# Sail Car - An EPS@ISEP 2019 Project

**Abstract.** This paper provides an overview of the development of a Sail Car project of the European Project Semester (EPS) at Instituto Superior de Engenharia do Porto (ISEP). The principal goal of the EPS@ISEP is to offer a project-based educational experience, improve teamwork, communication, interpersonal and problem solving skills in an international team of various types of engineering students. Sail Car team consists of six Erasmus students, who participated the EPS@ISEP at spring of 2019. The objective of the project was to design and develop a wind-powered land sailing vehicle, which would use the benefits of technology to be self correcting and easy to drive. In order to successfully match the requirements of the project the team conducted a research about the existing solutions on the market, also technical, marketing, ethics and sustainability studies. Based on those studies the team defined the list of components needed and the structure for the prototype. Next steps in the development are building the prototype and carrying out the functional tests.

**Keywords:** Project based learning · Land sailing · Wind-power · Sustainability · European project semester.

## 1 Introduction

European Project Semester (EPS) is a programme offered by several European universities, including ISEP, which is part of the Polytechnic Institute of Porto. During EPS, students from different countries with different academic backgrounds are developing together a new product. The combustion of fossil fuels is considered a polluting, non-renewable form of power production. It is the job of future engineers to develop clean and sustainable means of producing energymostly for generating electricity, but also for powering the vehicles [8]. Furthermore, the main problem is that earth natural resources are limited. In our case, though the sail car project, we can raise awareness about how wind can be used as the main resource. Sail cars have as target people that are willing to feel the adrenaline, to practice an interesting sport, to compete with others all of these defining a hobby. What we want to promote through our project is the idea of sustainable and eco-friendly entertaining activities (hobbies, sports). This way we are contributing to a better world, where people are getting aware that even for a sport is a green solution available. The paper in hand is a reflection of the work of Team 1 of EPS@ISEP 2019. Table 1 displays the information about the team members.

Team 1 chose this project because: (*i*) building a land sailing vehicle, is something that none of the team members has experienced before; (*ii*) designing

a car that is powered by an energy source that can be found naturally and used for free; and (*iii*) making one prototype in real size so it will be possible to test and drive with it afterwards.

Table 1: Background of members of Team 1.

| Name | Country | Study field |
|---|---|---|
| Ana Zhu | Portugal | Mechanical Engineering |
| Christopher Beer | Germany | Mechanical Engineering |
| Karl Juhandi | Estonia | Manufacturing and Processing |
| Marko Orlov | Estonia | Transport and Logistics |
| Narcisa-Laura Bacau | Romania | Engineering and Management |
| Levente Kadar | Hungary | Electrical Engineering |

This paper is structured in three sections. First, the Background section, it presents related projects in the field of land sailing as well as the studies on marketing, sustainability and ethical topics. Next, Design and Development, which describes the architecture of the prototype. Finally, Tests and Results, describing the planned functional tests, the team is planning to carry out with the prototype.

## 2 Background

This section is intended to provide the results of all initial studies.

### 2.1 Related Projects

**Blokart** was created in New Zealand by Paul Beckett. In 1999 he wanted to create a wind-powered vehicle, which was fun, fast and compact. There are rental places, which also offer lessons to use a Blokart, clubs, where gatherings and national as well as international races are held [1]. The vehicle is hand steered, with a handlebar and a rope. Blokarts frame is built from a durable and rust resistant stainless steel. It is built in such a way, that all of the components could be packed into a carry bag. The packed Blokart fