrifugal brakes use the same mechanism as the drum brakes, only here, they do not require an input from the user.

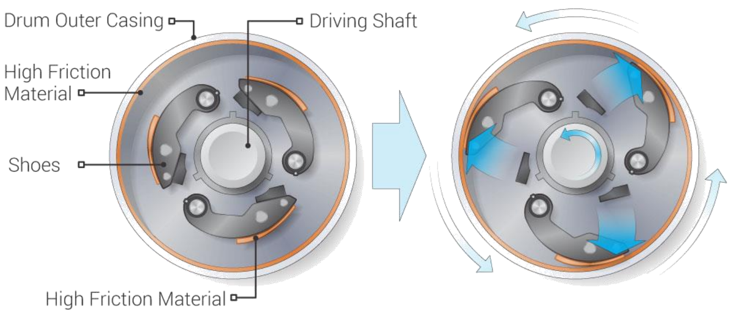


Figure 11: Centrifugal brake.

As any can guess from the name, these brakes make use of centrifugal force, an inertial force directed outwards from the centre of rotation of an object. When the driving shaft reaches a certain rotation speed, springs that held the shoes in place, now extend, due to the centrifugal force being now greater than the spring force. This results in the weighed brake shoes rubbing against the drum, thus creating friction, and finally braking power.

Advantages of centrifugal brakes:

- This type of brake is less complex than the drum brakes as it has fewer moving parts.
- A specific threshold rotation speed can be set by adjusting the spring constant thus needing no control interface.

Disadvantages of centrifugal brakes:

- Same as the drum brake.
- No real control over how much brake force is applied.

2.4.3 Disc brakes

The second to last brake solution we considered is the disc brake. They usually have the same range of applications as drum brakes as they are their most common alternative.

Figure 12: MTB brake.

This type of brake uses a brake calliper, holding two pistons either mechanically or hydraulically actuated. These pistons will squeeze the disc between two brake pads (in red) to create friction. The brake pads have the same function as the brake shoes of the previous two brakes. They have a high tolerance to heat and wear.

Advantages of disc brakes:

- Very compact, lightweight, and slim design.
- Has the easiest maintenance out of the three methods presented.
- Due to their design, discs are already prone to a better heat dissipation.
- If hydraulically actuated, the ratio between input force and braking force is extremely favourable. Also, this provides more responsive and accurate braking performance.
- If the brake pads overheat and glaze, the disc is usually manufactured to get rid of the glazed layer efficiently, contrary to drum brakes.

Disadvantages of disc brakes:

- A bit more expensive than the other methods.
- If the disc is contaminated with debris, it can result in a drop in braking performance. This can be accounted for by shielding the whole assembly.
- Squeal, a high-pitched noise that can occur when the brakes are applied. Not negatively affecting the brake-stopping performance, this can be a problem to the consumer and the environment.

2.4.4 Engine braking

The last solution is regenerative braking, equivalent of engine braking but for electric motors. It is a mechanism used to slow down a vehicle by converting its kinetic energy back into electrical energy. The electric motor operates in reverse, acting as a generator to produce electricity. This electricity is then, for electric vehicles for example, fed back into the vehicle's battery or electrical system, effectively slowing down the vehicle while simultaneously charging the battery.

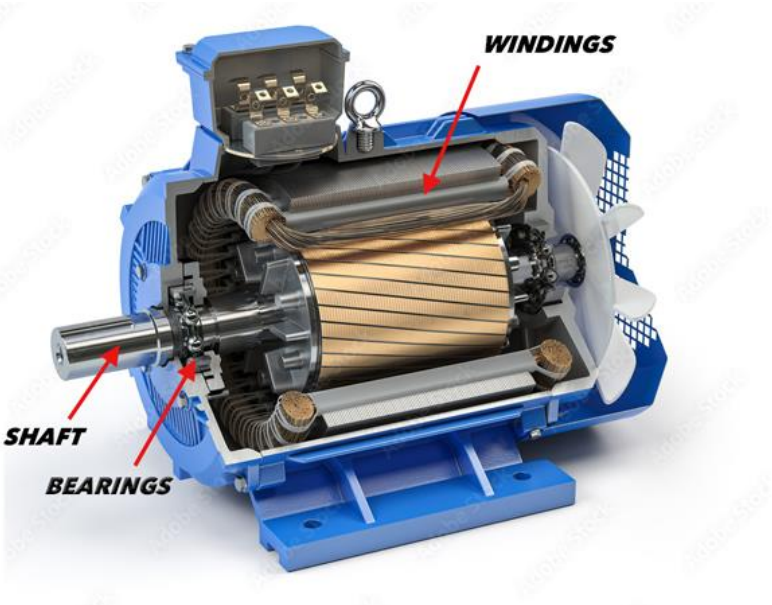


Figure 13: Electric motor.

Two diverse types of electric motors exist:

- Brushed motors, they are electric motors that use brushes and a commutator to switch the direction of current flow in the motor windings, generating a magnetic field that drives rotor rotation.
- Brushless motors are electric motors that operate without brushes and commutators. Instead, they utilise an external electronic controller to precisely control the power to the motor windings.

For our application, a brushless motor is more suitable as it has an improved efficiency, higher power-to-weight ratios, and longer lifespans compared to brushed motors.

The use of regenerative braking offers several advantages, including improved energy efficiency, reduced wear on mechanical brakes, and the ability to charge the vehicle’s battery.

However, it may require sophisticated control systems and may not be as effective at high speeds compared to traditional friction-based braking systems.

That is why we, for now, decided to try to combine regenerative braking from the motor with disc brakes.

2.4.5 Early Research Conclusion

For this project we plan to make use and combine two different brake methods.

The first one will be motor braking with the electric motor that will be implemented in the device. With this topology, we will be able to regulate the speed of the rope in a very efficient way, with less heat dissipation than a conventional brake, and with the appropriate electronic, we can even charge back the vehicle's battery when using this brake. This method will also help to reduce the final size of the device, as it is integrated in the motor, and there is no need for additional external devices to it, apart from compatible electronics.

However, with this type of brake it will not be enough to completely stop the rope, or to give enough braking force at some points of the launch. Also, because of security aspects (the motor brake depends on electronics) we will also implement a conventional disc brake, like the ones used in a motorcycle or some bikes. Even so, as the motor brake will be implemented, the size of this brake can be reduced significantly, as it will not need to support all the braking force of the device.

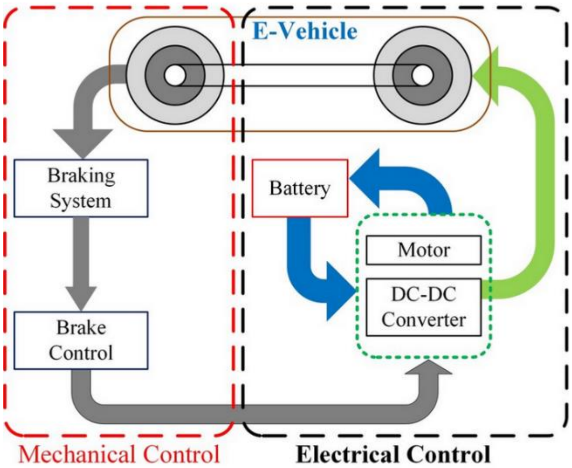


Figure 14: Regenerative braking principle.

With the combination of these two topologies, we will be able to have a braking system where we can easily control the braking force, the moment it starts working, and the balance between each type of brake, while having an efficiently balanced system, with security guarantees.

2.5 Human to machine interface

The human-machine interface (HMI from this point) is the part that the user will use to communicate with the device. Therefore, we need to have in mind all the parameters and options that the user will need to operate. To display the information to the user, a screen will be used, as it can display more information and graphs that a bunch of LEDs and seven segments display. For the data input from the user, some rotary encoders and buttons will be placed near the screen.

This input devices will allow the user to navigate through the menus, and change the parameters as he/she wants, but without surpassing some limiting values that will be established beforehand. Also, a data logger functionality will be implemented, via an SD card. This way, we will be able to collect all the important data that will be collected during the activity of the device, allowing us to analyse it afterwards. With this, the pilot will be able to see at what points of the launch, the speed, force, or other factors were not ideal, thus being able to make some changes to optimise the launch.

2.6 Calculations

The calculations will be necessary for the choices of materials, engines, and the design of the CombiWinch in order to respect the requirements and get the better design out. For that, a lot of factors are important such as the weights of the paraglider pilot and the paraglider itself as well as the weight of all the equipment. All the data tied to the rope and the wind also matters like air density, rope weight and drag coefficient.

2.6.1 Data

In the paragliding club, they use some equipment for all of them. There is an average of how much this equipment weighs. To be safe we choose to do the calculations with a weight of around 20 kg. It is distributed as following:

- Harness: 2,7kg (up to 10 kg)
- Rescue parachute: 1,5 (up to 3 kg)
- Paraglider: 5 kg
- Equipment: 1 kg
- Paraglider pilot weight depends.

Figure 15: Paragliding equipment.

Description	Unit	Designation	Value		Notes	
Flight Height (m)	(m)	Δh	1000			
Glider Drag Coef	X	Cd	0,33			
TL Materials Characteristics (g/m, daN)	(g/m, daN)	m, R	3,55	770	HMPE Rope	
Parag Weight (kg)	(kg)	wg	110		Pilot + Equipment	
End Angle (rad,°)	(rad,°)	θ	1,04719755	60		
TL Diameter (m)	(m)	d	0,0025			
Average Velocity (m/s)	(m/s)	V	10			
Takeoff Velocity (m/s)	(m/s)	Vt	2,78			
Air Density (kg/m3)	(kg/m3)	ρ	1,292		at 0°C	
Air Viscosity (µPa·s)	(µPa·s)	µ	18,5			
Angle Between the Horizontal and the Local Normal Vector to the Tow Line	(rad,°)	ϕ	0,78539816	45		
Pilot Reference Area	(m2)	Ap	0,7			
Paraglider Reference Area	(m2)	Ag	25,08			
Factor of Safety	X	FoS	1,5			

Figure 16: Calculations data.

- One of the requests made by the client was to have a flight height (Δh) of 1000 metres for the paraglider.
- The Glider Drag Coefficient (Cd), which is used to quantify the drag or resistance of the paraglider in a fluid environment, here air. This value has been determined in a research document you can find here:

3 Model Parameters

In this section we want to summarize important parameters used in this model. Values of some of the parameters are provided by the manufacturer or calculated analytically. Other parameters are tuned experimentally, for instant the damping coefficient d, to get a good image of the reality.

$$\rho_{air} = 1.27\,\frac{\text{kg}}{\text{m}^3} \qquad m_g = 6\,\text{kg}$$
$$M_p = 100\,\text{kg} \qquad l_{line} = 6.97\,\text{m}$$
$$A_{projected} = 24.26\,\text{m}^2 \qquad A_{pilot} = 1.0\,\text{m}^2$$
$$l_{MG} = 0.395\,\text{m} \qquad l_{Gm} = 6.575\,\text{m}$$
$$d = 10000\,\frac{\text{Nms}}{\text{rad}} \qquad c_{d,p} = 0.33$$

The aerodynamic coefficients c_l and $c_{d,g}$ are assumed to be functions of the angle of attack α. These dependencies are shown in Figure 8 graphically.

Figure 17: Model parameters.

- The Tow Line materials and characteristics have been chosen by looking and comparing various materials and already in-use solutions. We have decided to go with an HMPE (High-Modulus Polyethylene) Rope with a Rupture Force of 770 kg and mass (m) of about 3,55 g/m. That makes this rope the most suitable for our project, as it is light and thin. Also because of it has a lesser density than water, it allows it to float, so that makes it suitable for towing with a boat. Rope specifications can be found on DYNALIGHT.
- The Paraglider Weight (wg) is the combination of the equipment weight and the pilot weight. We decided to round it all up to 110 kg. Though this number does not really matter for now because, the weight is equal to the lift force, which does not come into account in these calculations.
- The angle the tow line end makes with the horizontal at the glider (θ) is first arbitrarily chosen. Here, making an average of videos and records of towing launches, we decided to make it 60°.
- The Tow Line Diameter (d) has also been arbitrarily chosen from the study of other existing solutions.
- The Average Velocity (V) is the required airspeed for a safe and controlled paragliding flight. Here it is 36 km/h or 10 m/s.
- The Take-off velocity (Vt) is the minimum speed necessary to achieve flight.

- The Air Density (ρ) is going to be needed for the calculation of the drag force. Here we chose to take the density of 1.292 kg/m^3 at an air temperature of 0°C.
- The Air Viscosity (μ) is here of 18,5 μPa.s.
- The Angle Between the Horizontal and the Local Normal Vector to the tow line (ϕ), has been chosen arbitrarily. We made an average of 45° by studying simulations of rope sag.
- The Pilot Reference Area (Ap) is the orthographic projection of the pilot on a plane perpendicular to the flight direction. Here we calculated an average of 0,7 m^2.
- The Paraglider Reference Area (Ag) is in this case would be the projected area of the paraglider, following this table:

Table 1 Full-scale wing dimensions

Dimension	Unit	Value
Arch height	m	3.00
Central chord	m	2.80
Projected area	m^2	25.08
Projected span	m	11.00
Projected aspect ratio	— —	4.82
Flat area	m^2	28.56
Flat span	m	13.64
Flat aspect ratio	— —	6.52

Figure 18: Wing dimensions.

- And finally, the Factor of Safety is chosen arbitrarily. In aeronautics it usually sits between 1,2 and up to four. We chose to take an average one of 1,5.

2.6.2 Formulas

a) The first thing we have to calculate is the Catenary Curve Constant (c) following this equation:

$$c = \frac{\Delta h * \cos(\theta)}{1 - \cos(\theta)}$$

b) This constant is then used in determining the tow line length (s) and weight (w_t):

$$s = \sqrt{\Delta h^2 + 2 * \Delta h * c}$$

$$w_t = m * s$$

c) Next, we calculate the Reynolds Number (Re) specific to the flight speed:

$$Re = \frac{V_c * \rho}{\mu}$$

d) Then, with the following graph, we determine the right Drag Coefficient (Cd) of the Tow Line to use in the calculation of the Tow Line Drag Force:

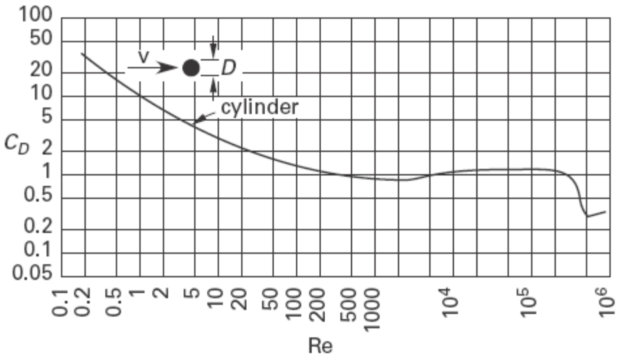


Figure 19: Reynolds of a cylinder.

e) The Tow Line Drag Force is comprised of two components, the form drags which is based on the locally normal component of velocity and frontal area and the frictional drag which is based on the parallel component of velocity and the reference area. It is expressed in the following equation. Cf which is the Tow Line coefficient of Friction, has been set to 0.1:

$$Dl = 0.5 * V^2 * s * d * (\sin^2(\phi) * \rho * Cl + Cf * \pi * \cos^2(\phi) * \rho)$$

f) Now the Glider Drag Force is calculated using the following simpler and more generic formula:

$$Dg = \frac{1}{2} * Cd * \rho * V^2 * A$$

g) Then the two forces are summed up into the Total Drag Force (D). This force is then converted into the power needed for towing with following this equation:

$$P = D * V$$

h) We then apply the Factor of Safety to this result.

i) And finally, we calculate the Maximum tension allowed by the rope (F), and compare it with the Total Drag Force (D), to see if our solution is viable:

$$F = \sigma_u * s = \sigma_u * \pi * \left(\frac{d}{2}\right)^2$$

Details about the formulas used and calculations can be found in annex: A2

2.6.3 Results

Here is the condensed result table from all the formulas listed previously:

Name	**Value**
TL length	~1750 m
TL weight	± 6.15 kg
TL Diameter	2.5 mm
Total Drag Force	± 59.40 kg
Power Needed	± 8.9 kW

Figure 20: Calculations results.

These are the most important ones in order to understand the forces in play in our future design.

- First the Tow Line Length, this one is pretty self-explanatory, in order to achieve the goal of allowing a 1000m height flight, we need to have a rope long enough to ensure this.
- Secondly, the Tow Line Weight, depending on the Tow Line Diameter. In order to size our design adequately, we need to know the total weight of the rope, as it is a force that will be applied to our winch.
- Second to last is the Total Drag Force, the horizontal component of the force applied to the winch. This component is far greater than the other one, so this is why we will only consider this one for our design.
- And lastly, the Power Needed is calculated for the sizing of the electric motor. Here, this value has been multiplied by 1.5, the Factor of Safety mentioned before to ensure that our assembly is safe for the user.

2.7 Impact on the environment

- HOW DOES PARAGLIDING IMPACT LAND USE IN AGRICULTURAL AREAS?

Paragliding in agricultural areas can have both positive and negative impacts on land use. On the positive side, it can bring in tourists and revenue to the area, which can benefit local economies. However, it can also lead to soil erosion and damage to crops if not managed properly. Additionally, the noise and disturbance from paragliding activities can disrupt farm animals and wildlife in the area. It is important for regulations and guidelines to be in place to ensure that paragliding activities in agricultural areas are sustainable and does not cause significant harm to the land and its use for farming.

- ARE THERE ANY POTENTIAL CONFLICTS BETWEEN PARAGLIDING AND TRADITIONAL FARMING?

Yes, there can be potential conflicts between paragliding and traditional farming in agricultural areas. The presence of paragliders can disturb farm animals and wildlife, affecting the peace and productivity of the farming environment. Additionally, the landing and take-off areas for paragliding can occupy space that would otherwise be used for agricultural purposes. It is crucial for both paragliders and farmers to communicate and find ways to coexist harmoniously to minimise any conflicts that may arise.

- HOW DOES LOCAL BIODIVERSITY GET AFFECTED BY PARAGLIDING ACTIVITIES?

Paragliding activities can impact local biodiversity by disturbing wildlife in the area. The noise and presence of paragliders can disrupt the natural habitats of animals, affecting their behaviour and potentially causing stress. It is important to consider these impacts and take measures to minimise the disturbance to preserve the biodiversity of the area.

- ARE THERE ANY ENDANGERED OR VULNERABLE SPECIES THAT MAY BE IMPACTED?

Yes, certain endangered or vulnerable species could be impacted by paragliding activities in agricultural areas. The disturbance caused by paragliders can affect the behaviour and habitats of these species, potentially leading to stress and disruptions in their natural environment. Conservation efforts should be taken to protect these species and their habitats from the negative effects of paragliding activities.

- WHAT IS THE IMPACT OF PARAGLIDING ON SOIL QUALITY AND THE RISK OF EROSION IN FARMING REGIONS?

Paragliding in farming regions can have an impact on soil quality and the risk of erosion. The activity can lead to soil compaction and disturbance, which in turn can affect the soil's ability to support plant growth and retain nutrients. Additionally, the landing and take-off areas for paragliding can contribute to soil erosion, especially in areas with steep terrain. It is essential to manage paragliding activities carefully in farming regions to minimise these risks and preserve the soil quality for agricultural purposes.

- HOW CAN NEGATIVE EFFECTS ON THE SOIL BE MINIMISED?

To minimise the negative effects of paragliding on soil in farming regions, it is important to implement proper land management practices. This can include designated take-off and landing areas that are strategically located to reduce soil compaction and erosion. Additionally, establishing buffer zones between paragliding sites and agricultural fields can help protect the soil from disturbance. Regular monitoring and maintenance of these areas can also help mitigate any potential impacts on soil quality.

- ARE THERE ECONOMIC BENEFITS FOR LOCAL COMMUNITIES THROUGH PARAGLIDING ACTIVITIES IN AGRICULTURAL AREAS?

Yes, there can be economic benefits for local communities through paragliding activities in agricultural areas. Paragliding can attract tourists and adventure enthusiasts, leading to increased revenue for local businesses such as hotels, restaurants, and shops. Additionally, offering paragliding services can create job opportunities and stimulate the local economy. It is essential to balance these economic benefits with environmental considerations to ensure sustainable development in the area.

- HOW DOES FARMING ECONOMY GET AFFECTED BY THE PRESENCE OF PARAGLIDING ACTIVITIES?

The presence of paragliding activities in farming areas can impact the local economy by attracting tourists, creating job opportunities, and stimulating businesses like hotels and restaurants. This can lead to increased revenue for the community.

- WHAT SAFETY ASPECTS MUST BE CONSIDERED TO PROTECT BOTH PARAGLIDERS AND FARMERS?

To ensure the safety of both paragliders and farmers, it is essential to establish clear communication channels between the two groups. Setting designated landing areas for paragliders away from farm activities can help prevent accidents and conflicts. Additionally, implementing safety guidelines, such as height restrictions for paragliding, can further protect both parties.

- ARE THERE ANY REGULATIONS OR GUIDELINES TO MINIMISE CONFLICTS AND SAFETY RISKS?

To minimise conflicts and ensure safety in paragliding activities, there are regulations and guidelines in place. These include establishing designated landing areas for paragliders to avoid interfering with farming activities and implementing height restrictions to prevent accidents.

Clear communication channels between paragliders and farmers are crucial for safety and conflict prevention.

- HOW DOES PARAGLIDING AFFECT THE LOCAL COMMUNITY AND ITS CULTURAL ASPECTS?

Paragliding activities can have various effects on the local community and its cultural aspects. The influx of tourists attracted to paragliding can bring economic benefits to the community by boosting local businesses such as hotels and restaurants. However, conflicts may arise between paragliders and traditional farmers, potentially impacting the cultural harmony and practices of the community. It is important to find a balance that respects both the cultural heritage of the area and the recreational activities of paragliders.

- ARE THERE OPPORTUNITIES FOR COLLABORATION AND CULTURAL EXCHANGE BETWEEN PARAGLIDERS AND LOCAL RESIDENTS?

Absolutely! There are great opportunities for collaboration and cultural exchange between paragliders and local residents. Paragliding enthusiasts can engage with the community through events, workshops, or even volunteer programs to share their passion for the sport while learning about the local culture and traditions. This kind of interaction can foster mutual understanding and appreciation, creating a positive impact on both groups.

3. Design process.

3.1 Specifications

The project's specifications are what will make the thinking and design process possible. Like every project or request of a product, there are some requirements and specifications wanted by the customer. Here, the main customer is Tobias as it was already expressed; and in the following lines will be the different specifications that he requested for the final product's design.

a) Towing winch with vehicle

The first aspect of the specifications is to be able to have a towing winch that can fit on a vehicle. Then the most important part would be the weight and space restrictions. Indeed, in order to fit on a vehicle, the final product needs to be the really light and less space taking possible. Other advantages about designing it the smallest possible would be the smart use of materials and budget. This, meaning, having only what is useful in those specific aspects. The goal during the design process is to have the smallest product possible in order to save space, but also choose materials that are the lightest possible for every part of our design.

b) Avoid using hydraulics systems.

Hydraulics systems in this project are not wanted because they are not that convenient. It can cause problems such as for the maintenance or even meanwhile using it. It was experienced with the one from the club about every slight problem occurring sometimes because of the hydraulics parts. Often, what can happen is the device getting dirty or being hard to maintain. For all these reasons, the specification is to avoid the use of hydraulics systems that we need to replace by something else, less inconvenient.

c) Combine two methods of launching.

Some designs already exist about the towing launch and the winching launch. But a better design and method is to combine both. Some of these designs also already exists but they are not answering every requirement from our customer and can be improved. This is mostly a design problem our thinking process must include for the final product. The combination must be the reflection of the ideal launching method. Of course, since some solutions already exists, there is a possibility to get ideas on how to improve it.

d) Be able to go up to at least one thousand metres high.

A factor for a good flight will be the time flying in the air and this mostly depends on the launching way. But one of the most crucial factors is the height the paraglider pilot is able to go while attached to the rope. And for that part, the specifications of the rope are the solutions needed to be answered. Some calculations and research are what will make us know what the figures about the length and the weight must be. This is a way to define the design of the drum since the drum is the main part that will support the rope.

e) Adaptability to any type of vehicle

The product in the process of designing need to be adaptable to every type of vehicle since it is still not known where it will be put for use. As an example, it was seen that in the club they are using either a snowmobile or an ATV. In the design, it must then include a way of fixing our product to any type of vehicle for any type of use. It means that the base where is placed the product must have a universal fixing way.

3.2 Solutions

3.2.1 General solutions

For this part of the solutions, the focus will be on the five specifications points made above and how the issues can be solved.

a) Towing winch with vehicle

The main idea of the towing winch is based on the drum where the rope will be wound. It will wind and unwind for every launch. The parameters and specifications of the drum are then, in fact, depending on the parameters of the rope. But the calculations were made as to have the smallest product and so drum possible. It is never useful to have a bigger design with too many materials or space. And as it was explained just above, space and weight must be saved up. One of the other features is the control of the unwinding by the brake to avoid getting the rope stuck or damaged. It is a safe way to control the modifications happening during and after the launch.

Lastly, as to save as much space as possible, the thought of having folding arms for the guider and the rope was considered. It would allow the final product to be more compact and convenient. This is why on the current design there are some parts represented below on the figures.

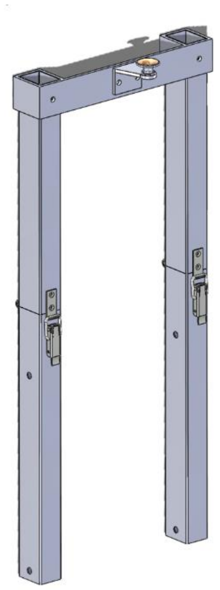


Figure 21: Guider arms and support.

The system is placed around the middle of the two arms aligned just above the central part of the drum. The system is done with two pieces on each side of each arm with the first ones being hinges and the other ones being toggle latches.

The opening of the arms will then be done towards the outside and resting on the motor and gearbox support parts. Hinges enable the moving and disassembling while the toggle latches enable the locking system for when using the winch.

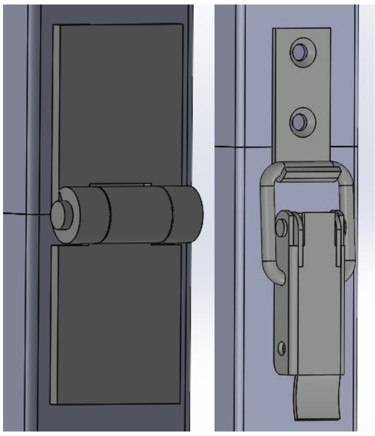


Figure 22: Hinges and toggle latches.

b) Avoid using hydraulics systems.

Hydraulics systems are not the best with these types of mechanical pieces. Here it was seen that it can cause some problems during use.

It is why, instead of hydraulics systems for this winch, were chosen electric systems for most of it.

One of the main reasons for choosing electric systems and actuators is because we are more familiarised with them, and we feel like they are simpler to manage and to adjust. Also, they allow the possibility of tweaking them during working.

c) Combine two methods of launching.

We managed to combine both methods of launching by using an electric motor with enough power to withstand the most demanding situation, which is the winching launch. This way, with the help of the electronics control and the motor controller we can choose the amount of power that the motor will deliver in each moment.

d) Be able to go up to at least one thousand metres high.

The ability for the paraglider pilot to go to at least one thousand metres high depends on the rope length. After some calculations, it was determined that for the goal of the height to be attained, the rope needs to be of at least 1750 metres long. Then, the drum needs to be adapted to this specification of the rope. The size of the drum was calculated and chosen after defining the parameters of the rope while keeping a security factor. As for the general design of the drum it is kept simple, but a more detailed explanation will be done in the further parts.

e) Adaptability to any type of vehicle

One of the main problems with suggesting a design is the adaptability of it. Here with this product, it needs to be mountable to any type of vehicle since it is not known how it will be used. The solution provided is to have a base plate where the winch is taking place, and this base plate is designed to fit a universal mount in order to be able to be fixed anywhere.

3.2.2 Parawinch guider design

Initially, for the design of the guider of the rope, the thought was to take a lot of ideas from the Parawinch design already existing that can be seen in the figure opposite. This design incorporates a system with a pulley where the rope is guided from the paraglider into the drum. It is a system allowing not too much friction with the aim of not damaging the rope. This being why the initial plan was to use the same idea with a pulley but having only two side steel plates to maintain it in place. The axle would have a role of a pivot since the rope would not come every time from the same direction.

Figure 23: Parawinch guider.

3.3 Design

3.3.1 The Drum

What we call the drum is the part that will hold the rope at all times. This specific part has to be sturdy enough and resistant to high forces applied to it. The design of this feature has been the first thing done in terms of drawing.

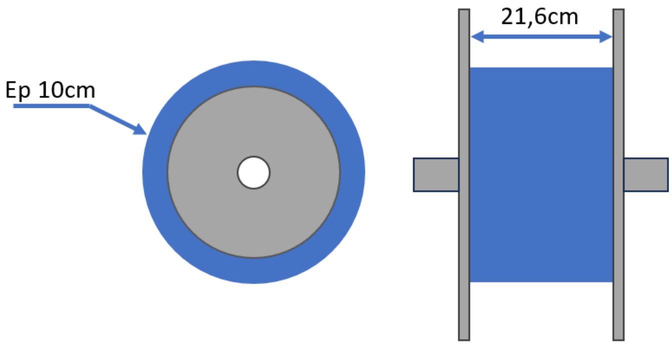


Figure 24: Drum dimensions.

The goal of this part is to take as little space as possible since it is the most massive of the whole winch. Through some calculations involving the width and the length of the rope, we determined specific dimensions for the drum that you can see above.

Now that the dimensions are dealt with, we needed to cope with the design itself and make sure that it is achievable.

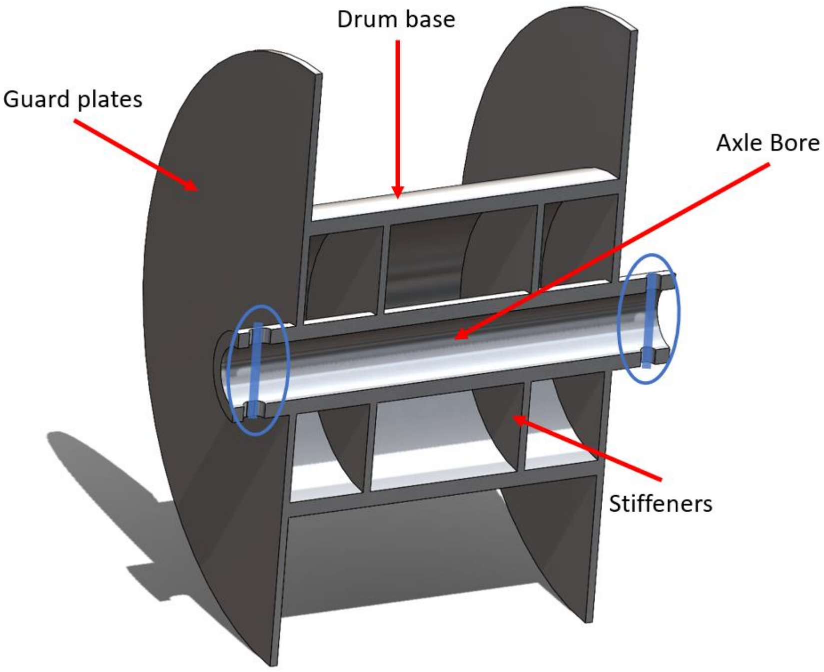


Figure 25: Drum section.

The drum is composed of four distinct parts, six in total but two are mirrored. Firstly, the Axle Bore, this part is made out of an aluminium tube with an inner diameter of 40 mm. The Drum base will also be made out of an aluminium tube with an external diameter of 200 mm. To centre the Axle Bore and make sure that the assembly is sturdy enough, two circular plates have been added as Stiffeners. And finally, to make sure that the rope does not slip out of the drum, some guard plates have been added.

On the Axle Bore, you can see two pairs of holes circled in blue at both ends of the tube. These are meant to interlock the axle in place using two aluminium pins schemed in transparent blue in the image above. One of the holes has been made oblong so that when mounting the axle in, we avoid having alignment issues caused by trying to block a degree of freedom too many times making it not isostatic. Thicknesses are 5 mm for the Guards and the Stiffeners and 10 mm for the Bore and Base.

3.3.2 The Frame

The Frame is the second part that has been designed for this project, as it is the part that will hold the whole Drum and the whole assembly. This frame has been undergoing some serious design changes throughout the whole drawing phase and it resulted in a second version being made. We will present both versions with each one's pros and cons.

- First design:

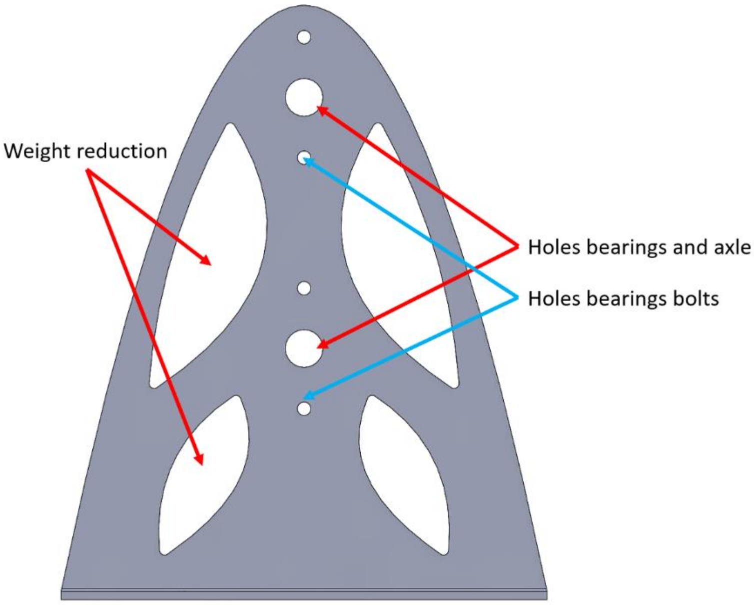


Figure 26: First frame.

This first design was made to be symmetrical, so it requires less machinery and reduces costs. As you can see on the image above, holes for bearings have been made on the same line vertically, this was to make use of the particularly good force distribution of this specific design, making a "spine."

The plate has been trimmed out of the useless matter for the structural strength of the assembly, making these weight reduction pockets. This plate is 10 cm thick and made out of aluminium.

- Final design:

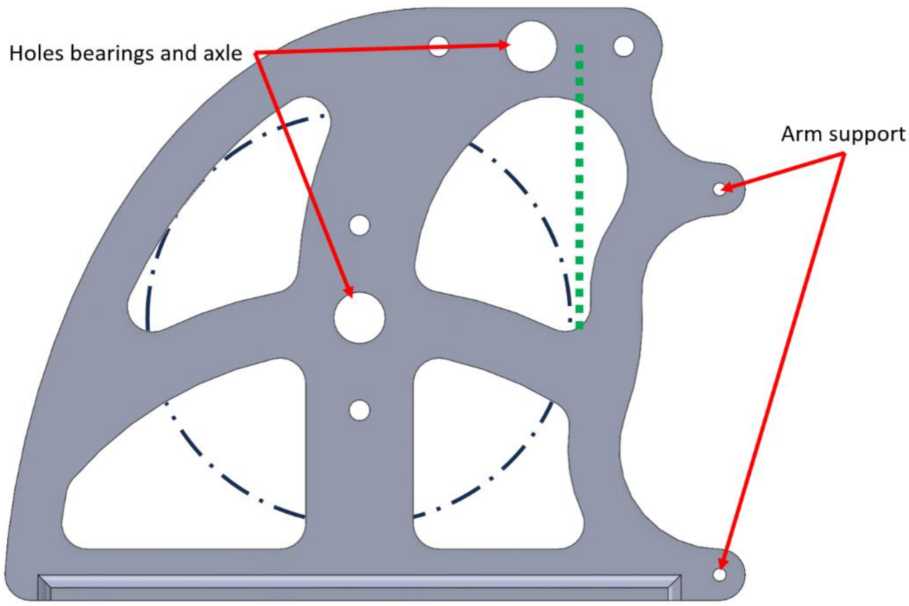


Figure 27: Final frame.

The final design bears some visible changes from the last one. Firstly, the vertical “spine” design has been set aside because of the rope placement. The upper bearing hole, which is going to hold the Guider Axle, is now aligned with the drum that is represented by the dots and dashes in blue. This was made so that the rope, green dots line, would not induce unnecessary forces into the axle and the frame making the whole thing more complicated and prone to failure. Instead, this design also allowed us to implement some mounting holes here marked as Arm support for the Guide that will be detailed further into the report. Same as the old design, weight reduction pockets have been cut to make the whole assembly lighter. The plate is also of similar thickness and material.

3.3.3 The Drum/Frame interface

The Drum/Frame interface will describe how the Drum is linked to the frame. This part is really important since it is the point of convergence of all the forces applied to the Drum.

- Main Axle

The Main Axle is the 40 mm diameter aluminium axle that will hold the drum and deliver or receive the forces from the rest of the assembly. This axle will also supply movement to all the other parts of the assembly, so it requires special machining.

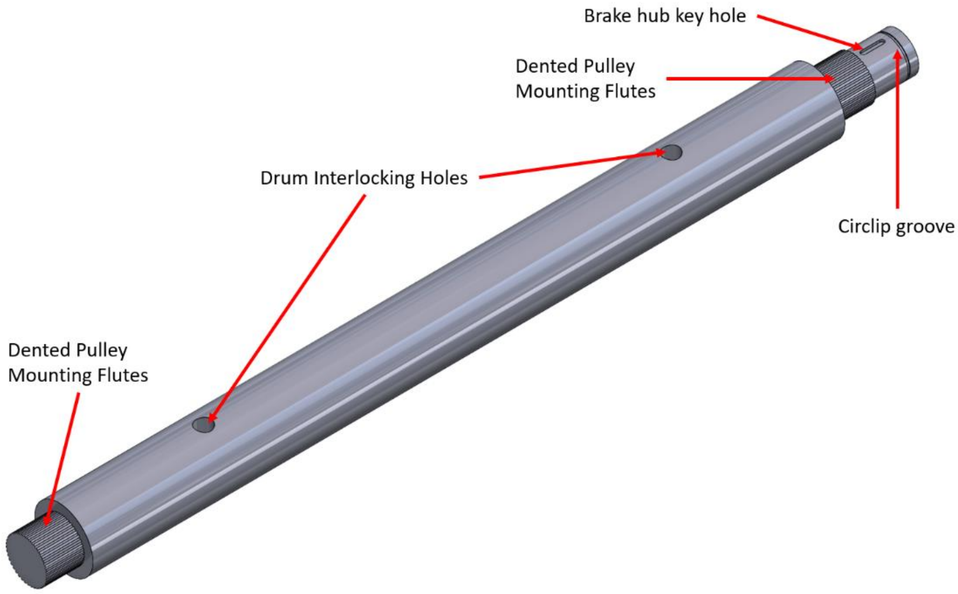


Figure 28: Main axle.

On the image above, we can first notice the Drum interlocking holes. These are the holes that the Interlocking pins will pass through. These are both regular drill holes since they are the ones deciding the placement.

On both outward sides of these holes, we find a patch of smooth surface, these will be held by a Flat Bearing, detailed just after.

Next to it, we can see the Flutes on the axle, these will have the role to interlock the pulleys to the axle. One each side, the closest one being for the Electric Motor drivetrain and the furthest for the Guide Axle drivetrain.

And last but not least, on the furthest end of the axle, there is a keyhole for the Brake Hub and a Circlip Groove. These will suppress the Brake Hubs degrees of freedom and embed it to the Main Axle.

- Flat Bearing

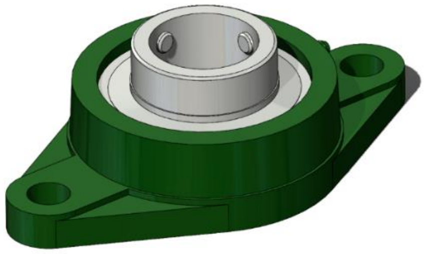


Figure 29: Flat bearing.

The Flat Bearing will hold the axle in the Frame with the benefit of limiting as much as possible the friction. This will make the drum spin freely and not wear down any important and expensive machined part. They are the same that will be used to hold the Guide Axle.

3.3.4 The Arm Assembly

What we call here the Arm Assembly is the assembly that will hold the guider part, which job is to guide the rope into the Guide.

- The Arms

The Arms are made out of hollow rectangular aluminium beams. They will hold the Funnel Support.

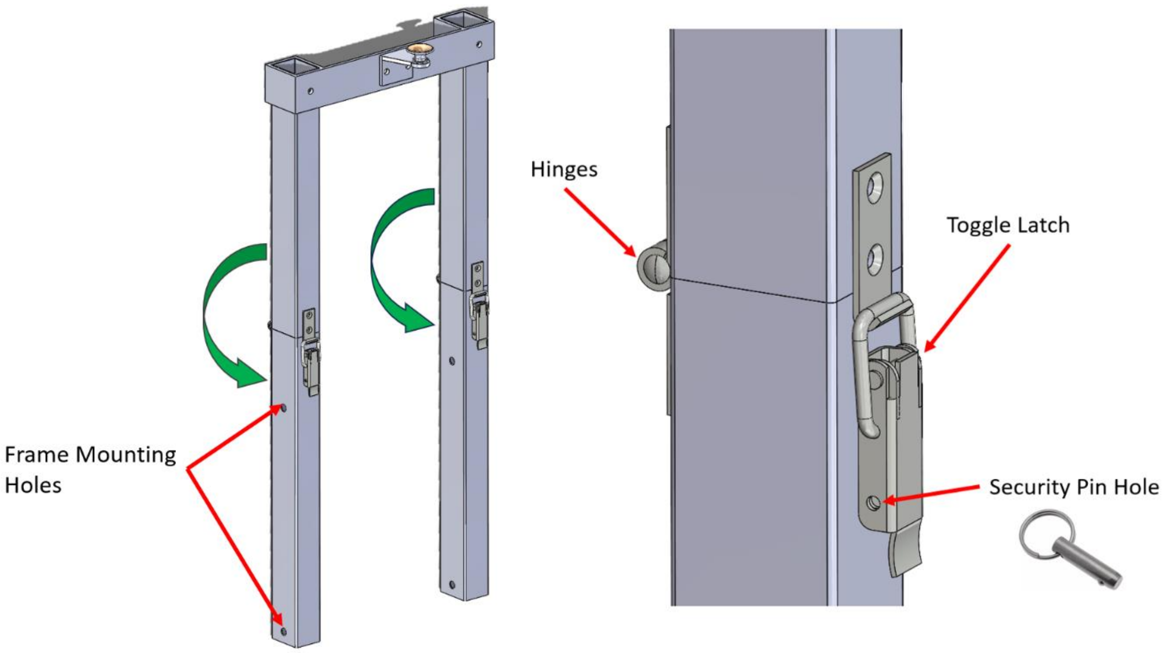


Figure 30: Final arm assembly.

This assembly is pretty simple, it features a fold point, to save space when handling and store the device when it is not in use. This allows us to save space, and also acts as a “fuse part,” a part that in case of failure, will break separately.

To lock the arms in place, we use a toggle latch that can be locked with a security pin to avoid any problems with vibrations causing it to open.

Figure 31: Inner reinforcement tube.

And lastly, to hold the arms straight, an aluminium tube stiffener can be fitted down the arms tube, overlapping the pivot point and thus, keeping the assembly in place.

- The Guider (first design)

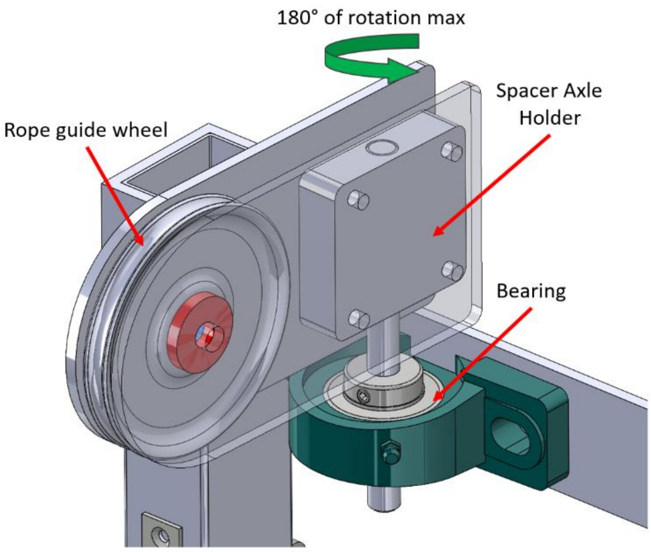


Figure 32: First guider design.

This design was inspired from a solution used in an existing winch, as said in the previous section. We modified it so it would not be blatant plagiarism. This solution is made out of five parts.

First, we have the guide wheel, which is going to hold the rope and make it wind up without friction. This wheel is held by an axle and centred using two spacers that you can see in red on the image above.

Two 5 mm thick aluminium plates hold the axle and cover everything from exterior access. These plates are also held together by a bigger spacer in grey, which is also going to hold the pivoting axle.

This axle is coming straight down into a bearing allowing it to swing from side to side following the direction of the rope with a maximum rotation angle of 180°. This specific feature made it unfit for our purpose because one of the rewards of having a full 360-angle capability is that you can reel the rope back, while driving back to the launch site. This means that the rope would overrun the 180° allowed here by this specific design.

- The Funnel (second design)

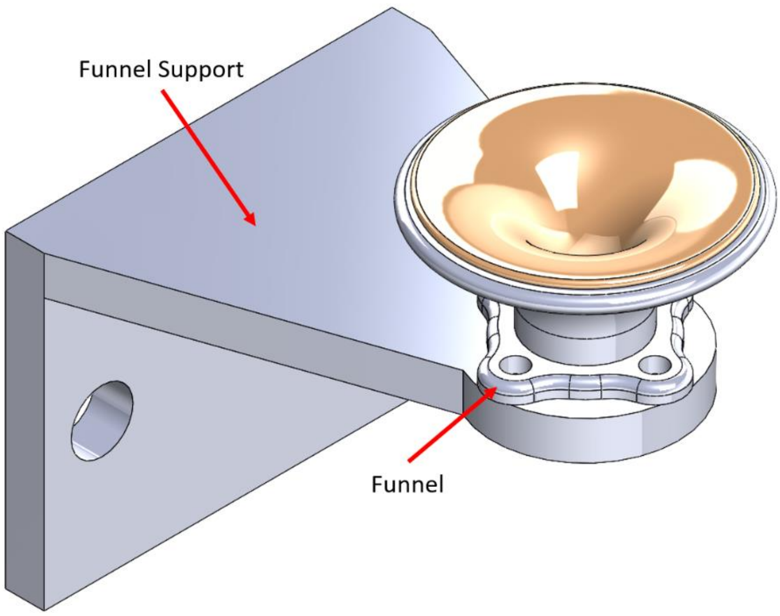


Figure 33: Second guider design.

This second design is using the principle of a funnel. It is a design that will increase the wear on the rope by a little because it has no moving part allowing the rope to avoid friction, though it has a feature allowing this to be a lesser risk.

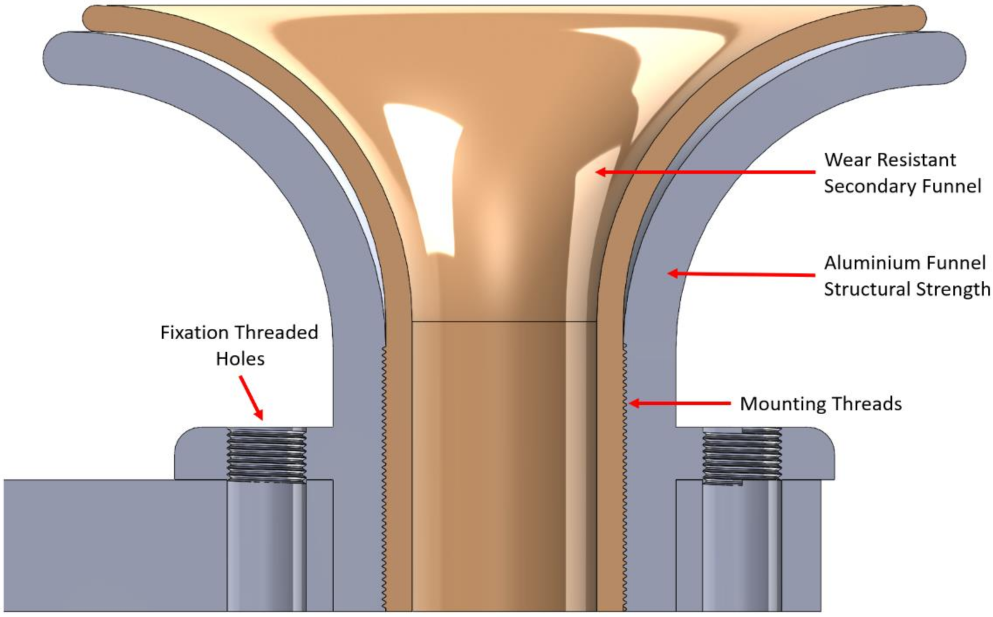


Figure 34: Funnel detail.

This funnel is composed of three main parts, first the support that you can see in the generic view above, then the first and second funnels.

The role of the first funnel, which is the one made out of aluminium, is going to be to give structural strength to the assembly. It is going to be fixed in place in the support with bolts that will screw in the four threaded holes on the sides.

The second funnel is going to be made out of a low-friction material. It will be less expensive than the aluminium variant used for the structure. This funnel will be interchangeable due to the fact that it is a bolt-on assembly. Once a secondary funnel is worn down, just unscrew it and replace it with a new one. This allows us to save on materials and machining costs.

Both parts should be feasible using Additive Layer Manufacturing, and extraordinarily little machining to achieve acceptable precision for the bores.

- The Ring (last design)

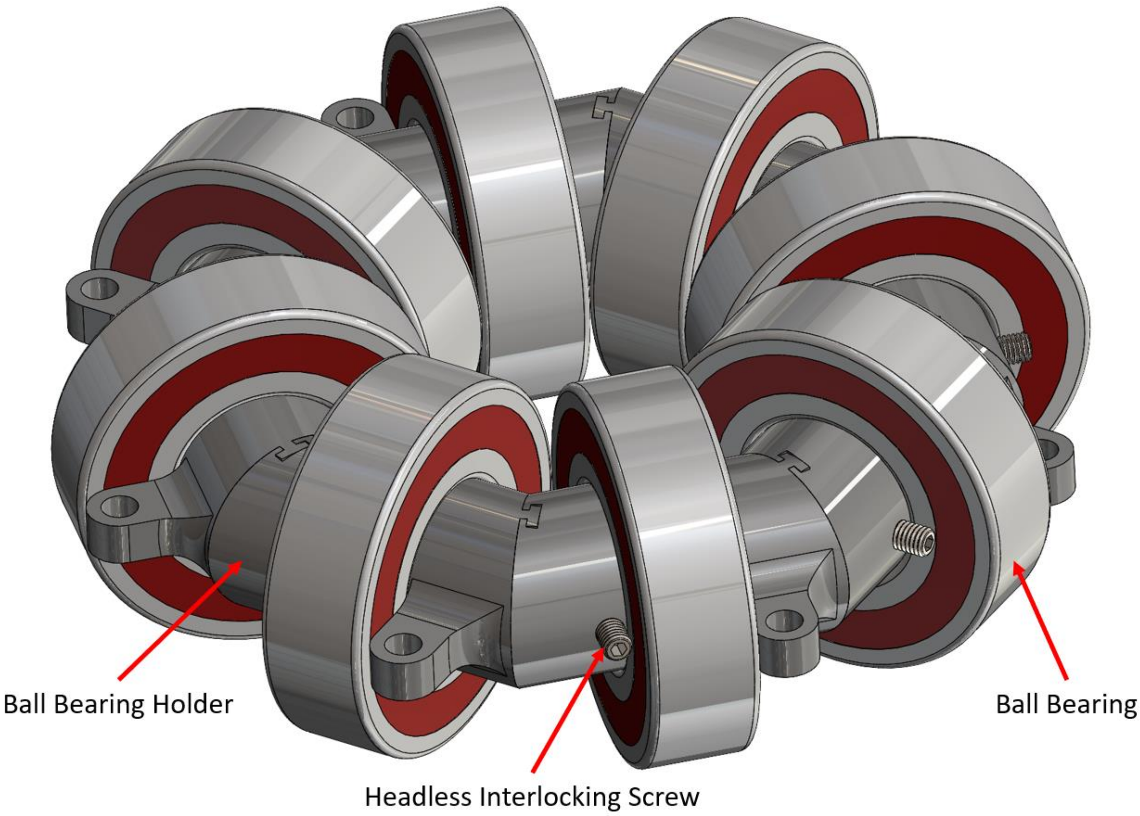


Figure 35: Final guider design.

This final design is using the same principle as the Funnel presented just above, only this time, the use of ball bearings, gets rid of the friction problematic.

This assembly is composed of eight identical parts interlocked in a circular pattern to recreate the funnel guiding properties.

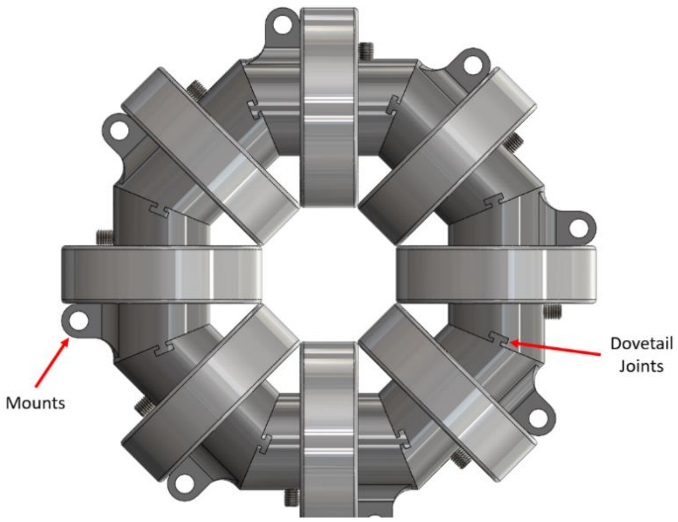


Figure 36: Ring top view.

On the image just above, you can see the eight parts more clearly. Each part has mounting holes for a tailor-made bracket that is going to hold it in place on the arm assembly. More details in the following view:

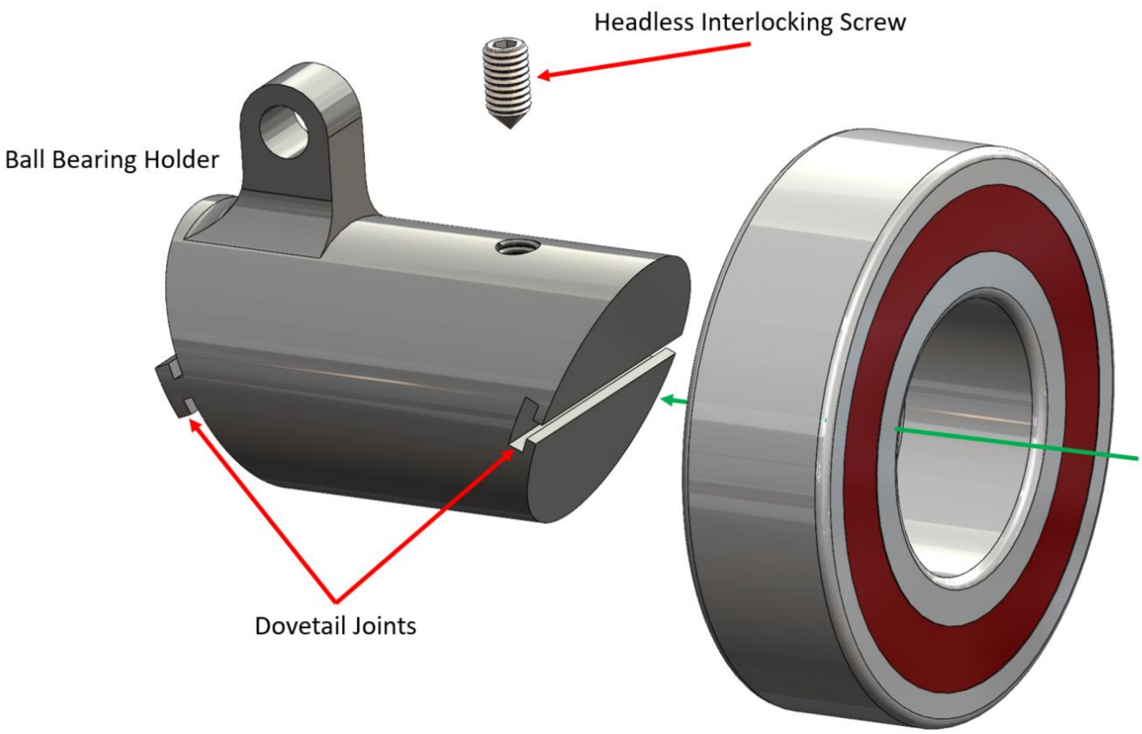


Figure 37: Ring detail.

You can see here how the bearing is going to be held in place. It will firstly come to rest on the flat face of the mounts. Once in place, we suppress the remaining degree of liberty by screwing the headless interlocking screw in its place, locking the ball bearing on the Holder.

These Ball Bearing Holders will come together to form the Ring using dovetail joints. They will be inserted along the line of the joints and held in place by the bracket.

3.3.5 The Guide

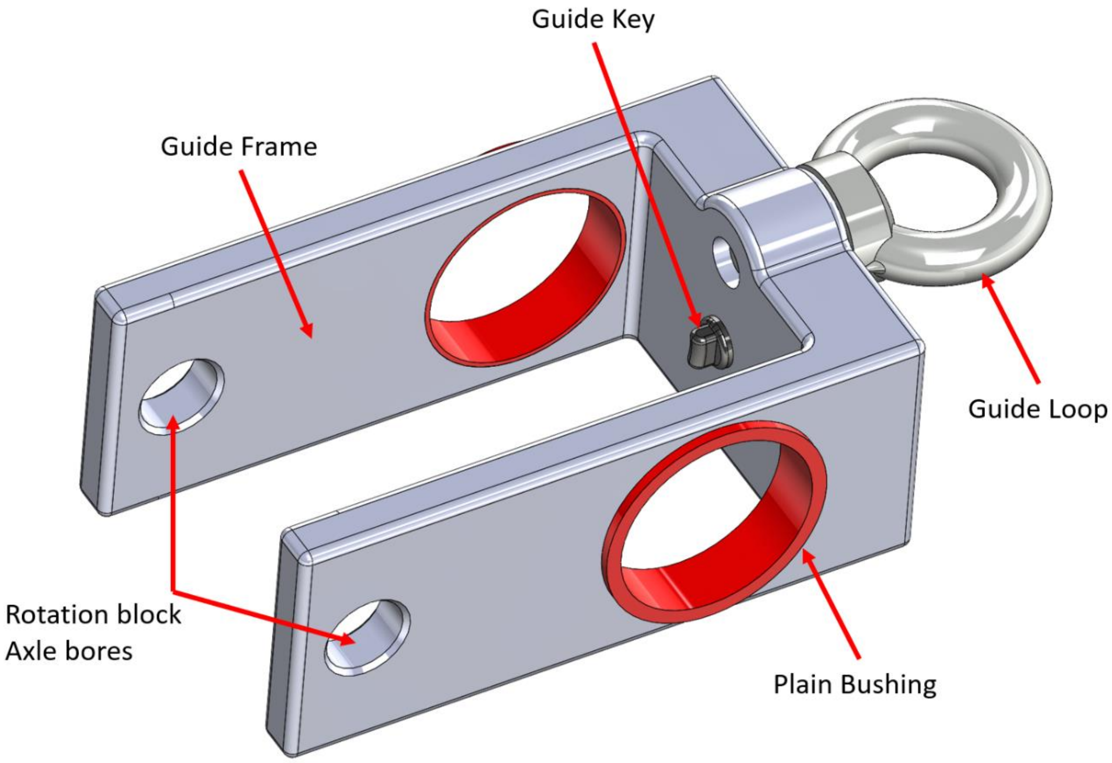


Figure 38: Guider view.

The Guide has a crucial role in this assembly. It is here to ensure that the rope is winding up perfectly onto the drum, thus not exceeding the maximum diameter set for the design of the drum. This part has to be sturdy enough to guide the rope onto the drum while it is under tension.

On the view above, we can firstly see two plain bushings in red. The role of these bushings is to let the Guide slide effortlessly on the Guide Axle. They are made to reduce friction and are able to preserve the Guide Frame which is much more expensive.

To avoid the whole Guide spinning around the axle, we added bores for another axle, making it impossible for it to pivot around the Guide Axle. This Secondary Axle will also function as a fixation for the bearings of the Guide Axle. This one does not need Bushings as it is not needed for the guiding function. In fact, the axle can even be slightly smaller in diameter than the bores that it would not change anything to how well the Guide works.

The Guide Loop is going to guide the rope onto the Drum, it is a regular lifting ring that is going to be screwed into the Guide Frame. It was the simplest and most inexpensive solution for this purpose.

The last and most important feature of this design is the Guide Key. This Guide Key is the part that will allow the Guide to go back and forth along the Guide Axle. This key can Pivot around its axle of revolution making possible for it to follow the tailor-made helicoidal grooves on the Guide Axle.

Here in this sectional view of the Guide Frame, you can see how the Guide Key is working. To mount the Key inside the assembly, just slide it in its bore. Once done, make sure that the key is inside or the helicoidal groove mentioned earlier on the Guide Axle. To lock the key in place, screw the Key Cap in, its length is just a little bit longer than necessary making it possible to have a tight and secure fit of the key.

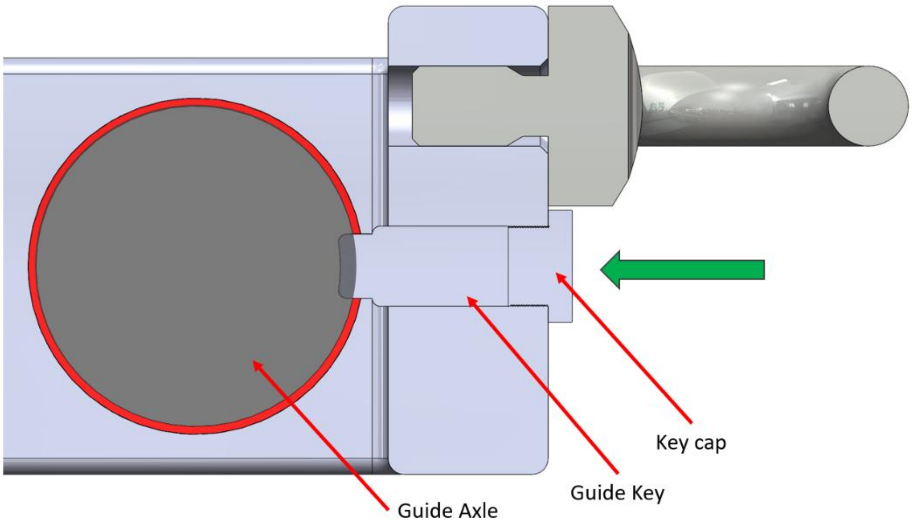


Figure 39: Guider detail.

This last illustration shows the Guide in place in the assembly. It will move along the line of the axle, as shown by the green arrow. Here you can see the helicoidal grooves machined in the Guide Axle.

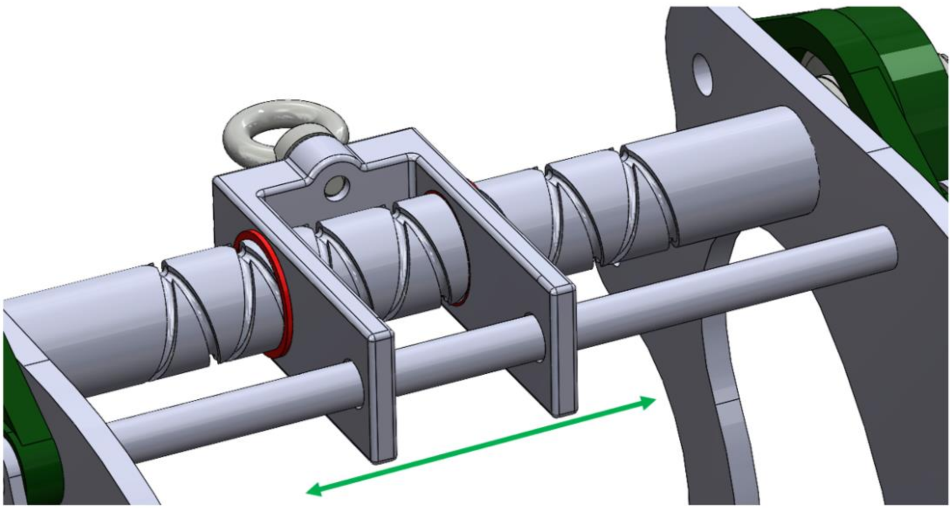


Figure 40: Guider in the final assembly.

3.3.6 The Guide Axle

The Guide Axle is the part that will allow the Guide to direct the rope perfectly on the drum when winding it back.

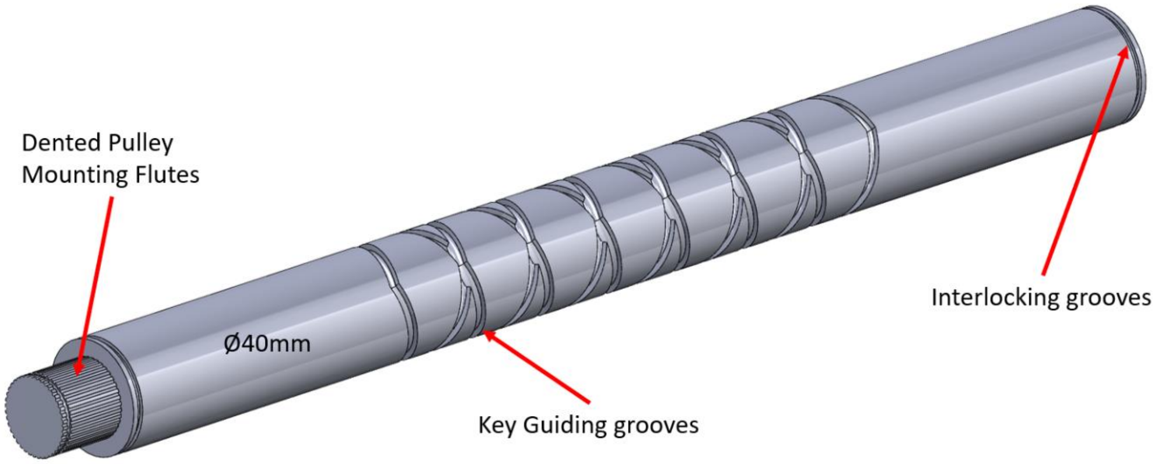


Figure 41: Guider axle detail.

This axle is made of aluminium as well and has a diameter of 40 mm to use the same bearings as the Main Axle.

The main feature of the axle is the helicoidal groove that coils around the axle, one way and back. This allows us to transform a rotation movement into a linear movement easily. The axle will be held in place by circlips on each end of the 40 mm diameter.

The axle shoulders on the left side is made to hold the dented pulley connected to the Main Axle. It has machined flutes to hold the pulley in place. And to make sure that the pulley does not slip, another circlip is holding it in place.

3.3.7 The Disc Brake Assembly

This assembly is here to ensure good and easy to control braking force for the drum. It is the simplest design of the assembly, as it is the same as on a regular mountain bike.

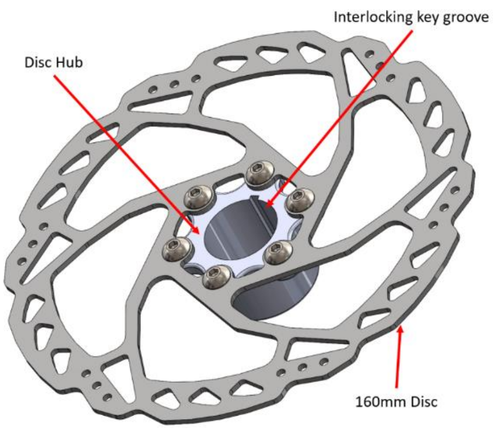


Figure 42: Disc brake assembly 1.

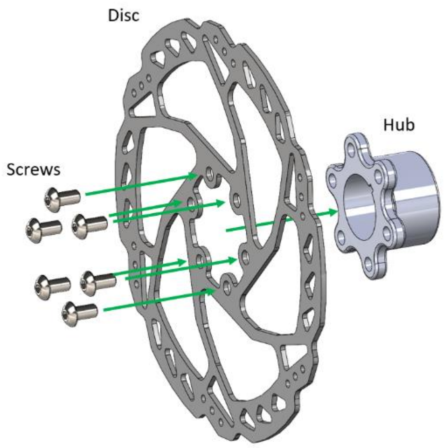


Figure 43: Disc brake assembly 2.

The disc brake is going to be mounted on a Hub similar to what you would find on a mountain bike. This hub is made to fit the Main Axle, and you can see the Interlocking Key groove that is going to hold it in place and allow it to transmit the brake force to the Drum.

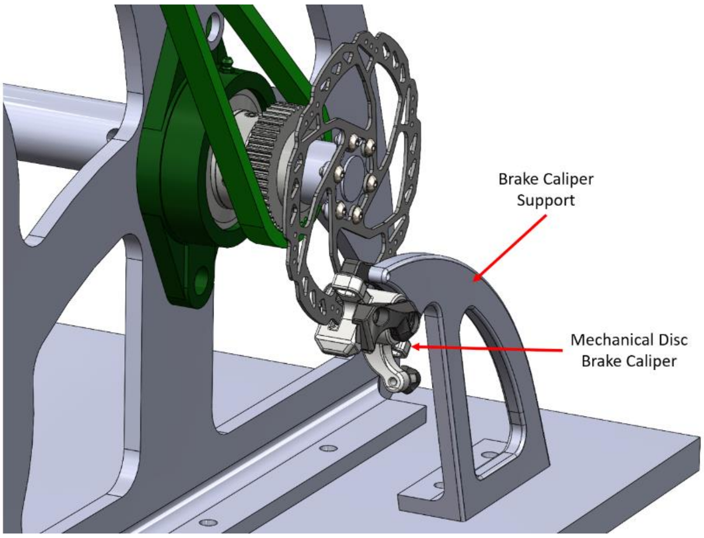


Figure 44: Brake mounted in the assembly.

The mechanical brake calliper which is going to be actuated by a cable pulled by a servomotor is mounted on a tailor-made support. This support can either be CNC machined out of a plate of aluminium or 3D printed using Additive Layer Manufacturing techniques. It is designed to withstand the tangent forces induced by braking.

3.3.8 The Motor & Gearbox Assembly

The Motor & Gearbox Assembly as its name suggest is going to connect the motor to the drum. Since the motor we chose has a high rotation speed, we needed to lower it in order for it to be regulated more easily. After some calculations done with a software that will be detailed later on, we used a planetary gearbox with a gearing ratio of 15:1, which means that the gearbox output shaft will spin fifteen times slower than the motor output shaft.

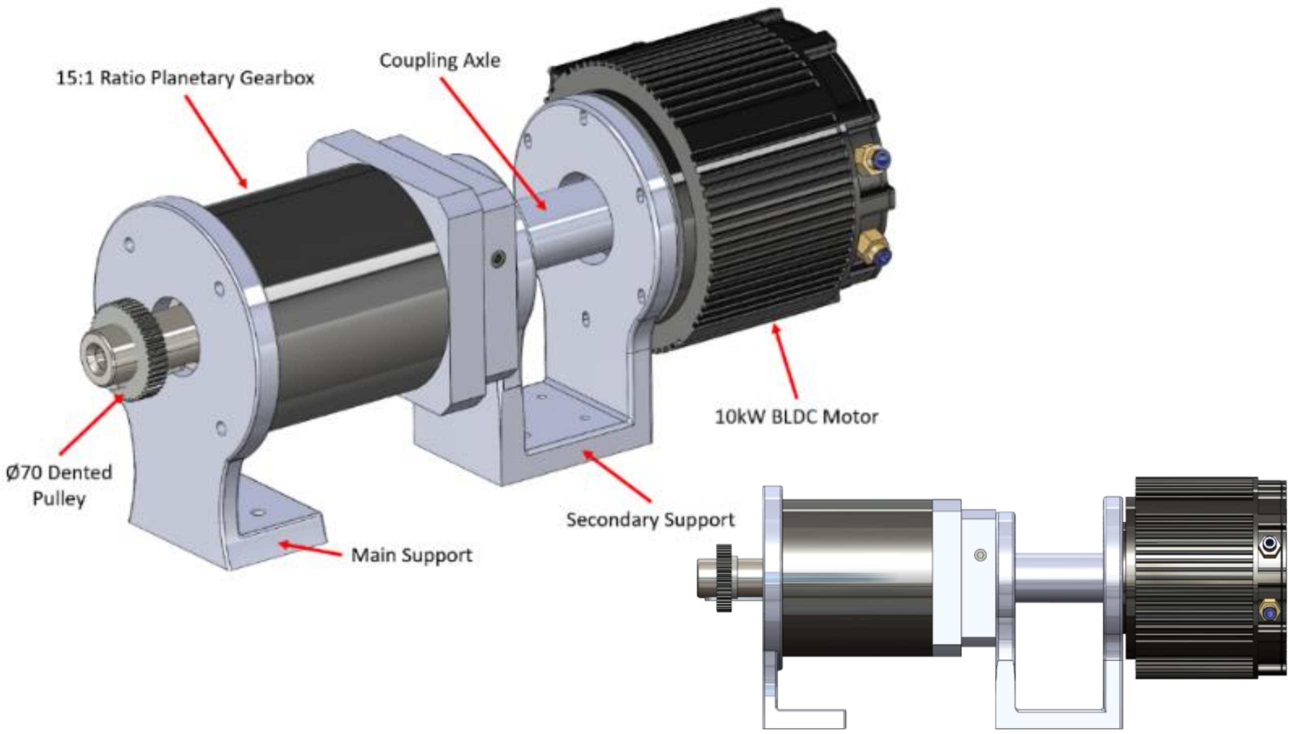


Figure 45: Motor and gearbox assembly.

In the image just above, you can see the full assembly. The Main support is holding the gearbox, closest to its output shaft since it is the point where most of the torque will be, thus needing to be fixed in place. The secondary support is here just to support the weight of the whole assembly and aligning the gearbox and motor.

Since the motor and the gearbox have different specifications, the motor output shaft did not fit in the input bore of the gearbox. We then had to design a small coupling axle to link the two together and ensure good power transmission.

The secondary support holes for fixing the motor and the gearbox are oblong so that it does not over constrain the assembly by blocking a degree of liberty more than once. This support is only made to stabilise and centre the assembly.

3.3.9 The Pulleys and Belts

The pulleys and belts are the most important part of this assembly because they are what allows for the power to be transmitted to the assembly, thus allowing it to fulfil its requirements.

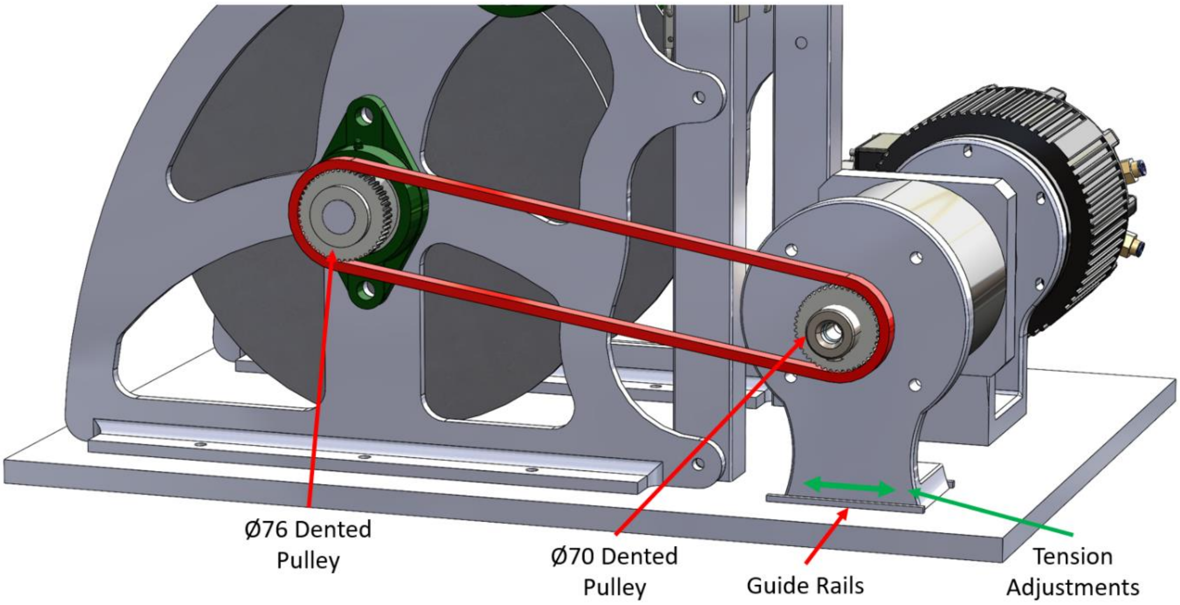


Figure 46: Main transmission belt.

On this illustration just above, you can see the belt in red. Two pulleys are used, they will be re-machined to fit the Flutes of the Main Axle and the output shaft of the gearbox.

As you know, belts are not like chains, you cannot shorten it on command just by removing links. Belts have to be under constant tension to ensure that they do not slip. They have to be the perfect length, and so to mount them in place, you have to reduce the centre distance between the pulleys. On our design, this is made by using oblong fixation holes in the Base

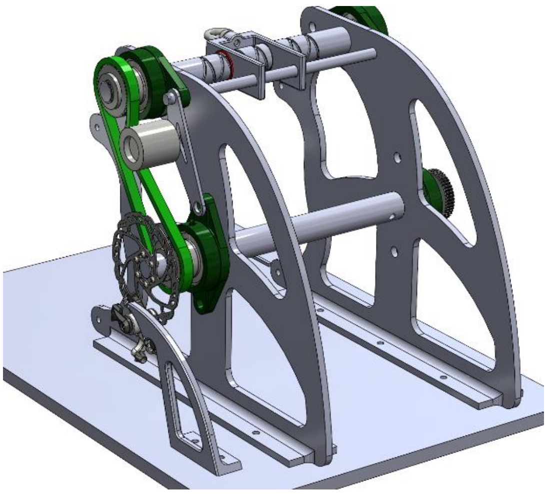


Figure 47: Belt assembly.

Plate and guide rails to keep the support straight while increasing the centre distance to stretch the belt.

This Second belt is going to transmit power to the Guide Axle in order for the Guide to lay the rope properly on the drum. In this case, the centre distance cannot be adjusted due to the axle being fixed to the Frame.

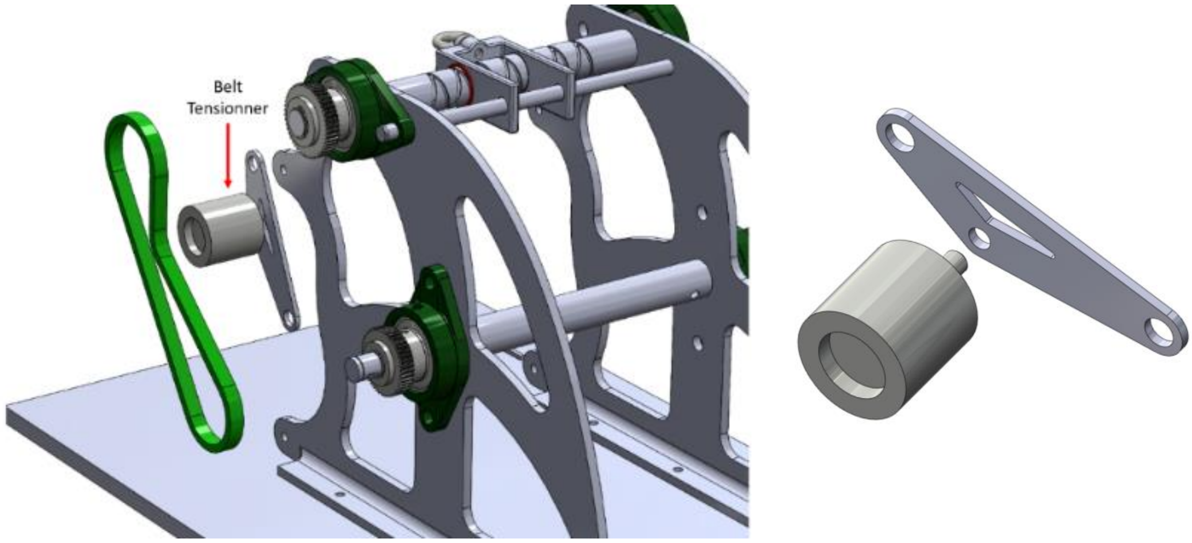


Figure 48: Guide belt & belt tensioner.

Because of this, the only other way to stretch out the belt onto the pulleys is to use a Belt Tensioner. What this does is that it is going to apply pressure directed inward on the belt to put it under tension. The Tensioner is composed of just a wheel on bearings, and a frame that is going to be mounted using the fixation bores of the Flat Bearings in green in the illustration above. And lastly, the size of the pulleys will depend on the ratio we want for the Guide Axle, and also, the pitch of the helicoidal groove on the said axle. Some further testing might be necessary to find the optimal combination.

4. Final choices and designs

As a recap of the midterm report and the research made for it, here are the final choices of materials and features we decided on. Firstly, the material chosen for the rope is the HMPE (high-modulus-polyethylene), a synthetic material with a yield strength of 2.4 GPa and the density of 0.97 g/cm^3. The rope would need to be at least 1750 m long and have a diameter of 3 mm.

Now, after the latest part of the design, following is the final choices about the mechanical design and how we came to have this type of design.

4.1 Mechanical design

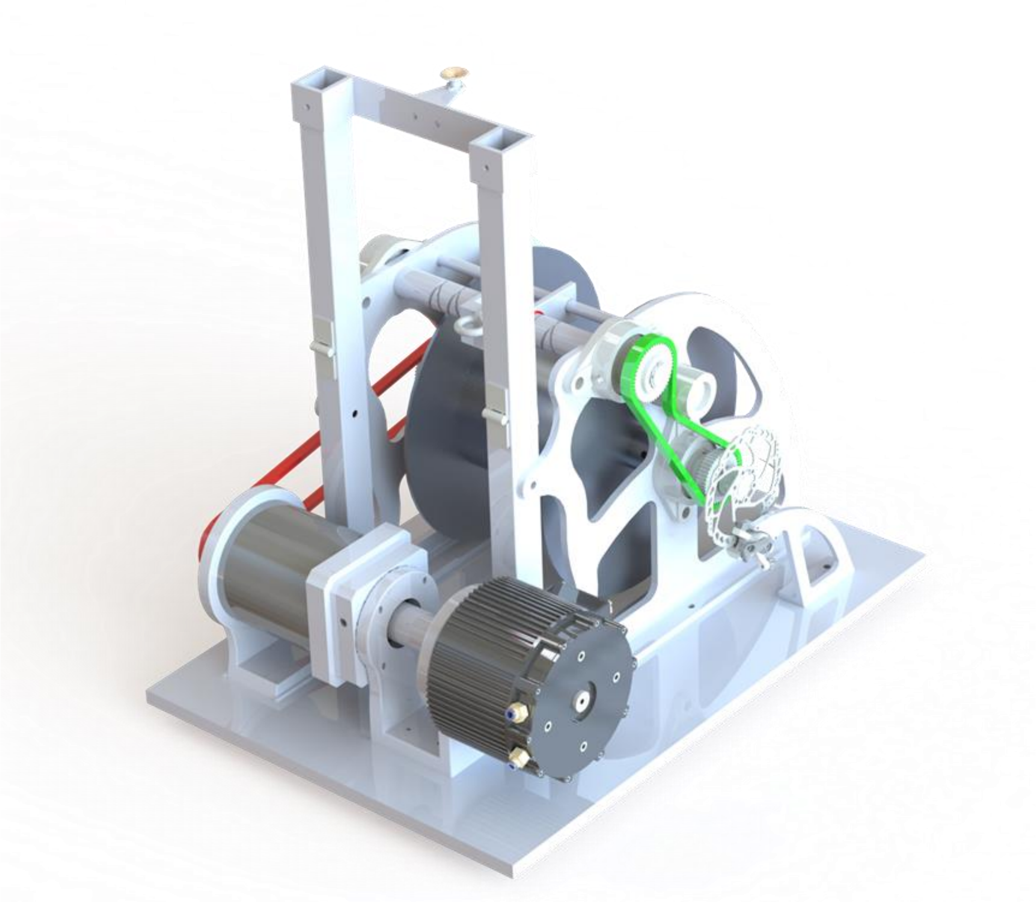


Figure 49: Final assembly.

As seen on the figure above, it is the final design our team is suggesting for this CombiWinch project. It evolved a lot during the multiple meetings and the feedback we had to get we have now.

In the same way it was explained just before, we changed the frames to allow the support of both arms while keeping a protective frame fitting every bearing support for the pulleys and axles. It led to a change in the way the arms would be folding. In fact, first the arms were folding only for a small upper part, but we could change it to fold it in the middle. That way, the closed product is more compact for transportation and also safer because avoiding any damage as much as possible.

Regarding the guider, the design also changed in the end because of a problem of needing the rope to be coming from every direction. The thought was that this design would be the best out of the two we had in mind. The advantage being the plastic funnel which is replaceable when wearing out. The rope would be guided through this funnel and into the ring to go on the drum and being well distributed thanks to the guiding axle and support.

On the foreground of the figure, it is possible to see the motor and gearbox. It is carrying the belts and pulleys for the whole working and controlling of the winch. There are two supports where they are resting and fixed in place. An adapting coupling axle was needed since the motor and gearbox do not have the same axle dimensions.

4.2 Actuators selection

An electric motor was selected as the actuator for the device, as it is really simple to operate, and it allows us to use the e-brake feature when operating the device.

Among the diverse types of motors that could be used, we finally decided to use a BLDC type motor, as it works with DC current (the one available in the batteries) and it has a really good relation between power output, price, and size. They also do not need huge voltages to operate, as they normally work between 48 and 96 volts.

In order to use these types of motors, we will need to use an electronic controller, which will receive the input from another device, and will operate the motor from the battery. It will also log data into its internal memory and will give the possibility of modifying some values in order to change the behaviour of the motor.

From what we obtained from the calculations; we know that we need a motor of at least 10 kW of output power. After looking on the internet for some options that may cover our needs, we found two options:

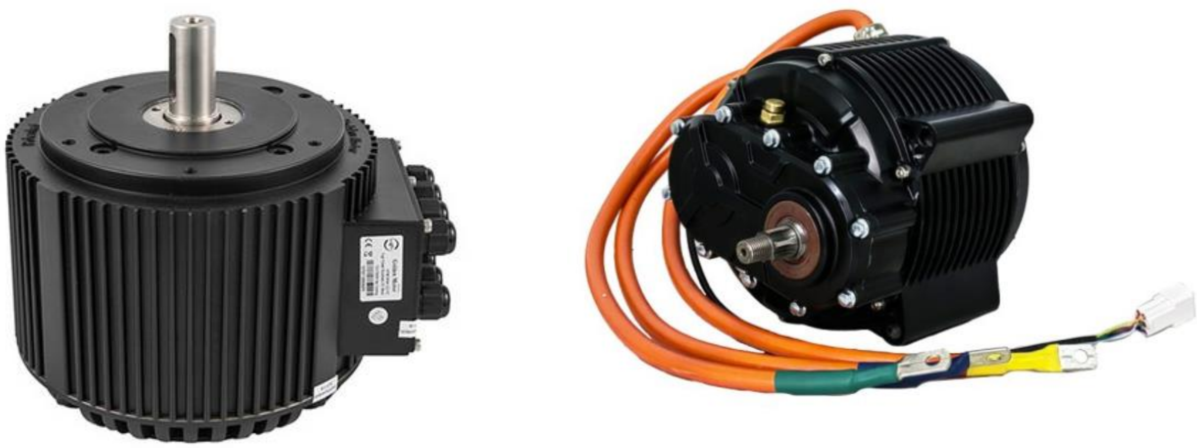


Figure 50: BLDC motors.

The picture on the left shows one of the options that suits our needs. It is the golden motor HPM-10Kw, from the brand “golden motor”. As the name suggests, it can deliver up to around 10 kW of power while having a restrained weight of 17 kg. The picture on the right shows the other option we found, the QSMOTOR QSJ165B-60, which can deliver a bit more than 10 kW. The key point of the QSMOTOR is that it integrates a gearbox that lowers down the speed of the shaft by a relation of 2.37:1.

The power and data curves for both motors are shown below:

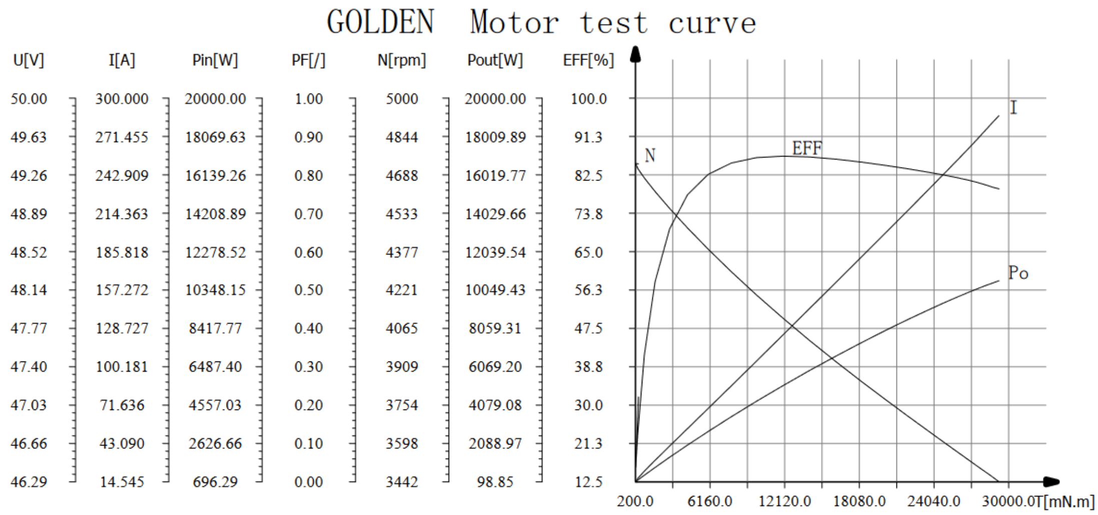


Figure 51: HPM-10kW power curves.

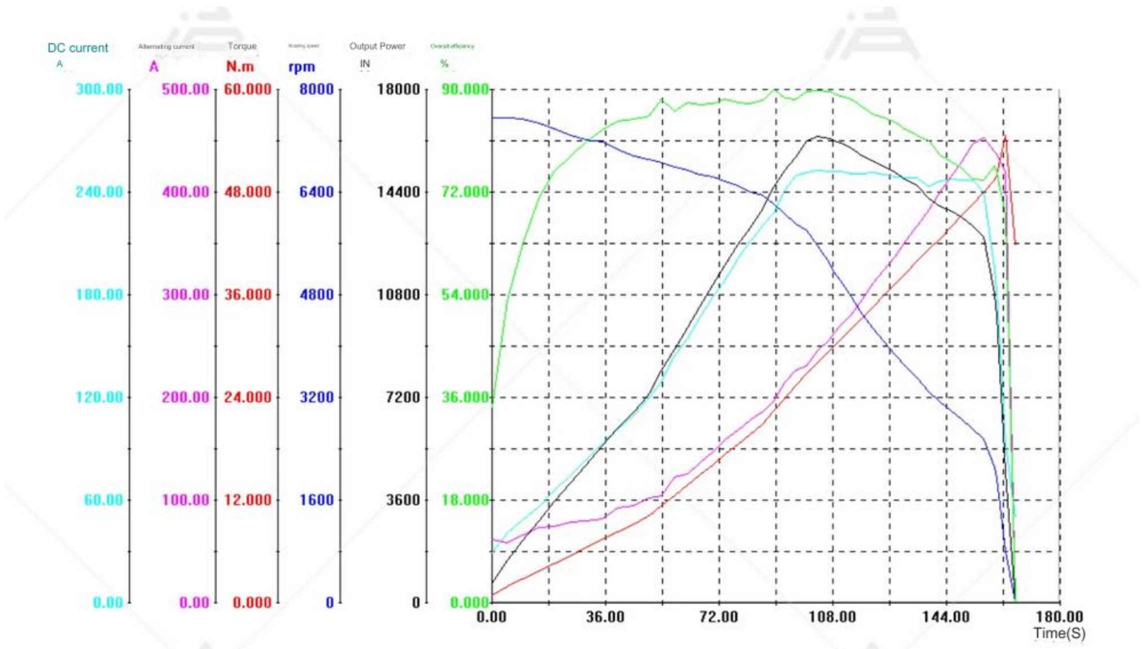


Figure 52: QSJ165B-60 power curves.

The first curves are the ones extracted from the golden motors one, while the second ones are from the QSMOTOR. As it can be seen, the second motor can give more power than the first one, but as both of them can reach around 10 kW of output power, we do not need to focus that much on the maximum output. The torque levels of both of the motors are similar, so this will not be a key point to decide which one we will use. Instead, we will focus on the rotation speed of the motor. As the device will be attached to the pilot, we do not need big rotation speeds, as it can be dangerous. Instead, we will need to use some type of transmission that will take down this speed. We will then use the golden motor one, as it is cheaper than the other one, and, as we will need a transmission in both cases, the integrated gearbox of the motor is not a key point for the decision.

To control the motor, we will use the controller recommended by the manufacturer. This model is also from golden motor, which means that the compatibility between the motor and the controller will be guaranteed. The model we will use is the VEC500-48, which uses field-orientated control to maximise the efficiency and power output of BLDC motors. Some of its benefits include low noise, as we can achieve smoother torque output, meaning that there will not be much noise caused by the fluctuation of torque. It also allows us to programme it "on-site," in order to change some parameters about the motor behaviour. Finally, it also allows us to use motor braking, as well as including many self-checking functions to increase safety.

It also features a heat sink in the bottom to help cool down all the internal electronics, allowing for better performance, and extended use life.

Figure 53: VEC500-48 BLDC motor controller.

4.3 Transmission systems

In order to assure the safety of the pilot, we need to control the speed of the drum and reduce it in comparison to the speed of the motor. For the motor, we have a nominal speed between 2000 and 6000 rpm, but we will move between 2000 and 3500, as that is the range where we will achieve and ideal value of torque and power according to the motor data.

To select the appropriate gearbox, we have used a programme from the manufacturer Neugart, that allows you to simulate the whole construction from the motor to the output. This software is called NCP, and the interface is the one shown below:

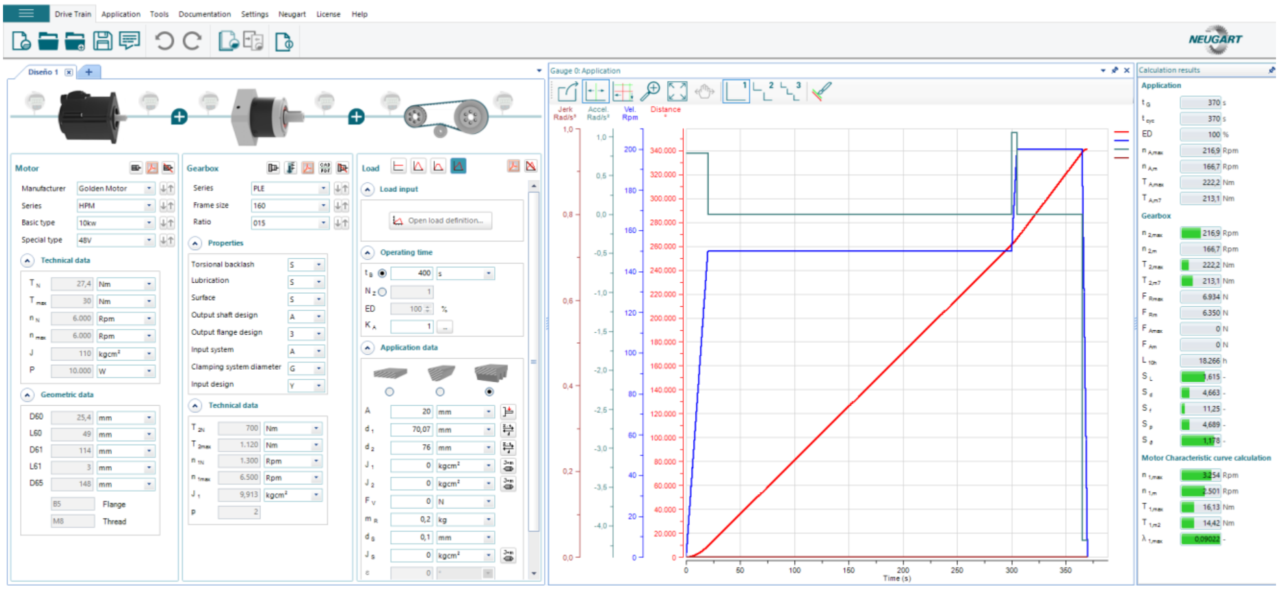
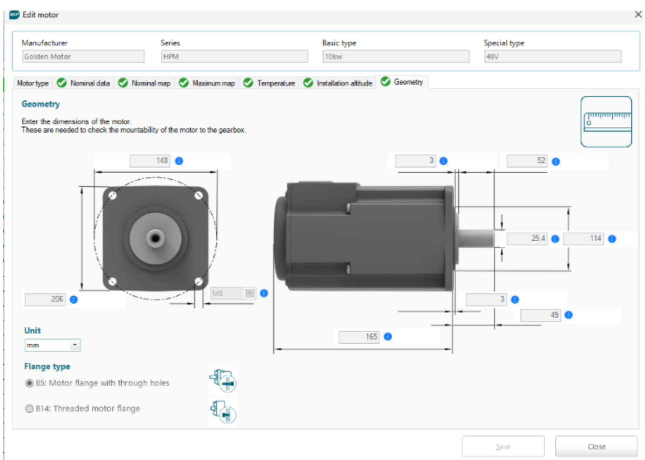


Figure 54: Neugart software interface.

Here, we can select a motor from the large catalogue that the programme includes, with manufacturers like ABB, Delta, Emod, Panasonic, Siemens. In our case, as we will use a motor



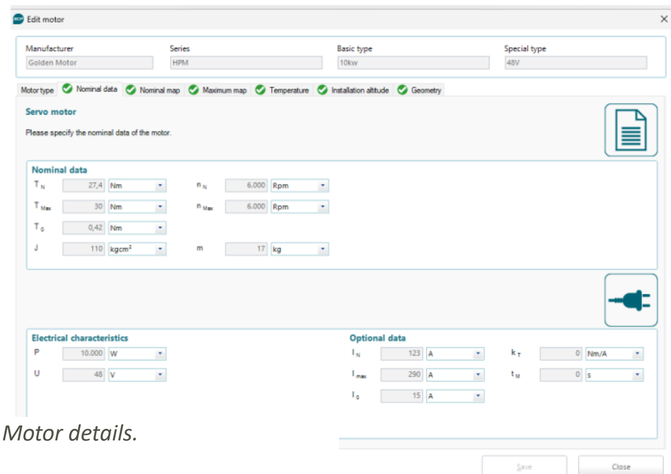


Figure 55: Motor details.

from a company that does not exist in the included list, we will add it manually with the data provided by the golden motor website. Some of the data we need to include are the geometric parameters, power and torque curves, or electric parameters. Some of the tabs used for this are shown below.

Then, we need to model the load that the system will be subjected to. For this, we will model it with a two pulleys and belt system, using diameters of 70,07 mm for the driver pulley, and 76,6 for the driven one. For the load values, we will use some approximate speeds and torque values obtained from the previous calculations made when sizing the device. We have five different segments in the load. The first acceleration, when the drum starts at 0 rpm, and get speed for the towing, at around 150 rpm. Then a maintained segment at this speed, until the pilot detaches the rope. Then the drum accelerates up to around 200 rpm to reel back the rope, in a constant segment. And finally, a deceleration from this point until the stop of the device. The total duration of the process has been estimated at 370 seconds (around 6,2 minutes). The load profile is shown below, with the rpms shown in blue.

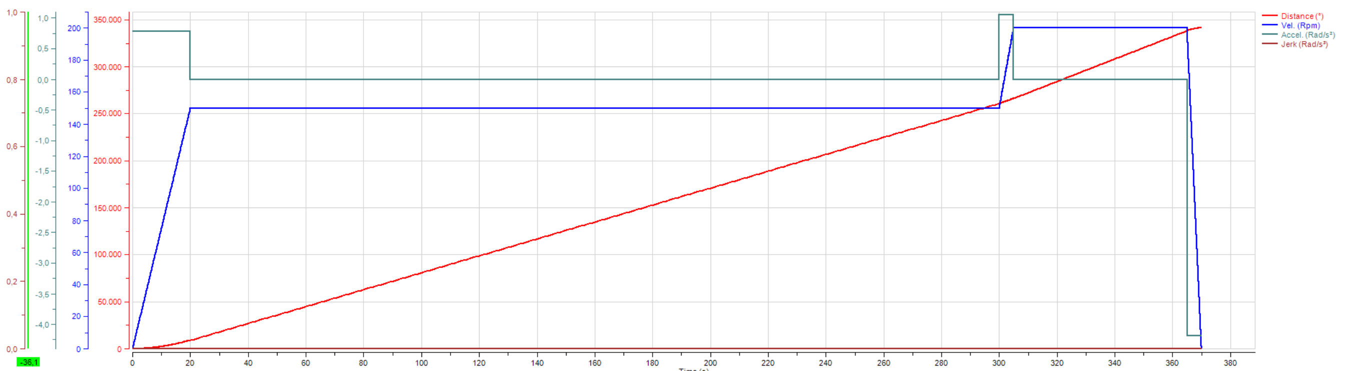


Figure 56: Load profiles.

With all these parameters added to the software, we can start choosing a gearbox from all the ones available in the programme. The interface will show us with some colour indicators whether the gearbox will suit the application or not. After trying with some different models from the PLE series, we decided to use the PLE-160-015, that according to the software will be valid for this purpose. Following the load indicated before, and with this gearbox, the motor will spin between 2500 and 3250 rpm, which is a valid range, considering the desired segment said before. Also, we see that the gearbox is not overloaded in any moment of the use of the device, assuring longer reliability of the elements. A detailed report of the drivetrain, including data and simulated measurements in each point of the system is generated by the software, and it can be found in the appendices at the end of this document.

The selected gearbox is shown below these lines:

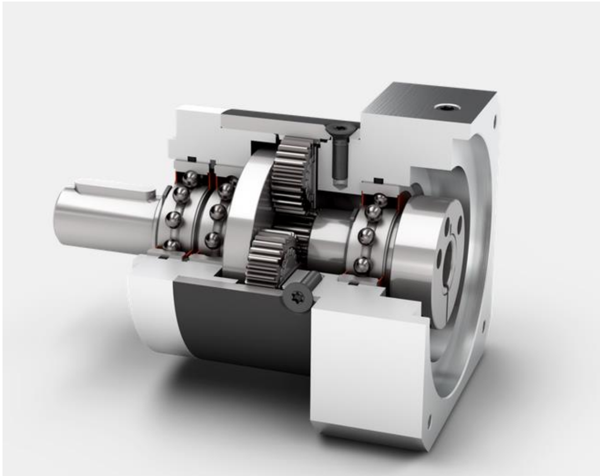



Figure 57: PLE-160-015 planetary gearbox.

Before finally deciding for this transmission method, we investigated and thought about using some other devices to achieve the desired speed.

One of the first options was to use a hub motor, typically used in small vehicles or bicycles. The main benefit was that we could avoid using any type of transmission, as the drum will have been directly mounted into the motor, transmitting the speed and force directly to it. Although, some critical issues appeared. First of all, we could not find any option in the market that could achieve the power we need for this application. Also, the problem of not having any transmission is that we would have needed the motor to spin at the same speed as the drum (around 150 rpm), which would have mean that the motor cannot achieve either good efficiency or power. For these two reasons, we decided not to use these types of motor.

Then, we thought about using a belt transmission system, as the one selected finally, but without using a gearbox in the motor, only pulleys and belts. This was a good option in the first place, as it would have meant that the system stays as simple as possible, having two belts and four pulleys, without any complicated mechanics. Nevertheless, an issue similar to the hub motor appears, as we need to reduce the speed of the motor significantly. Considering that belt systems are not recommended to have huge transmission ratios, we could not achieve the desired speed without using big pulleys, meaning that the total space of the device was increased significantly.

After seeing that the option using only pulleys and belts was not suitable, we decided to investigate about using some gearbox placed at the shaft of the motor. We first thought about using a transmission system used in robotics, called harmonic drive, which gives a really high reduction ratio with small space used and high efficiency. Despite these benefits, we ended up not using this system, as it does not enable the option of using engine braking, as the mechanism is not reversible.

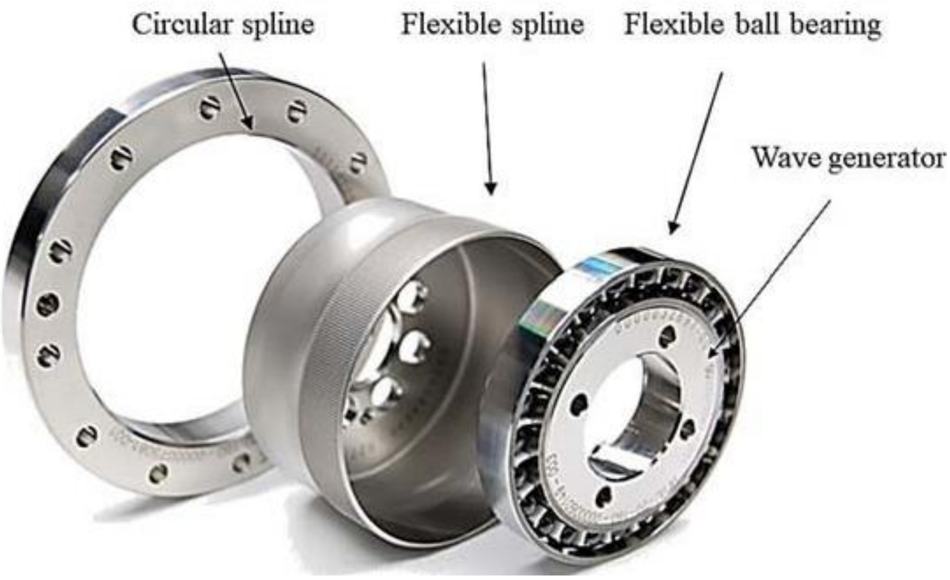


Figure 58: Harmonic drive transmission.

Finally, after discarding all the previous options, we came to a similar approach as the commercial options we ended up choosing. Tobias suggested looking into the use of planetary gearboxes, as they provide with huge transmission relations in a compact package. Doing some research on this device, we found many 3d printable models from people trying to solve some lower scale problems, and a simulator and calculator to now sizes of gears for a given ratio. Even though we ended up using a commercial option, where we do not need to size the gears and splines, we used in the first place, to get an idea of what the best option was. This

Figure 59: Split spline planetary gearbox.

calculator is made to size a special kind of planetary gearbox, called split spline planetary gear, characterised because of a higher transmission ratio than a conventional one.

In this variation of the gearbox, the fixed part of the gearbox is one of the rings, instead of the carrier (that in this case does not exist), the input is normally the sun (the central gear), and the output is the not fixed ring.

The website that we used to get the values for the size of the gears has an interface as shown below:

Split Ring Planetary Gear Calculator by Pål Saugstad. Use the demo page to see the gears in action. Background information.

Calculate! End Ratio (i:o): 20:1 Input limit: 0.9 Found: 0 Help

```
Calulate Gear ratios for the planetary gear of the type 'Split Ring Planetary Gear'.

They are mainly used for huge gear ratio reductions for stepper motors when high torque and low speed is needed.
The Sun gear of a planetary gear is the input gear, and the split ring of the planetary gear is the stationary
base plus the output gear. There is a small difference in number of teeth between the two rings. That is what makes
the output turn relatively slowly compared to the input gear. The Planets might be floating (not mounted in a carrier),
since they are driving the system with their teeth only, not their axles.

The number of teeth for the planets won't alter the gear ratios, as long as all connections (the planet parts) use the
same number of teeth.

For the 'Split Ring Planetary Gear' we have:

   Input:  Sun gear
   Base:   One half of the Ring gear (stationary)
   Output: Other half of the Ring gear

An inverted form of this setup might also be used. The input is then located at the outside (the ring) and the sun is
the component which is split into two halves. In the table, ratios where 'I' is bigger than 'O' is more sutable
for inverted, or 'split sun'. The table is sorted with increasing values of the 'c'-ratio. Hence, the gear setup at the start
of the table more suitable for 'Split ring' and at the end of the table, the 'Split sun' alternatives are located.

'Split sun' might be used to implement the gear reduction between the hands of a clock. By using the inverted form for this,
there can be a match between the length of the hands and the positions of the gears, since the the convension for clocks
is that the longer the hand is, the faster it runs.

For the 'Inverted Split Ring Planetary Gear' or rather 'Split Sun Planetary Gear' we have:

   Input:  Ring gear
   Base:   One half of the Sun gear (stationary)
   Output: Other half of the Sun gear

Input parameters:

   Calculate!  : Find the first 25 solutions
   Continue!   : Find the next 25 soltions
   Working...  : While searching, the search can be aborted by pressing here
   End         : End the session so that a new ratio can be checked
   Ratio (i:o) : The ratio bewteen input and output. Input must turn faster than output. Examples:
                  200:3 - all solutions
                 +200:3 - only 'same direction' solutions
                 -200:3 - only 'opposite direction' solutions
   Input limit : Input can have max same number of teeth as output times this factor. The value can
                 be less than 1. A '+' makes a minimum limit of 1. Examples:
                  0.5  - 'I' can be max half the size of 'O'
                  2    - 'I' can be max twice the size of 'O'
                 +2    - 'I' can be max twice the size of 'O', and min same size as 'O'
   Help        : This text
```

Figure 60: Planetary gearbox calculation web.

And it gives the solutions obtained for a given ratio in the following format:

```
The table:

   Sequence number of found solutions this run
   |      Number of teeth of input gear
   |      |     Number of teeth of output gear
   |      |     |     Number of teeth of base gear
   |      |     |     |          Relationship of turns for the input, the (imaginary) carrier and the output
   |      |     |     |          |                 Same as left, but normalized so 'o' is 1 always
   |      |     |     |          |                 |
   |      |     |     |          |                 |
   |      |     |     |          |                 |
   |      |     |     |          |                 |
   |      No of teeth   |          Ratios        |  Approx. Ratios  |
   #:     I     O     B |     i : c : o        |    i : c : o     |

  16:     3     9    13 |    48     9    -4 |    -12   -2.25 1 |
  10:     2     9     6 |    12     3     1 |     12    3.00 1 |

For ratios where 'B' is bigger than 'O' the output will turn in opposite direction of the input. This is shown in the table
with opposite signs for the input and output in the ratio columns.

Copy [I O B] values and check details regarding a gear by pasting them into the [I O B] field found in the demo page.
```

Figure 61: Planetary gearbox result format.

Using an example ratio of 20:1, we introduce this value in the corresponding field, and click on the calculate button, obtaining the following solutions:

	No of teeth			Ratios			Approx. Ratios		
#:	I	O	B	i	c	o	i	c	o
15:	1	8	14	60	4	-3	-20	-1.33	1
24:	1	18	9	20	2	1	20	2.00	1
6:	1	6	9	20	2	-1	-20	-2.00	1
5:	1	5	7	40	5	-2	-20	-2.50	1
13:	4	16	21	100	16	-5	-20	-3.20	1
11:	3	16	12	20	4	1	20	4.00	1
12:	5	16	20	20	4	-1	-20	-4.00	1
16:	5	25	19	120	25	6	20	4.17	1
25:	14	40	49	180	40	-9	-20	-4.44	1
14:	6	24	19	100	24	5	20	4.80	1
7:	4	15	12	20	5	1	20	5.00	1
1:	2	5	6	20	5	-1	-20	-5.00	1
19:	15	42	35	20	6	1	20	6.00	1
2:	3	6	7	20	6	-1	-20	-6.00	1
20:	18	45	38	140	45	7	20	6.43	1
17:	17	40	34	60	20	3	20	6.67	1
18:	23	40	46	60	20	-3	-20	-6.67	1
22:	33	55	63	160	55	-8	-20	-6.88	1
8:	11	22	19	60	22	3	20	7.33	1
9:	14	24	21	20	8	1	20	8.00	1
3:	6	8	9	20	8	-1	-20	-8.00	1
23:	39	65	57	160	65	8	20	8.13	1
10:	20	25	28	60	25	-3	-20	-8.33	1
21:	48	64	57	140	64	7	20	9.14	1
4:	9	10	9	20	10	1	20	10.00	1

25 solutions

Figure 62: Planetary gearbox results.

As it can be seen, there are many different options to achieve the desired ratio, with the only difference between them that some of them change the way of spinning in the way, meaning that the output will spin the opposite direction of the motor (these cases are the ones that have a negative ratio).

As said before, we ended up not using this transmission method because we found the commercial planetary gearboxes, while we could not find any real application of this concept, beside the 3d printed versions.

4.4 Battery size and design

As this device will be mounted in a vehicle, and we will not have access to power from a plug, we will need to use a battery to power the device. After the calculations made previously, we produced a power need of 10 kW. From Tobias' experience, we extracted that for a normal towing we can take an approximate elapsed time of 5 minutes, and that five launches should be enough for the budget. With these data, and knowing the voltage needs of the motor and controller, we created an Excel spreadsheet to help us calculate the number of batteries needed.

	Data		Unit
	Motor nominal power	10000	W
	Supply voltage	48	V
	Security factor (Sf)	0,15	-
	Duration of launch	5	Min
	Number of launches	5	-
18650 Cell	Vmin	2,8	V
	Vnom	3,6	V
	Vmax	4,2	V
	Capacity (C)	2,7	Ah
	Max Amp output	1	C
	Appox price of cell	3	€
LiFePO4	Vnom	3,2	€
	Capacity (C)	280	Ah
	Appox price of cell	500	€ 5pcs
Car battery	Vnom	12	V
	Capacity (C)	100	Ah
	Appox price of cell	100	€

	Results		Unit
	Nominal current	208,33	A
	Corrected current	239,58	A
	Desired time of use	25	-
	Capacity needed	100	Ah
18650 Cell	Series cells	14	-
	Parallel cells	38	-
	Battery energy	4,8	KWh
	Total number of cells	532	-
	Approx. Price	1596	€
LiFePO4	Series cells	15	-
	Parallel cells	1	-
	Battery energy	13,44	KWh
	Number of cells	15	-
	Approx price	1500	€
Car battery	Series cells	4	-
	Parallel cells	1	-
	Battery energy	4,8	KWh
	Number of cells	4	-
	Approx price	400	€

Figure 63: Battery data and calculations.

To obtain these values, we used different formulas. Some of them are shown below:

$$Nominal\ current{:}\ \ In(A) = \frac{P(W)}{V(v)}$$

$$Corrected\ current{:}\ \ Ic(A) = In\ (A) * Sf$$

$$Capacity{:}\ C(Ah) = Ic(A) * t\ (h)$$

$$Series\ cells{:}\ \ Ns = \frac{V(v)}{Vnom(v)}$$

$$Parallel\ cells{:}\ \ Np = \frac{Ic(A)}{Max\ Amp\ output\ (A)}$$

$$Battery\ energy:\ \ KWh = C(Ah) * V(v)$$

In order to select the best battery technology for our application, we compared three diverse types of battery. The first one is the 18650 cells, widely used due to its high energy density and low price. The second one is the $LiFePO_4$ cells, famous for their high capacity. Finally, we also compared with car batteries, as they tend to be cheaper and high capacity.

After doing a detailed analysis of these technologies, we produced the following advantages and disadvantages.

18650 cells

- They have high energy density, meaning that they have high capacity in less space than other technologies. They give a high discharge capacity, being able to give a high current when demanded. As they are used in many applications, they are easy to find at a moderate price.
- Not every type of these cells can stand high current applications. They have a limited life cycle, especially when used in high current applications. To achieve appropriate performance of the battery pack, complex electronics and security features need to be used, increasing the price of the battery pack.

$LiFePO_4$ Cell

- They provide high discharge ratios, meaning that they can stand continuous draining at higher amps than other types of cells. They have an increased life cycle when compared to 18650 cells, under the same circumstances. They are safer than other types of cells, as they do not suffer from spontaneous combustion, or overheating when taking out of ideal working conditions.
- They have less energy density than other technologies. They tend to be more expensive than other technologies, caused partially by their limited availability.

Car Batteries

- They provide large capacity and high discharge ratio, as they are designed to start an engine. They are really easy to find, and for accessible prices. They are also easy to install, as they do not need special electronics to work properly.
- Their life cycle can get reduced if charged and discharged repeatedly and until low or elevated levels. They are larger in size and heavier than other technologies, as they normally have thicker housings and cases. Following this aspect, they do not have a good energy density value.

After comparing these three technologies, we also looked at the estimated price that will cost to build the necessary battery pack for this purpose. We finally decided to use car batteries, as they significantly simplify the complexity of the pack and its electronics. It also provides a large capacity, and the possibility of having high discharge values, while keeping the price low.

Figure 65: 18650 battery cells.

Figure 64: LiFePO4 battery cell.

Figure 66: 12v 100Ah car battery.

4.5 Electronics and interface

As planned from the beginning, the device will have an electronic interface to show the parameters and relevant data to the user. To accomplish this goal, we will use a microcontroller, an Arduino MKR Wi-Fi 1010 in specific. This device will control an LCD display, where we will show the relevant information, and will use a potentiometer to receive the input from the user when changing the parameters. It will also use an LED to show any malfunction detected, and a high torque servo to actuate the brake calliper. We have decided that no menu will be needed in the definitive version, as all the parameters will be shown at the same time thanks to a 40x4 LCD display. The parameters shown will be the braking force level (from 1 to 10, changeable with the potentiometer), if there is any emergency state or alert active and the speed of the rotor in that moment, shown in rpms. An extra line of the LCD is still available in case some other data needs to be shown. One of the problems that we encountered through the development of the control electronics is that we do not have any device to evaluate them in, as the device will not be built. To solve this problem, we decided to programme the electronics the same way it would have been in the real case, but with some changes. One of these changes is that the speed of the rotor will be simulated according to a random number generator and the braking level and will not be read from any input. Also, there will not be any output for the speed of the motor, as this has to be done at the same time with the motor controller, adjusting parameters both in the Arduino and in the controller at the same time. The final code used for this simulation can be found in the appendixes (see appendix A8). The connections for the electronics are shown below.

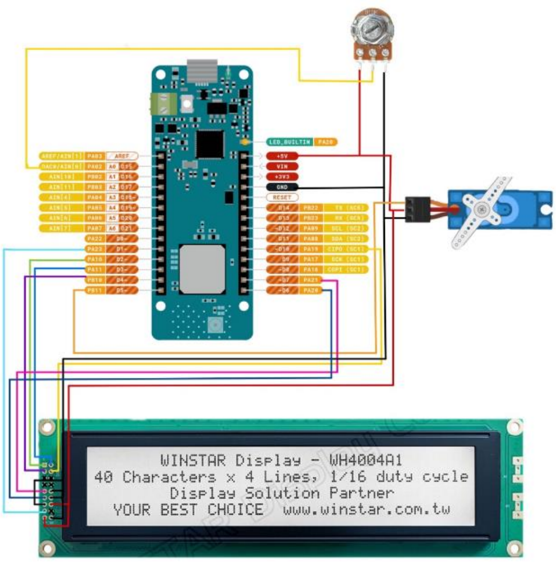


Figure 67: Electronics wiring.

As future development, we planned to integrate the electronics and the telemetry collected by the Arduino with a web page developed by Tobias to show and collect different data about paragliding flights, combining GPS data with electronics data.

4.6 Belts

A toothed belt, also known as a timing belt, is a type of belt with teeth on the inside surface.

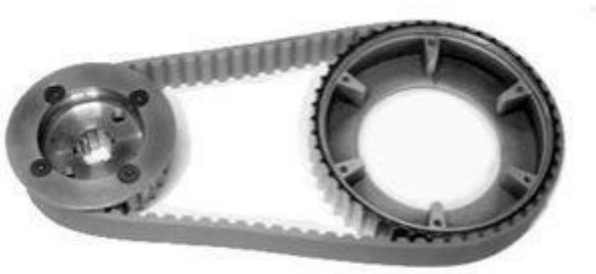


Figure 68: Belt transmission.

These teeth mesh with corresponding grooves on the pulleys or sprockets it connects to. The main characteristics of a toothed belt are its ability to transmit power efficiently, its high torque capacity, and its resistance to slipping. It is commonly used in various applications such as automotive engines, industrial machinery, and even some consumer products.

The teeth on the belt help provide precise timing and synchronisation, making it an essential component in many mechanical systems. Belts' Benefits and Drawbacks -Belt drives do not require axially aligned shafts and are easy to use and affordable.

The toothed belt is connected onto the pulley by fitting the teeth of the belt into the grooves of the pulley. The teeth on the belt mesh with the grooves on the pulley, creating a secure connection. It is required to make sure the belt is properly tensioned for optimal performance.

Toothed belts have several advantages over other types of belts.

Firstly, they provide precise power transmission due to the positive engagement between the teeth and grooves. This ensures minimal slippage and efficient energy transfer.

Additionally, toothed belts are known for their durability and resistance to wear, making them suitable for demanding applications. They also operate quietly and require less maintenance compared to some other belt types.

Overall, toothed belt is the suitable and best option for our paragliding project.

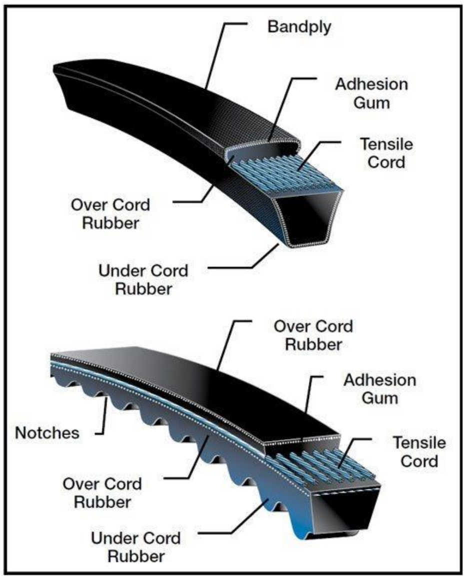


Figure 69: Belt types and parts

The Bandply involves stacking layers of fabric and coating them with adhesive. The layers are then pressed together to form a solid composite structure. This process helps to enhance the strength, flexibility, and overall performance of the belt.

The Adhesion gum is a type of glue that is used to bond materials together. It is specifically designed to provide strong adhesion between different surfaces. The gum is applied to the surfaces that need to be bonded, and when it dries, it forms a strong and durable connection.

The Tensile cord is used in the belt which is typically made of materials like aramid, fibreglass, or steel which have high tensile strength. The purpose is to provide additional strength and stability to the belt, allowing it to withstand the forces and tensions it may encounter during operation.

The Over cord rubber is applied over the tensile cord in a belt. It serves as a protective covering, providing durability, resistance to wear, and protection against external elements such as heat and chemicals. It also helps to prolong the lifespan of the belt and maintain its performance in various environments.

The Under-cord rubber is a layer of rubber that is applied underneath the tensile cord in a belt. It provides additional support and protection to the cord, helping to enhance the overall strength and durability of the belt. It also helps to improve the bonding between the cord and the other layers of belt, ensuring a secure and long-lasting construction.

The Notches are indentations or cuts made in a material such as wood or metal to create a specific shape or allow for a secure connection with another component. Notches are like puzzle pieces that interlock to create a strong and precise connection.

5. Conclusion

To conclude this report, during all this project, the work was about designing a winch combining two types of launch for paragliding. Some solutions already existed but with some weaknesses according to our tutor Tobias which is also the "customer" of the project. Relying on the specifications required, the existing solutions, the knowledge we have and the calculations we did, our project took shape during these last four months.

Research was made during the first part of the semester before the midterm presentation. This is what occupied most of our days working on this project since we needed to learn a lot about the subject which was completely unknown to most of us. A lot of the research was about the existing devices, the materials used and that we can use but also a lot of calculations that were primordial for the future decisions we would make about the design.

These calculations were, then, the starting point for the designing part which occurred just after the midterm presentation. As said before in the report, the calculations allowed us to define the varied sizes of a lot of parts of the design. For example, the drum size was decided based on the parameters of the rope such as the length and the diameter. And this drum size was the base for every other part since it is the main one. Every other designing phase took place around the drum. In the end, the design was most of the concern for the second segment of the semester as well as some other important research mostly about electric systems we wanted to use. The design and research we presented along the semester evolved depending on the feedback it got in the hope of having the best results. In the end, for the project, we have the opportunity to show what we made of this project, our final design and suggestion for a combination of two ideas of winching.

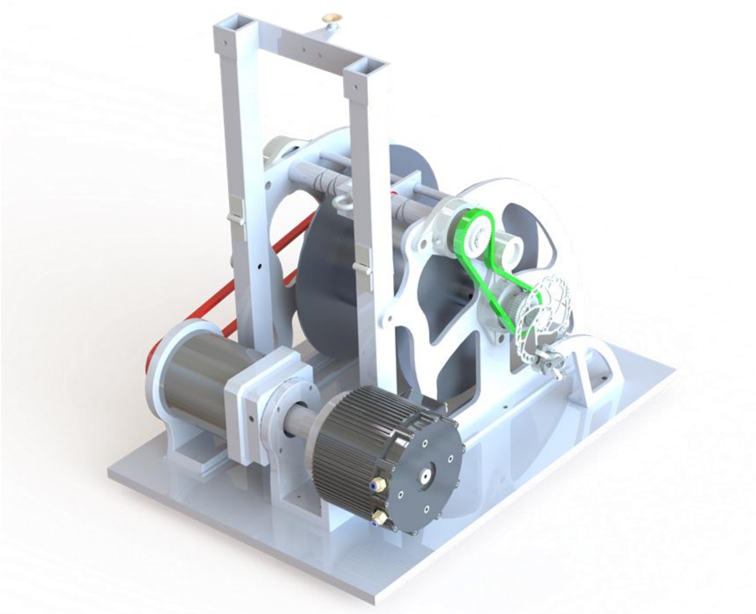


Figure 70: Final assembly.

6. Personal opinion

Rodrigo:

The EPS project is an extraordinary opportunity for students in order to expand their academic and personal horizons. This project not only allows the student to exchange knowledge between diverse cultures, but also encourages team working in a multicultural environment.

One of the most valuable aspects of the EPS program is how it tries to encourage the learning in an experimental way, giving the opportunity to work in real-world projects beyond the traditional classes.

Another key point of the EPS is how it helps the students develop their soft skills, like team working, communication, or problem solving. These types of skills is not only helpful for the project, but also for the student's working future.

I personally find the EPS working environment really inspiring thanks to its variety of perspectives, opinions and experiences during the classes and the working time.

In summary, I am grateful to have been able to participate in this program, as I feel it has taught me many valuable lessons, also from outside of my academic career.

Anaïs:

To be finished with the EPS project, it made me learned a lot of new things and skills but also improve myself in some other fields than mine.

Firstly, meeting new personality as well as new nationalities is a way to discover other cultures while communicating with new people that will be our comrade for the rest of the semester. In a way, other international students are our reference in those four months here since we are all in the same situation to be foreigners. I have learned a lot from absolutely every single one of my classmates and team members.

Secondly, I developed a lot my soft and hard skills. As an example, soft skills would be communication in a multicultural team, teamwork or even writing skills. For the hard skills, I had the opportunity to work on a design-oriented project. And so, I learned a lot of designing methods and tips on a CAD software. For the first part of the semester, my team members really helped me for the physics and mechanical part and calculation methods.

Finally, this EPS project made me discover and learn a fair amount of things about new topics. I want to thank everyone single person being involved in this Erasmus project as well as my team members for having done an amazing job on the project together.

Thomas:

As the others said just before, the European Project Semester is a great way to meet new people and learn how to work with them. It is an opportunity that one shouldn't miss, and I would recommend it to anyone I know. I find it way more enriching than a regular Erasmus where you into another country to follow classes that might not even relate fully to your studies.

With the EPS, you get to experience and learn a new way of life, a new culture in a different country. And not just one, but multiple since you are working in a team full of foreign students from all over the world. In groups of three to four people, you get to work on a project for the whole semester. You have very few classes and they are only related to the project, and these are going to be useful when coming back to your university and also in the future when working with a team of say engineers, for example.

All in all, I am grateful for this opportunity and to have been able to work in this team. I met some amazing people, and some I won't forget anytime soon. I have been able to give some help on the mechanical engineering side of the project and learn a lot as well.

Finland is also a great experience in itself. The winter, the northern lights, and the spring are really a nice sight that you can't really get in France that easily. Although it lacks some relief, it looks amazing from the sky while paragliding. So again, the EPS program is an experience I would 100% recommend to the students looking for an international mobility destination at ENIT.

Sherifatu:

Participating in the EPS project was an enriching journey that expanded my horizons in various ways. Interacting with classmates from diverse backgrounds not only exposed me to different cultures but also fostered invaluable communication and teamwork skills. Additionally, diving into a design-oriented project enabled me to delve into research methods and problem-solving techniques. I'm grateful for the collaboration of my team members and the opportunity to contribute to this endeavour. I have also been able to have access to facilities that are not common in my school and had the privilege to experience paragliding despite the cold windy weather. I am very happy with the opportunity granted to me by Novia University of Applied Sciences and am grateful.

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A. Appendices

Overview over grading elements.

element	EPS examination	Total Mark %	Supervisor	External Examiner	Student
PERSONAL	1. Oral presentation	15	X	X	
PRODUCT	Report 50 % 1.Professional content 2.Communication value	35 15	X X	X X	
PROCESS	Teamwork	35	X		X Point distribution. Self and peer assessment of project performance
	Total	100			

A monthly peer evaluation is made within each team in order to help the supervisors to detect possible hidden problems in the team.

Novia EPS 2013

Monthly **self** and **peer** assessment to be handed in to the supervisor

Team: Student:

Date:

The assesment has the following elements:
individual contribution to the group report, the **documentation** submitted (questions 1 and 2)
individual contribution to the team work, the **process performed** (questions 3, 4, 5, 6, 7)

		poor				Excellent
	Give your evaluation like this (example):	1	2	(3)	4	5
1.	Technical contribution (quality)	1	2	3	4	5
2.	Technical contribution (quantity)	1	2	3	4	5
3.	Willingness to build on the ideas of others	1	2	3	4	5
4.	understanding of team process	1	2	3	4	5
5.	leadership at appropriate times	1	2	3	4	5
6.	positive attitude	1	2	3	4	5
7.	initiative shown	1	2	3	4	5

Evaluation type: Peer self

Team: Student:

Date:

A1 EPS grading scale

NOVIA

EPS Final Examination EXAMPLE

Date:

Student Name: **John Malkovich**

Team: Future Film

	Oral presentation	Report	Report	Team Work
John M	0. Individual	Prof. Content	Comm. value	Process Perf.
Supervisor	80%	70%	80%	TWL: 70 %
Examiner	80%	60%	70%	
Mark	80%	65%	75%	TW: 84 %

Table 1

TW = TWL x WF

Assessment of project performance Team: Future Film

student name	a Students point distribution	Weight factor: WF= a/c	remarks
John	30	1,2	
Jim	20	0,8	
Jill	25	1	
Justin	25	1	
Average c =	25		

Table 2.

Student name:

	Assessment	% from table 1	Final mark (%)
0	Oral presentation, individual	80 x 0,15	12
1	professional content	65 x 0,35	22,75
2	communication value	75 x 0,15	11,25
TW	process performance	84 x 0,35	29,4
		Sum:	75,4
		ECTS Mark:	C

Table 3.

Finnish Marking Scale

Scale	Percent >	ECTS
5	92	A
4	80	B
3	69	C
2	56	D
1	50	E
0		F

A2 Tower glider paper

High Altitude Towed Glider PDF

6351

NASA Contractor Report 198493

High Altitude Towed Glider

Anthony J. Colozza
NYMA, Inc.
Brook Park, Ohio

June 1996

Prepared for
Lewis Research Center
Under Contract NAS3–27186

National Aeronautics and
Space Administration

Analysis

There are three main areas of interest in the analysis of this concept.They are the glider aircraft, the tow line, and the tow aircraft. For the present analysis the main concern is the operation and design of the tow line. The major forces that govern its shape and design are the drag and gravitational forces. The actual loading on the tow line would be the vector sum of these forces. The following diagram shows the glider / tow aircraft arrangement and forces on the tow line.

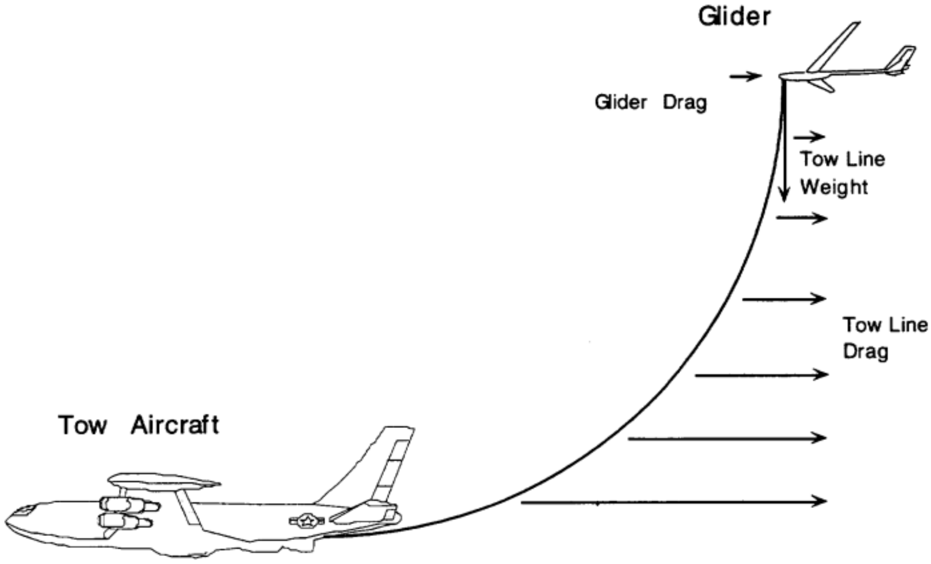

Figure 1 Tow Aircraft / Glider Configuration

2

With this initial information the tow line length and weight can be calculated as follows. The angle the tow line end makes with the horizontal at the glider (θ) is first arbitrarily chosen. With this angle the catenary curve constant , c, can be calculated (equation 1). This constant is then used in determining the tow line length and weight (equations 2 and 3 respectively).

$$c = \Delta h \cos(\theta) / (1-\cos(\theta)) \quad (1)$$

$$s=(\Delta h^{2} + 2\,\Delta h\, c)^{0.5} \quad (2)$$

$$w_t = \pi\, (d/2)^2\ s\, \rho_t\, 9.81 \quad (3)$$

For the calculation of the tow line weight, an initial thickness for the tow line is chosen. With the initial tow line thickness and the known spacing between the aircraft, the drag force on the tow line can be calculated. The drag is comprised of two components, the form drag which is based on the locally normal component of velocity and frontal area and the frictional drag which is based on the parallel component of velocity and the wetted area[1]. The drag is expressed in the following equation.

$$\Sigma D_i = 0.5\, V^2\, \Delta s\, d\, (\Sigma \sin^2(\phi_i)\, \rho_i\, C_{di} + C_f\, \pi\, \Sigma \cos^2(\phi_i)\, \rho_i) \quad (4)$$

The atmospheric density (ρ) varies significantly from the tow aircraft to the glider. Therefore the drag on the tow line must be done incrementally as a function of vertical distance between the two aircraft. The drag coefficient of the tow line is also a function of Reynolds number. This relationship can be found from empirical data for an infinite cylinder and is given in reference 2.

A3 Team management

A3.1 Belbin test

Team skills have been assessed using the Belbin and leadership test and based on these results (see below) we have assigned distinct roles and tasks for each member. First, we should introduce what is the Belbin test:

Raymond Meredith Belbin, while studying at Henley Management College, conducted some research on the influence of varied factors on the outcome of a certain team. (Belbin, n.d.).

At first, Belbin made the teams take a battery of psychometric different psychometric tests and, he made the hypothesis that high-intellect teams would outperform lower-intellect teams. Though his research showed in the end that some high-intellect teams would fail to fulfil their potential whereas the lower-intellect teams would outperform them.(Belbin, n.d.).

It became then obvious that intellect was not the answer to a team's success and productivity, but rather the balance between each type of roles.

In the end, the Belbin Team Inventory test was created and based on eight different team roles, where these roles would not define how someone is, but rather how strongly they express behavioural traits from some of these roles, while working in a team.

This test is crucial in the understanding of the differences and similarities of others in a group, by a safe and non-confrontational way.

The test consists of a series of seven interrogations, being the following:

- I love a piece of work because…
- Characteristic for my way of working in a group is…
- Once I get involved in a project, together with others…
- What I think that I can contribute to a team…
- Shortcomings, which I have, when working in a team are…
- If I suddenly get a challenging task, with a limited time and with people unknown…
- Problems I am coping with, when working in a group, are…

The participant then has ten points that he needs to attribute to each answer by order of preference. This will allow to, based on the participant's answers, dress up the top three roles he is most likely to show in a team.

The distinct roles are organized in the following manner:

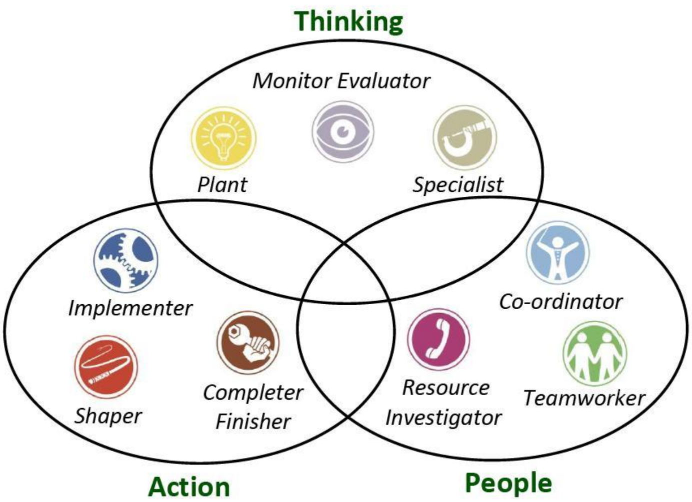

Figure 71: Belbin roles

Then, each of these roles will have something specific they can contribute to the team, and also usual acceptable shortcomings.

The roles generic definitions are the following:

	Role		Team Role Contribution	Allowable Weakness
Thinking	Plant	PL	*Creative, imaginative, free-thinking. Generates ideas & solves hard problems.*	*Ignores incidentals. Too pre-occupied to fully communicate.*
Thinking	Monitor Evaluator	ME	*Sober, strategic and discerning. Sees all options and judges accurately.*	*Lacks drive and ability to inspire others. Can be overly critical.*
Thinking	Specialist	SP	*Single-minded, self-starting, dedicated. Provides rare knowledge and skills.*	*Contributes only on a narrow front. Dwells on technicalities.*
Action	Shaper	SH	*Challenging, dynamic, thrives on pressure. Has drive to overcome obstacles.*	*Prone to provocation. Offends people's feelings.*
Action	Implementer	IMP	*Practical, reliable, efficient. Turns ideas into actions and organizes tasks.*	*Somewhat inflexible. Slow to respond to new possibilities.*
Action	Completer Finisher	CF	*Painstaking, conscientious, anxious. Finds errors. Polishes and perfects.*	*Inclined to worry unduly. Reluctant to delegate.*
People	Coordinator	CO	*Mature, confident, identifies talent. Clarifies goals. Delegates effectively.*	*Can be seen as manipulative. Offloads own share of the work.*
People	Team Worker	TW	*Co-operative, perceptive and diplomatic. Listens and averts friction.*	*Indecisive in crunch situations Avoids confrontation.*
People	Resource Investigator	RI	*Outgoing, enthusiastic, communicative. Explores opportunities, develops contacts.*	*Over-optimistic. Loses interest once initial enthusiasm expires.*

Figure 72: Belbin roles explained.

The key to an efficient and productive team then is to have the most balanced distribution of these roles within it.

The teammates will also have to learn how to work with the weaknesses of others, rather than wasting time and effort trying to eliminate them. This understanding of each people's strength and weaknesses will grant the team that makes the most of it, an increased productivity and efficiency, and overall, a better work atmosphere.

To put the following results into context, some definitions for the roles defined by Belbin are given below these lines:

Team Worker

Team Workers are the people who provide support and make sure that people within the team are working together effectively. These people fill the role of negotiators within the team, and they are flexible, diplomatic, and perceptive. These tend to be popular people who are very capable in their own right, but who prioritise team cohesion and helping people get along. Their weaknesses may be a tendency to be indecisive, and to maintain uncommitted positions during discussions and decision-making.

Completer-Finisher

Completer-Finishers are the people who see that projects are completed thoroughly. They ensure that there have been no errors or omissions, and they pay attention to the smallest of details. They are overly concerned with deadlines and will push the team to make sure the job is completed on time. They are described as perfectionists who are orderly, conscientious, and anxious. However, a Completer-Finisher may worry unnecessarily, and may find it hard to delegate.

Implementers

Implementers are the people who get things done. They turn the team's ideas and concepts into practical actions and plans. They are typically conservative, disciplined people who work systematically and efficiently and are very well organized. These are the people who you can count on to get the job done.

Coordinators

These are the ones who take on the traditional team-leader role and have also been referred to as the chairpersons. They guide the team to what they perceive are the objectives. They are often excellent listeners, and they are naturally able to recognize the value that each team member brings to the table. They are calm and good-natured, and delegate tasks very effectively. Source: Belbin.com

Individual results of Belbin test

Thomas:

In the following section, you will find the results of my personal Belbin test, and my analysis of the said results.

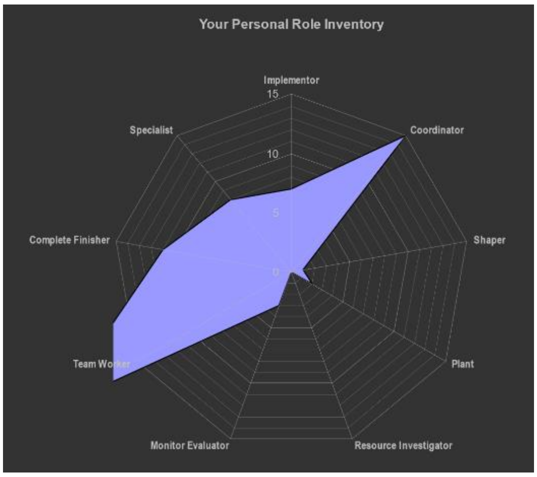

Figure 73: Thomas belbin result.

Looking at the graph, we can see that my two main roles are firstly Team Worker, then Finisher. My third role is actually a draw between Coordinator, Shaper, and Plant.

I tend to mostly agree with team worker. In a group I usually make sure that everyone knows what to do, and by extent, dislike it a lot when I do not know what to do. When brainstorming, I listen a lot to all of the available propositions and then support the most “correct” decision. I really enjoy a group that can get along one another really nicely and tend to try assessing the problem when that is not the case. When working in a group, I indeed can get indecisive on some decision-making but not more than the average.

I can agree on the fact that I will always check that the project done correctly, I will always try to lookout for any errors I can see before handing it over. I would not qualify myself as a perfectionist, but I like the diligence and am on the lookout for flaws in something that will be read, reviewed, or graded by someone else. Due to my calm personality, I would not say that I am overly worried and anxious though I can be stressed sometimes, especially near the deadline, but again, not much more than the average.

Anaïs:

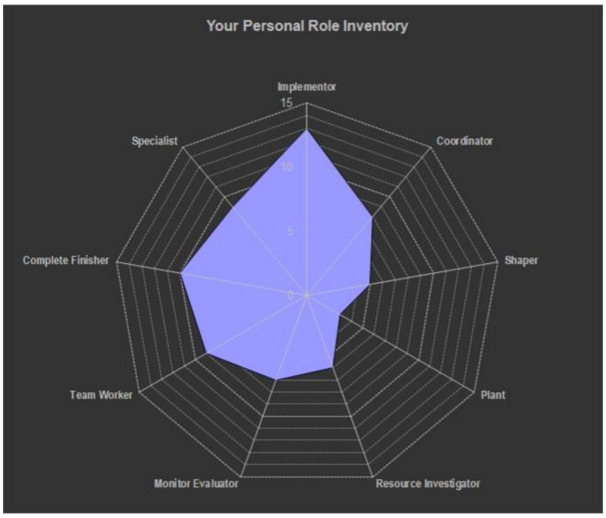

Figure 74: Anaïs belbin result.

The results show that I am more of an Implementer, Team worker and a Finisher. In the definitions of all of them, I find myself there. The Implementer role is quite close to the one of leader and I know that I am capable of taking this kind of role if needed in the group project. In the term of inflexible, I know that is one of my weaknesses since I do not like the unexpected. For the finisher definition, this seems to fit perfectly with my habits in most of the group project I do. Lastly, for the Team Worker part it is also really appropriate for the way I work in a team.

Rodrigo:

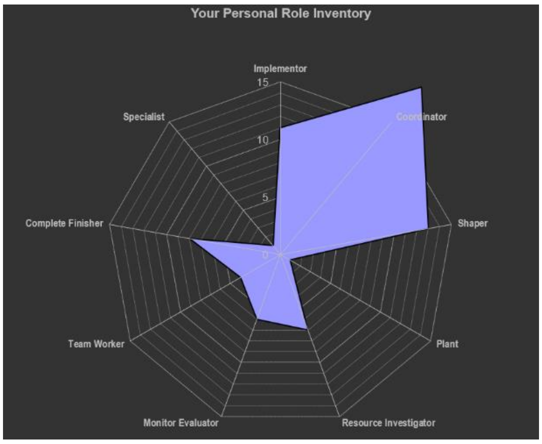

Figure 75: Rodrigo belbin result.

From the graph, we can see that my main roles are coordinator and implementor.

I agree with the roles that the test showed, as I normally do not find any issues, or do not bother to lead a group in order to get the work done. I find this task rewarding and challenging, and I enjoy collaborating with people in this way. Also, I agree as well with the implementor role, as I have a more practical view of things than other people. I sometimes find it difficult to come across the idea that will suit a problem, but I do not really have this issue when it comes to materialise this idea.

Sherifatu:

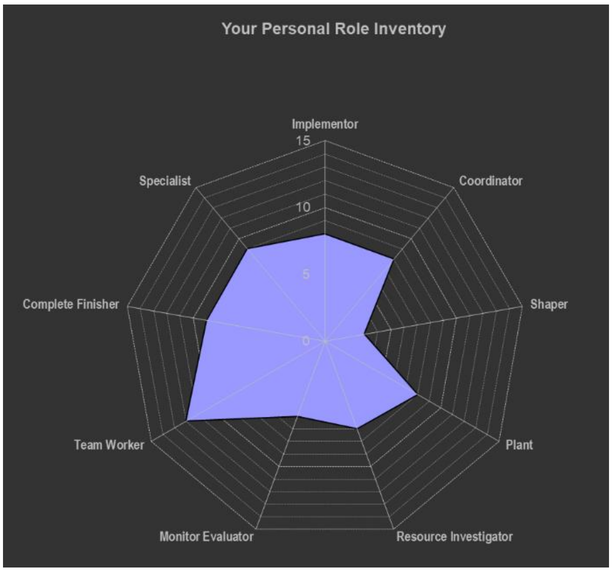

Figure 76: Sherifatu belbin result.

From the graph, we can see that my main roles are Team Worker and a Finisher.

I agree with the test to some level, I am more of a support provider than an individual player; moreover, I am more interested in making sure that a project is well completed before I can focus elsewhere. Aside that, Monitor and Resource Investigator in my list scores, that clearly describe my fewer abilities in those fields.

A.3.1.2 Team comparison

As it can be seen from the tests from the group, there is no one especially strong in roles that involve creativity thinking. This can be a problem in the beginning of the project, but we will try to make ourselves stronger in this aspect. On the other hand, all the group has satisfactory results in the roles that involve turning the ideas into a real thing, and collaborating with other people, either as coordinators/leaders, or as collaborators.

Again, as said previously, these roles are not mandatory, they just are personality traits that we might express while working in a group. So, the point is that even if our group does not seem to have that much strength in creative thinking, we will manage.

A3.2 Leadership test

The leadership test is divided into five parts, and it shows the comparison of the qualities of a typical project manager. The five parts are Leadership, Planning, Communication, Dealing with uncertainty and Creative thinking. It is scored on a five-point scale and comparing the results is a nice insight on how the different team members might behave and adapt to a given situation.

Individual results of leadership test

Thomas:

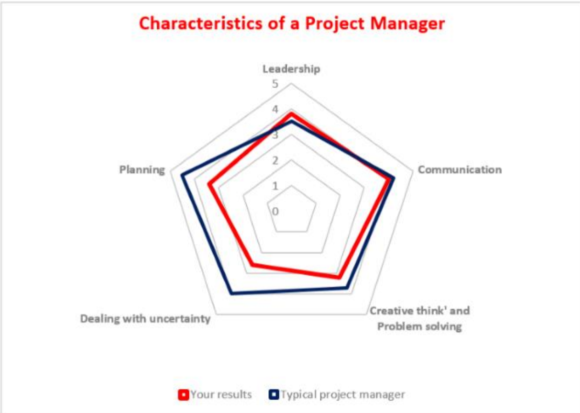

Figure 77: Thomas leadership result.

Here are the results for the leadership test. As we can see, I have the typical tendency of a project manager for the leadership, communication and Creative thinking/Problem Solving part, but on the other hand, I lack a little on dealing with uncertainty and planning. As I said before, since this group we have is pretty small, I think that everyone will balance each other's assets and drawbacks.

Anaïs:

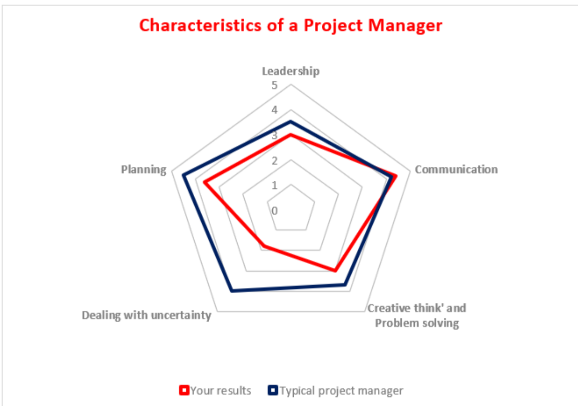

Figure 78: Anaïs leadership result.

The test shows results on five aspects. Based on the different ones, I already knew in which I would have an exceptionally low score. One of my greatest weaknesses is the unexpected and so the uncertainty. Surprisingly for me I have quite high scores in Communication and Leadership. As I already expressed, I do not like to lead but I really can do it if no one does it in the group and if it is needed. My graph seems a little off compared to the one of a typical project manager, but I do not think it means I am not at all capable of doing the job.

Rodrigo:

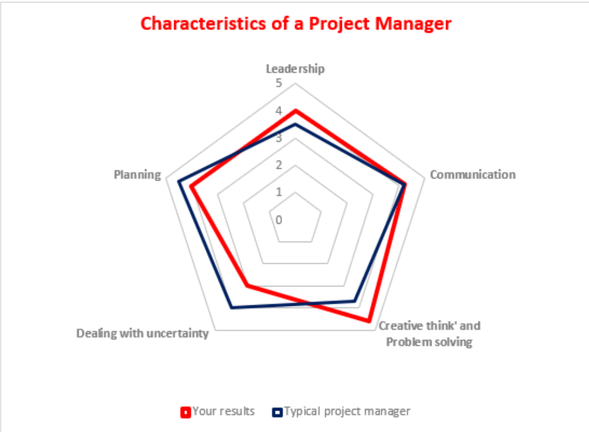

Figure 79: Rodrigo leadership result.

Talking about the leadership test, it follows the results from the Belbin one. I understand that the aspect where I differ more from the typical manager is dealing with uncertainty, as I find quite challenging to work without knowing some aspects that may condition the result and the undergo of the project.

Sherifatu:

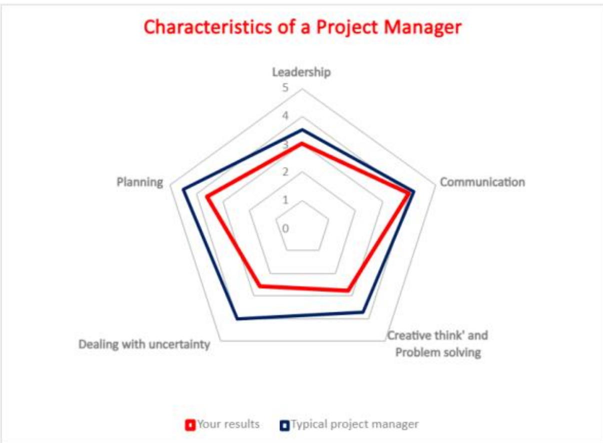

Figure 80: Sherifatu leadership result.

My strength from the leadership test is planning and communication, and I do not agree with leadership quality since I don't have the capacity to lead in a group.in the other hand I lack a little dealing with uncertainty, creative think and problem solving so I think my other group members will take care of that and it will match the leadership test.

A3.2.2 Team comparison of the leadership test results.

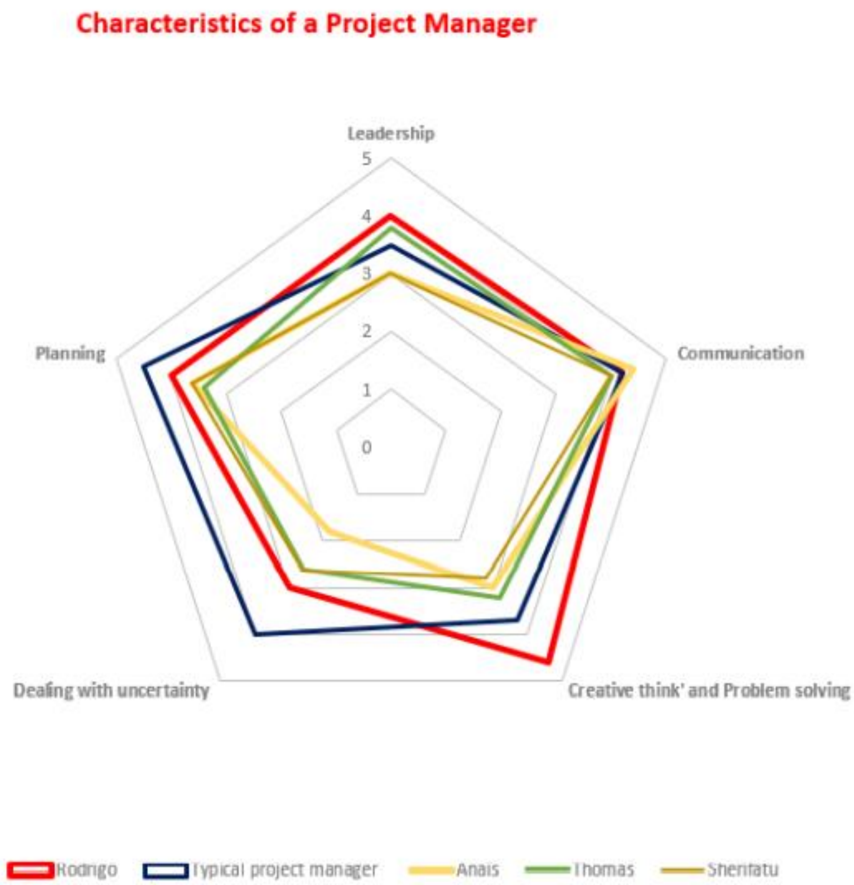

Figure 81: Team comparison in leadership test.

From this graph we can see that every member of the team has pretty comparable results in the communication and Leadership characteristics. The only aspect that the team, according to this test, might struggle with, would be dealing with uncertainty. Overall, the team seems pretty balanced, every weakness one might have would be balanced by the other members. Overall, the result is quite similar to the Belbin analysis we did just before.

A3.3 Hofstede comparison

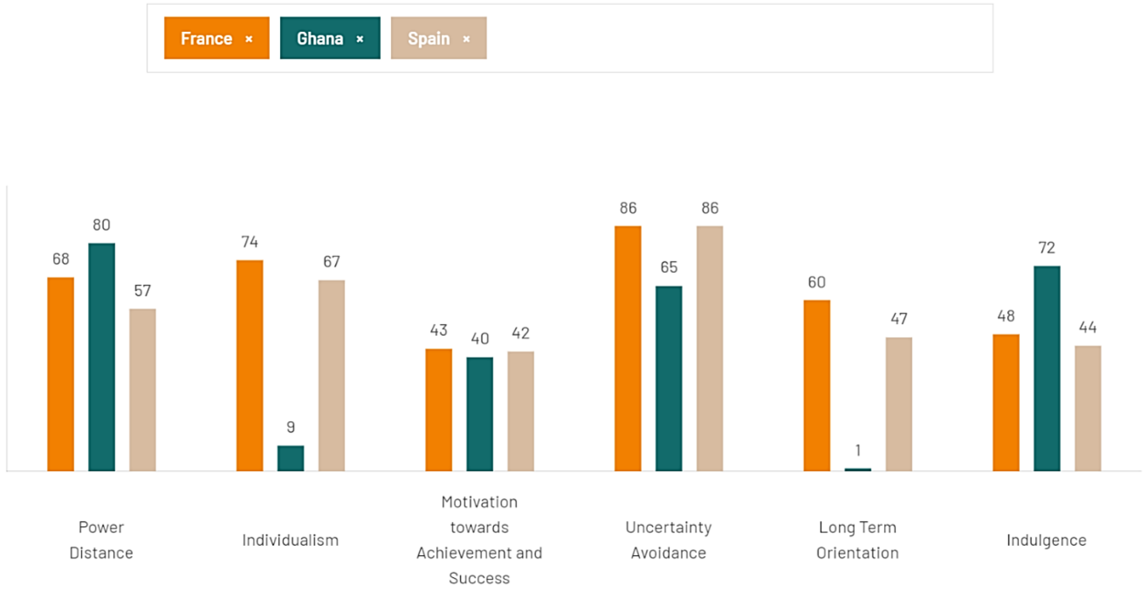

Figure 82: Hofstede comparison.

Differences can be seen mostly for some subjects like Individualism, Long-term orientation, and Indulgence. What we observe is that most of the differences are between France/Spain and Ghana. It is logical since France and Spain are close and remarkably similar countries. But Ghana has another culture, from another continent. The proximity between France and Spain, and the distance with Ghana explains a lot of the differences we can find on this Hofstede cultural dimension comparison.

So as examples, we see that for the Motivation towards achievement and success, our three countries are quite the same. Which means there is no difference regarding this dimension for us in the team. Something similar happens with the power distance aspect. Here, the results between Spain and France are the same, with some bigger difference with Ghana. This shows that all three societies are similar regarding how people think the population is distributed along the power scale.

Some big differences can be seen in the individualism and long-term orientation categories, where Ghana has an incredibly low score in comparison to Spain and France, which are quite similar. Talking about long-term orientation, this shows that people from Ghana tend to follow traditional costumes more than French and Spaniards. In the individualism, this shows that Ghana's society tends to be more like a group that other ones, while the Spanish and French society works more on the one of everyone.

More detailed analysis of the main fields with a “big” difference: Geert’s views on individualism in Spain, France, and Ghana. However, in general, Spain and France are often seen as having more emphasis on individualism compared to Ghana. Individualism in these countries values personal goals, self-expression, and individual rights. In Ghana, there tends to be a stronger emphasis on collectivism and community values. It is important to remember that these are general observations, and individual beliefs can vary within each country.

When it comes to long-term orientation, Ghana, Spain, and France have some interesting differences. In Ghana, there is a strong emphasis on tradition and respect for elders, which contributes to a long-term perspective. In Spain, there is a balance between tradition and modernity, with a focus on enjoying the present moment. And in France, there is a strong emphasis on planning for the future and achieving long-term goals. So, each country has its own unique approach to long-term orientation.

When it comes to indulgence, Spain, France, and Ghana have interesting differences. In Spain, there is a culture of enjoying life and indulging in pleasures, such as food, wine, and siestas. In France, there is also a strong appreciation for indulgence, with a focus on art, fashion, and cuisine. In Ghana, there is a more moderate approach to indulgence, with an emphasis on community values and self-control. So, each country has its own unique perspective on indulgence.

We all mostly agree with the results from the Hofstede investigation, we feel that this data represents ourselves in some way, although in some aspects of the comparison we think that the score is a bit inaccurate.

Notes: This test is a generalisation about nationalities. We do not want to generalise our team from this test.

A3.4 Team communication

Communication between the team will be held through different channels. The first one, being from our perspective the handiest and simplest one is via WhatsApp, with the help of a WhatsApp group that we created at the start of the project. We will also use Microsoft Teams to communicate between us, either via a call or with the group chat. This channel will also be used to communicate with our supervisor, Tobias.

Of course, we will also communicate with each other at the scheduled meetings that will be held in usual places, like the EPS room.

For the documentation and files sharing, we will use Microsoft Teams and OneDrive, as they allow us to work simultaneously in one file. This will also be helpful, as we could access the files from anywhere, just needing internet connection.

A4 Scope management

To achieve the final goal of the project is vital that we need to have clear objectives, phases, deliverables, and dates for the things that we are asked for. Here is where the scope of the project appears. It consists of a series of elements that marks what should be and what should not be done in the project. This way, we can focus on the really essential elements and tasks that are critical to the project itself.

A4.1 Project aims and objectives.

As said in the beginning, the aim of this project is to design and build a paragliding launcher solution that implements simultaneously the towing method and the winching method. We can divide this main objective in smaller goals, which would make the project look easier to develop, and more manageable.

With the help of the hi-level planner that we used at the beginning of the course, we were able to differentiate clearly from the real objectives of the project, and the things that are out of scope.

The final aim, as said, is to combine both options for paragliding launching, while trying to improve the current commercial products. This is, as the existing models are expensive, while taking in consideration what they can offer.

The objectives of the project can be divided into four diverse groups of deliverables. We first have the research part, with some objectives regarding the search of information about the existing ideas, the real needs of the problem we are trying to solve, or the exact parameters we need to consider. We also need to investigate about the mechanism that we need to use, including what parts we need to design, and which we need to buy. Finally, before moving into the next phase, we need to analyse the feasibility of the project with the elements found and make the necessary calculations to check all the steps from this point on. The next phase will consist of the design of the different elements that take part in the device, from the mechanical designs to the electronics and programmable elements. The third step will consist of building the prototype, including the tasks of contacting with the potential suppliers, and the building of the device itself. Also, we will check that the device satisfies the different requirements that need to be accomplished by the physical prototype. These three phases will be executed one after another, but the fourth one will advance all the way with the project, as it consists of the documentation and management of the project. The main point of this phase is to work on the necessary reports while the work is being done, and also make sure all along the way that the deliverables are being accomplished through the duration of the project.

A4.2 Work breakdown structure.

To manage these objectives through the project, a Work Breakdown Structure graph has been created. This scheme helps when trying to differentiate between different tasks and deliverables, and also gives information about to which group of tasks one corresponds to.

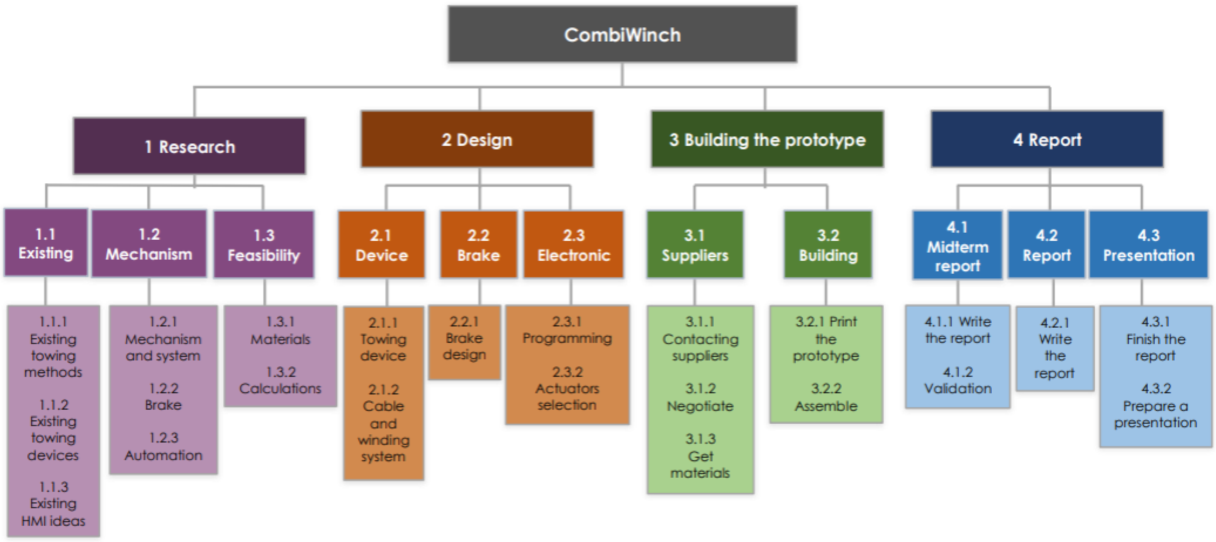

Figure 83: Combiwinch WBS

As it can be seen in the figure, all the tasks were divided into four diverse groups. The first one corresponds to the research and investigation phase. Here, we will collect information about the existing mechanisms and ideas and will analyse the feasibility of the ideas. The second phase consists of the design of the device. This was also divided into three smaller groups, one for the design of most of the mechanical parts, another one for the design of the brake and the final one for the design of the electronics components. The third phase is the building of the prototype itself, and it was divided in two smaller groups, one that consist of contacting the suppliers for the parts needed to build the device, and another one for the construction itself. The final one will be done all along the duration of the project, as they are the tasks that includes all the documentation and reports necessary for these types of work. It consists of the midterm report, the final report, and the final presentation of the project.

A5 Time management

In a project of this type, the time management is a crucial part of the work, as it will condition the correct progress of the tasks. To make a good management of the available time to work on the project, we need to know the tasks that we need to work on, and their importance to the project, as most of the time, the planification of the tasks is made based on the priority of the task.

A5.1 Time schedule

To arrange the necessary tasks, with their deadlines, expected time, owners, and other details, we made a Gantt like planner, which shows the dates and expected necessary time for each of the tasks that form the project, as shown in the following pages.

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	% of TASK COMPLETE
D1. Research					
T1.1 Existing					
T1.1.1 Existing towing methods	Everyone	2024-02-16	2024-03-01	2w	100%
T1.1.2 Existing towing devices	Everyone	2024-02-16	2024-03-01	2w	100%
T1.1.3 Existing HMI ideas	Everyone	2024-02-22	2024-02-24	2d	100%
T1.2 Mechanism					
T1.2.1 Mechanism and system	Everyone	2024-02-16	2024-03-01	2w	100%
T1.2.2 Brake	Thomas	2024-02-26	2024-02-27	2d	100%
T1.2.3 Automation	Rodrigo	2024-02-27	2024-02-28	2d	100%
T1.3 Feasibility					
T1.3.1 Materials	Anaïs - Thomas	2024-02-25	2024-02-26	2d	100%
T1.3.2 Calculations	Everyone	2024-03-04	2024-03-11	1w	100%
D2. Design					
T2.1 Device					
T2.1.1 Towing device	Thomas	2024-03-17	2024-03-31	2w	0%
T2.1.2 Cable and winding system	Sheriffatu	2024-03-17	2024-03-31	2w	0%
T2.2 Brake					
T2.2.1 Brake design	Thomas - Anaïs	2024-03-17	2024-03-31	2w	0%
T2.3 Electronic					
T2.3.1 Programming	Rodrigo	2024-03-19	2024-04-02	2w	0%
T2.3.2 Actuators selection	Rodrigo	2024-03-15	2024-03-16	2d	0%
D3. Building the prototype					
T3.1 Suppliers					
T3.1.1 Contacting suppliers	Everyone	2024-03-31	2024-04-07	1w	0%
T3.1.2 Negotiate	Everyone	2024-03-31	2024-04-07	1w	0%
T3.1.3 Get materials	Everyone	2024-04-07	2024-04-21	2w	0%
T3.2 Building					
T3.2.1 Print the prototype	Everyone	2024-04-21	2024-04-23	3d	0%
T3.2.2 Assemble	Everyone	2024-04-24	2024-04-28	5d	0%
D4. Report					
T4.1 Midterm report					
T4.1.1 Write the report	Everyone	2024-02-16	2024-03-15	4w	100%
T4.1.2 Validation	Everyone	2024-03-15	2024-03-20	6d	100%
T4.2 Report					
T4.2.1 Write the report	Everyone	2024-02-16	2024-05-10	12w	0%
T4.3 Presentation					
T4.3.1 Finish the report	Everyone	2024-05-11	2024-05-12	2d	0%
T4.3.2 Prepare a presentation	Everyone	2024-05-12	2024-05-15	4d	0%

WEEK 1							WEEK 2							WEEK 3						
M	T	W	R	F	SAT	SUN	M	T	W	R	F	SAT	SUN	M	T	W	R	F	SAT	SUN

Figure 84: Time schedule 1.

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	% of TASK COMPLETE	WEEK 4	WEEK 5	WEEK 6
						M T W R F SAT SUN	M T W R F SAT SUN	M T W R F SAT SUN
D1. Research								
T1.1 Existing								
T1.1.1 Existing towing methods	Everyone	2024-02-16	2024-03-01	2w	100%			
T1.1.2 Existing towing devices	Everyone	2024-02-16	2024-03-01	2w	100%			
T1.1.3 Existing HMI ideas	Everyone	2024-02-22	2024-02-24	2d	100%			
T1.2 Mechanism								
T1.2.1 Mechanism and system	Everyone	2024-02-16	2024-03-01	2w	100%			
T1.2.2 Brake	Thomas	2024-02-26	2024-02-27	2d	100%			
T1.2.3 Automation	Rodrigo	2024-02-27	2024-02-28	2d	100%			
T1.3 Feasibility								
T1.3.1 Materials	Anaïs - Thomas	2024-02-25	2024-02-26	2d	100%			
T1.3.2 Calculations	Everyone	2024-03-04	2024-03-11	1w	100%			
D2. Design								
T2.1 Device								
T2.1.1 Towing device	Thomas	2024-03-17	2024-03-31	2w	0%			
T2.1.2 Cable and winding system	Sheriffatu	2024-03-17	2024-03-31	2w	0%			
T2.2 Brake								
T2.2.1 Brake design	Thomas - Anaïs	2024-03-17	2024-03-31	2w	0%			
T2.3 Electronic								
T2.3.1 Programming	Rodrigo	2024-03-19	2024-04-02	2w	0%			
T2.3.2 Actuators selection	Rodrigo	2024-03-15	2024-03-16	2d	0%			
D3. Building the prototype								
T3.1 Suppliers								
T3.1.1 Contacting suppliers	Everyone	2024-03-31	2024-04-07	1w	0%			
T3.1.2 Negotiate	Everyone	2024-03-31	2024-04-07	1w	0%			
T3.1.3 Get materials	Everyone	2024-04-07	2024-04-21	2w	0%			
T3.2 Building								
T3.2.1 Print the prototype	Everyone	2024-04-21	2024-04-23	3d	0%			
T3.2.2 Assemble	Everyone	2024-04-24	2024-04-28	5d	0%			
D4. Report								
T4.1 Midterm report								
T4.1.1 Write the report	Everyone	2024-02-16	2024-03-15	4w	100%			
T4.1.2 Validation	Everyone	2024-03-15	2024-03-20	6d	100%			
T4.2 Report								
T4.2.1 Write the report	Everyone	2024-02-16	2024-05-10	12w	0%			
T4.3 Presentation								
T4.3.1 Finish the report	Everyone	2024-05-11	2024-05-12	2d	0%			
T4.3.2 Prepare a presentation	Everyone	2024-05-12	2024-05-15	4d	0%			

Figure 86: Time schedule 2.

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	% of TASK COMPLETE	WEEK 7	WEEK 8	WEEK 9
						M T W R F SAT SUN	M T W R F SAT SUN	M T W R F SAT SUN
D1. Research								
T1.1 Existing								
T1.1.1 Existing towing methods	Everyone	2024-02-16	2024-03-01	2w	100%			
T1.1.2 Existing towing devices	Everyone	2024-02-16	2024-03-01	2w	100%			
T1.1.3 Existing HMI ideas	Everyone	2024-02-22	2024-02-24	2d	100%			
T1.2 Mechanism								
T1.2.1 Mechanism and system	Everyone	2024-02-16	2024-03-01	2w	100%			
T1.2.2 Brake	Thomas	2024-02-26	2024-02-27	2d	100%			
T1.2.3 Automation	Rodrigo	2024-02-27	2024-02-28	2d	100%			
T1.3 Feasibility								
T1.3.1 Materials	Anaïs - Thomas	2024-02-25	2024-02-26	2d	100%			
T1.3.2 Calculations	Everyone	2024-03-04	2024-03-11	1w	100%			
D2. Design								
T2.1 Device								
T2.1.1 Towing device	Thomas	2024-03-17	2024-03-31	2w	0%			
T2.1.2 Cable and winding system	Sheriffatu	2024-03-17	2024-03-31	2w	0%			
T2.2 Brake								
T2.2.1 Brake design	Thomas - Anaïs	2024-03-17	2024-03-31	2w	0%			
T2.3 Electronic								
T2.3.1 Programming	Rodrigo	2024-03-19	2024-04-02	2w	0%			
T2.3.2 Actuators selection	Rodrigo	2024-03-15	2024-03-16	2d	0%			
D3. Building the prototype								
T3.1 Suppliers								
T3.1.1 Contacting suppliers	Everyone	2024-03-31	2024-04-07	1w	0%			
T3.1.2 Negotiate	Everyone	2024-03-31	2024-04-07	1w	0%			
T3.1.3 Get materials	Everyone	2024-04-07	2024-04-21	2w	0%			
T3.2 Building								
T3.2.1 Print the prototype	Everyone	2024-04-21	2024-04-23	3d	0%			
T3.2.2 Assemble	Everyone	2024-04-24	2024-04-28	5d	0%			
D4. Report								
T4.1 Midterm report								
T4.1.1 Write the report	Everyone	2024-02-16	2024-03-15	4w	100%			
T4.1.2 Validation	Everyone	2024-03-15	2024-03-20	6d	100%			
T4.2 Report								
T4.2.1 Write the report	Everyone	2024-02-16	2024-05-10	12w	0%			
T4.3 Presentation								
T4.3.1 Finish the report	Everyone	2024-05-11	2024-05-12	2d	0%			
T4.3.2 Prepare a presentation	Everyone	2024-05-12	2024-05-15	4d	0%			

Figure 85: Time schedule 3.

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	% of TASK COMPLETE	WEEK 10							WEEK 11							WEEK 12				
						M	T	W	R	F	SAT	SUN	M	T	W	R	F	SAT	SUN	M	T	W	R	F
D1. Research																								
T1.1 Existing																								
T1.1.1 Existing towing methods	Everyone	2024-02-16	2024-03-01	2w	100%																			
T1.1.2 Existing towing devices	Everyone	2024-02-16	2024-03-01	2w	100%																			
T1.1.3 Existing HMI ideas	Everyone	2024-02-22	2024-02-24	2d	100%																			
T1.2 Mechanism																								
T1.2.1 Mechanism and system	Everyone	2024-02-16	2024-03-01	2w	100%																			
T1.2.2 Brake	Thomas	2024-02-26	2024-02-27	2d	100%																			
T1.2.3 Automation	Rodrigo	2024-02-27	2024-02-28	2d	100%																			
T1.3 Feasibility																								
T1.3.1 Materials	Anaïs - Thomas	2024-02-25	2024-02-26	2d	100%																			
T1.3.2 Calculations	Everyone	2024-03-04	2024-03-11	1w	100%																			
D2. Design																								
T2.1 Device																								
T2.1.1 Towing device	Thomas	2024-03-17	2024-03-31	2w	0%																			
T2.1.2 Cable and winding system	Sheriffatu	2024-03-17	2024-03-31	2w	0%																			
T2.2 Brake																								
T2.2.1 Brake design	Thomas - Anaïs	2024-03-17	2024-03-31	2w	0%																			
T2.3 Electronic																								
T2.3.1 Programming	Rodrigo	2024-03-19	2024-04-02	2w	0%																			
T2.3.2 Actuators selection	Rodrigo	2024-03-15	2024-03-16	2d	0%																			
D3. Building the prototype																								
T3.1 Suppliers																								
T3.1.1 Contacting suppliers	Everyone	2024-03-31	2024-04-07	1w	0%																			
T3.1.2 Negotiate	Everyone	2024-03-31	2024-04-07	1w	0%																			
T3.1.3 Get materials	Everyone	2024-04-07	2024-04-21	2w	0%																			
T3.2 Building																								
T3.2.1 Print the prototype	Everyone	2024-04-21	2024-04-23	3d	0%																			
T3.2.2 Assemble	Everyone	2024-04-24	2024-04-28	5d	0%																			
D4. Report																								
T4.1 Midterm report																								
T4.1.1 Write the report	Everyone	2024-02-16	2024-03-15	4w	100%																			
T4.1.2 Validation	Everyone	2024-03-15	2024-03-20	6d	100%																			
T4.2 Report																								
T4.2.1 Write the report	Everyone	2024-02-16	2024-05-10	12w	0%																			
T4.3 Presentation																								
T4.3.1 Finish the report	Everyone	2024-05-11	2024-05-12	2d	0%																			
T4.3.2 Prepare a presentation	Everyone	2024-05-12	2024-05-15	4d	0%																			

Figure 88: Time schedule 4.

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	% of TASK COMPLETE														
						SAT	SUN	M	T	W	R	F	SAT	SUN	M	T	W	R	SAT
D1. Research																			
T1.1 Existing																			
T1.1.1 Existing towing methods	Everyone	2024-02-16	2024-03-01	2w	100%														
T1.1.2 Existing towing devices	Everyone	2024-02-16	2024-03-01	2w	100%														
T1.1.3 Existing HMI ideas	Everyone	2024-02-22	2024-02-24	2d	100%														
T1.2 Mechanism																			
T1.2.1 Mechanism and system	Everyone	2024-02-16	2024-03-01	2w	100%														
T1.2.2 Brake	Thomas	2024-02-26	2024-02-27	2d	100%														
T1.2.3 Automation	Rodrigo	2024-02-27	2024-02-28	2d	100%														
T1.3 Feasibility																			
T1.3.1 Materials	Anaïs - Thomas	2024-02-25	2024-02-26	2d	100%														
T1.3.2 Calculations	Everyone	2024-03-04	2024-03-11	1w	100%														
D2. Design																			
T2.1 Device																			
T2.1.1 Towing device	Thomas	2024-03-17	2024-03-31	2w	0%														
T2.1.2 Cable and winding system	Sheriffatu	2024-03-17	2024-03-31	2w	0%														
T2.2 Brake																			
T2.2.1 Brake design	Thomas - Anaïs	2024-03-17	2024-03-31	2w	0%														
T2.3 Electronic																			
T2.3.1 Programming	Rodrigo	2024-03-19	2024-04-02	2w	0%														
T2.3.2 Actuators selection	Rodrigo	2024-03-15	2024-03-16	2d	0%														
D3. Building the prototype																			
T3.1 Suppliers																			
T3.1.1 Contacting suppliers	Everyone	2024-03-31	2024-04-07	1w	0%														
T3.1.2 Negotiate	Everyone	2024-03-31	2024-04-07	1w	0%														
T3.1.3 Get materials	Everyone	2024-04-07	2024-04-21	2w	0%														
T3.2 Building																			
T3.2.1 Print the prototype	Everyone	2024-04-21	2024-04-23	3d	0%														
T3.2.2 Assemble	Everyone	2024-04-24	2024-04-28	5d	0%														
D4. Report																			
T4.1 Midterm report																			
T4.1.1 Write the report	Everyone	2024-02-16	2024-03-15	4w	100%														
T4.1.2 Validation	Everyone	2024-03-15	2024-03-20	6d	100%														
T4.2 Report																			
T4.2.1 Write the report	Everyone	2024-02-16	2024-05-10	12w	0%														
T4.3 Presentation																			
T4.3.1 Finish the report	Everyone	2024-05-11	2024-05-12	2d	0%														
T4.3.2 Prepare a presentation	Everyone	2024-05-12	2024-05-15	4d	0%														

Figure 87: Time schedule 5.

A5.2 Stakeholder analysis

The definition of a stakeholder is a party that has interest in a company and can either affect or be affected by the business. In our case, we can extend this definition to any person interested or with influence in our Combi Winch project.

As a small academic project, the list of stakeholders is not that long, but this does not mean that they do not influence the decision or the future of the project.

Our main stakeholders are, of course, the members of the project, including Thomas, Rodrigo, Sherifatu and Anaïs. As the managers and workers in the project, their interest and influence on the project is maximum. Another stakeholder with high impact on the project is Tobias, as the supervisor of it. His influence and interest on the project are also high, as he is the one that produced the idea of this project. The members of the group expect from him advice and guidance in many topics that will appear along the semester, where he will have more experience than any other member.

Other stakeholders are, for example, Novia UAS, as the support institution for the whole project. As it does not have the same direct implication of the work as the members or Tobias has, its interest and influence are not as high, but still not significant. As the support institution, it is expected from them to provide with the resources and tools that may be needed to develop the project.

Philip Hollins is also considered another stakeholder for the project, but not because of his implication in the topic, but rather because of his knowledge and advice regarding the management of the group and the project.

Finally, we also consider the paragliding club of Tobias as a minor stakeholder, as they can help solve some doubts that may appear regarding the sport and the factors that are needed to be considered for the project.

PROJECT NAME	CombiWinch				PROJECT MANAGER	Anaïs, Rodrigo, Sherifatu, Thomas	
NAME OR GROUP	**ROLE**	**CONTACT**	**CATEGORY**	**INTEREST**	**INFLUENCE**	**EXPECTATIONS**	**CONTACT METHOD**
Sponsors, managers, users, etc.							
Thomas Donny	Project Manager	**Name:** Thomas **Phone:** +33 6 70 81 56 66 **Email:** thomas.donny@edu.novia.fi	Internal	High	High	Work all along the project	Groups meeting, Whatsapp, Teams, email
Rodrigo Garcia	Project Manager	**Name:** Rodrigo **Phone:** +34 601 48 20 08 **Email:** rodrigo.garciapascual@edu.novia.fi	Internal	High	High	Work all along the project	Groups meeting, Whatsapp, Teams, email
Sherifatu Issah	Project Manager	**Name:** Sherifatu **Phone:** +233 54 060 9784 **Email:** sherifatu.issah@edu.novia.fi	Internal	High	High	Work all along the project	Groups meeting, Whatsapp, Teams, email
Anaïs Bombardier	Project Manager	**Name:** Anaïs **Phone:** +33 6 27 65 02 45 **Email:** anais.bombardier@edu.novia.fi	Internal	High	High	Work all along the project	Groups meeting, Whatsapp, Teams, email
Tobias Ekfors	Supervisor	**Name:** Tobias **Phone:** +35863285312 **Email:** tobias.ekfors@novia.fi	Internal	High	High	Help with doubts or problems that may appear	Meetings, Teams, email
Novia UAS	Support Institution		External	Medium	Low	Provide resources and tools to develop the project	
Philip Hollins	Writing Format Supervisor	**Name:** Philip **Phone:** +358 63 28 55 42 **Email:** philip.hollins@novia.fi	External	Medium	Medium	Provide the team with managment advices to work towards better efficiency	Email, meetings
Paragliding Club	Adviser	**Name:** Tobias **Phone:** +35863285312 **Email:** tobias.ekfors@novia.fi	External	Low	Low	Help solving some doubts about paragliding itself	Meetings, Teams, email

Figure 89: Stakeholder register.

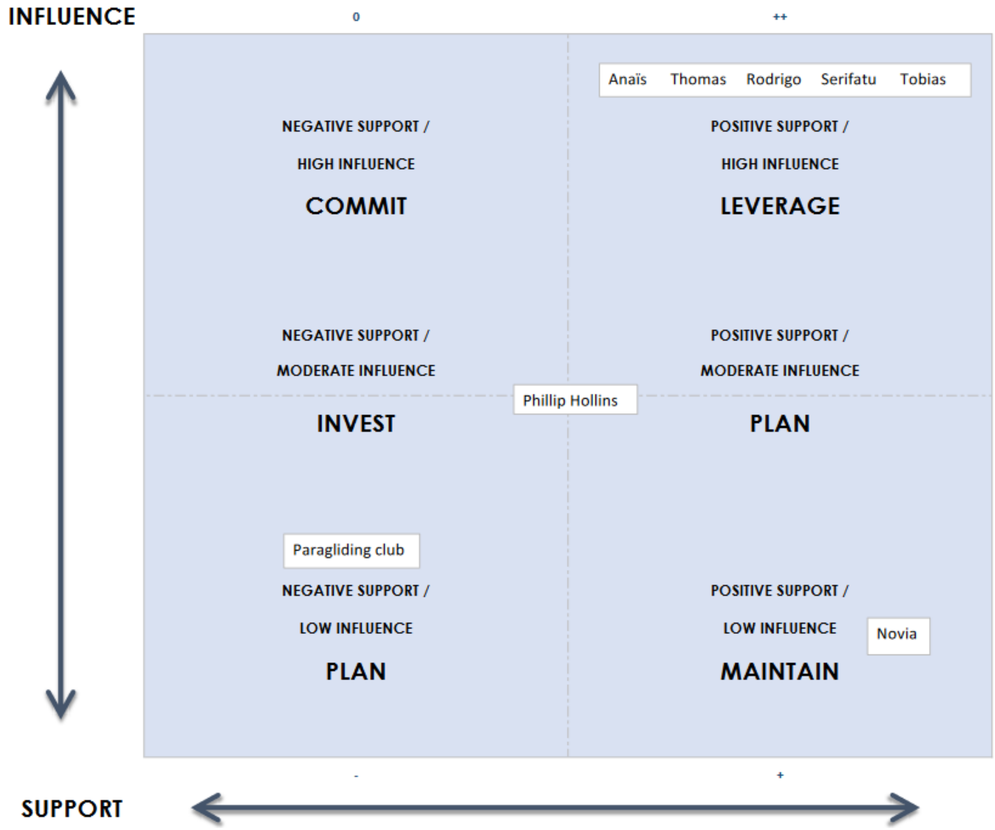

Figure 90: Stakeholder matrix.

A5.3 Project charter

1. General Project Information		
Project Name:	CombiWinch	
Team Leaders:	Thomas Donny, Rodrigo Garcia Pascual, Sherifatu Issah, Anaïs Bombardier	
Sponsors:	Novia UAS	
Date:	1.02.2024 - 16.05.2024	
2. Project Team		
Name	**Title**	**Responsabilities**
Thomas Donny	Project Manager	In charge of planning and executing the project
Rodrigo Garcia	Project Manager	In charge of planning and executing the project
Sherifatu Issah	Project Manager	In charge of planning and executing the project
Anaïs Bombardier	Project Manager	In charge of planning and executing the project
Tobias Ekfors	Supervisor	Researching support and feedback
Novia UAS	Support Institution	Do formalities and provide access to university tools
Philip Hollins	Writing format supervisor	Support writing, feedback and stakeholder's manager
3. Project Scope Statement		
Purpose Of The Project		
Come up with a new design of paraglider launching winch. The device has to be able to launch a paraglader with the vehicle towing method, and also should incorporate a self-tow solution as well.		
Objectives		
Investigate existing ideas for the problem		
Design our best ideas		
Manufacture a reduced scale prototype		
Test the prototype		
Deliverables		
Working design for a new winch solution		
Report		
Presentation		
Scope		
This project includes the research of existing options, the design of a model that combines both functionalities, and the possibility of adding more functions in comparison with the existing options		

Figure 91: Project charter.

In this project charter, we define everything about the project. Being the same as the Hi-level plan, it is indicating the project name, members, goal. But also, the main objectives and deliverables requested for the end of the project.

Therefore, the main project member included are the four of us with Tobias, this project's initiator, and tutor.

In the way the project charter is built and what it contained allows to easily understand, see, and know the objectives to achieve.

A6 Risk management

Risks being a crucial factor to consider, here was written the list of every one of them. Ranking the risks level with their impacts and solutions helps determine which we need to care more about to avoid it. Distributing risks to everyone in the team allows us to focus on less potential problems and give responsibility equally.

Risk Tracking Template

Date of last review: 08/03/2024

ID	Description of Risk	Impact	Risk Reponse	Risk Level	Risk owner
1	Forgetting factors for the power and force calculations	Design not dimensionned properly	Re-do some parts	High	Team
2	Miscalculations of the power needed and/or force applied to the structure	Design not dimensionned properly	Re-do some parts	High	Team
3	Limited budget	Not enough to test with 3D printing	Reduce cost in possible aspects	Medium	Anaïs
4	Not finding a solution of combining the vehicle towing launcher and the static self-launcher	Still meet the requirements but w/o the bonus	Improve in other design aspects	Low	Team
5	Problem with the suppliers	Supplies not available on time	Find other suppliers	Low	Rodrigo
6	3D printing device availability	Delay for the down-scaled tests	Try use other manufactoring methods	Medium	Thomas
7	Delays compared to the scheduler	Miss some deadlines	Re-schedule the project from this point	Medium	Team

Figure 92: Risk register.

The risk matrix presented under is the same as the risk register but easier to understand and more representative with the evolution of the severity and likelihood.

SEVERITY →

LIKELIHOOD ↓	1	2	3
1	LOW	LOW - 5 -	MEDIUM - 7 -
2	LOW - 4 -	MEDIUM - 6 -	HIGH - 1 - - 2 -
3	MEDIUM - 3 -	HIGH	HIGH

1. Forgetting factors for the power and force calculations
2. Miscalculations of the power needed and/or force applied to the structure
3. Limited budget
4. Not finding a solution of combining the vehicle towing launcher and the static self-launcher
5. Problem with the suppliers
6. 3D printing device availability

Figure 93: Risk matrix.

A7 Quality assurance and closure

In this part is developed how in a given project, it is possible to ensure the excellent quality of the research, results, and knowledge we acquired. The closure is the ending of the project. It consists of finishing and presenting all the deliverables but also documenting the project.

A7.1 Quality assurance

To make sure that the deliverables and objectives of the project have been achieved, a quality control is needed all along the project. For this, all the deliverables need to be reviewed when finished, before marking them as definitive. This will also be made by reviewing periodically this task, while they are still ongoing.

To achieve the marked objectives, some tests will also be performed during the development of the project, such as simulations, or documentation controls, to ensure that all the project is going forward as smooth as possible.

Feedback from the stakeholders will also be taken into consideration in all the process, to ensure that all the points discussed in the project meet the real-world requirements.

A7.2 Project closure

To mark the project as finished, and continue to its closure, some points need to be reviewed beforehand.

First, all the achieved deliverables need to be noted, making sure that all of them are correct and in the way they were intended. Also, it must be noted that the minimum percentage of deliverables needed has been accomplished, including the essential ones.

The next step in the closure will be taking the final feedback from the stakeholders, making any changes that appear based on their recommendations and suggestions.

With the engineering work of the project done, all the pending documentation, such as final reports, manuals, data sheet, etc. must be finished before finally handing the project. This documentation must follow the last changes (if made) after the stakeholders' advice. All the documents generated must follow the same aspect and be easy to navigate and understand with a minimum knowledge of the topic.

Finally, the project will be marked, based on the deliverables and objectives achieved, and the way they were performed, following the marking sheets and grades that can be found in the annex.

A8 Code for interface and Arduino electronics

```
/*
    Arduino programme to control the electronics and interface of the
    combiwinch project.
    Combiwinch team, Novia UAS, EPS Spring 2024
    Rodrigo García
*/

// include the libraries
#include <LiquidCrystal.h>
#include <Servo.h>


// initialize the library by associating any needed LCD interface pin
// with the arduino pin number it is connected to
const int rs = 6, en = 1, enTop = 7, d4 = 10, d5 = 4, d6 = 3, d7 = 2;

//Declaration of pins
const int pinPot = A0;
const int servoPin = 5;
int valueBrake = 0;
int valueBrakeRaw = 0;

//Initialize the servo
Servo servo;

//Initialize the LCD
LiquidCrystal lcdBottom(rs, en, d4, d5, d6, d7);
LiquidCrystal lcdTop(rs, enTop, d4, d5, d6, d7);

//Time variables and global variables
unsigned long lastTime = 0;
unsigned long lastTimeSerial = 0;
unsigned long lastTimeUpdate = 0;
int speedValue = 0;
int value = 0;


void setup() {

  // set up the LCD's number of columns and rows:
  lcdTop.begin(40, 2);
  lcdBottom.begin(40, 2);
  lcdTop.clear();
```

```
  lcdBottom.clear();

  servo.write(0);
  servo.attach(servoPin);

  Serial.begin(9600);

  valueBrake = 10;
}

void loop() {

  //Read the potentiometer every 750 ms
  if (millis() - lastTimeSerial >= 750) {

    //Read the potentiometer and scale the value
    valueBrakeRaw = analogRead(pinPot);
    valueBrake = map(valueBrakeRaw, 0, 1023, 1, 10);
    lastTimeSerial = millis();

  }

  //Update the display every five hundred ms
  if (millis() - lastTimeUpdate >= 500) {

    updateDisplay(valueBrake, false, randomSpeed(150, 165));
    lastTimeUpdate = millis();

  }
}


//Function to update display with the values recived
void updateDisplay(int valor, bool emergency, int speed) {

  lcdTop.clear();
  lcdBottom.clear();
  lcdTop.setCursor(0, 0);
  lcdTop.print(String("Current braking level: ") + String(valor));
  lcdTop.setCursor(0, 1);

  if (emergency == true) {

    lcdTop.print("Detected emergency");
```

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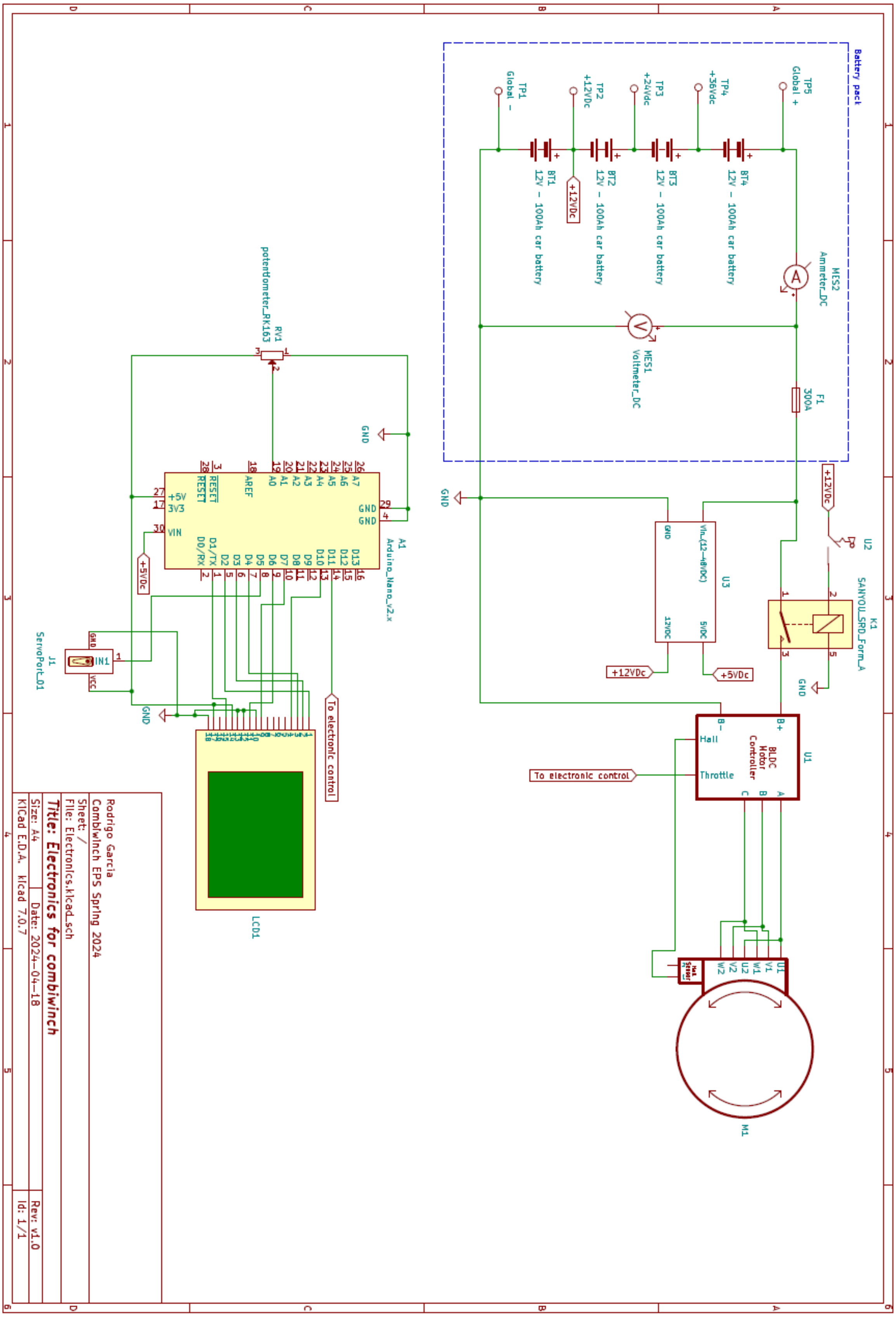
```
  } else {

    lcdTop.print("No emergency detected");

  }

  lcdBottom.setCursor(0, 0);
  lcdBottom.print("");
  lcdBottom.setCursor(0, 1);
  lcdBottom.print(String("Drum speed (rpms): ") + String(speed));

}


//Function to read the serial port, in case the PC wants to be used
int readSerialValue() {

  if (Serial.available()) {

    value = Serial.parseInt();
    Serial.read();

  }

  return constrain(value, 0, 10);
}


//Function to generate a random speed and simulate the normal working
int randomSpeed(int min, int max) {

  if (millis() - lastTime >= 500) {

    lastTime = millis();
    speedValue = random(min - valueBrake * 100, max + 1 - valueBrake *
100);  //Generate random value in accordance to braking force
  }

  return speedValue;
}
```

A9 Electronics schematics



A10 Motor and gearbox assembly exploded view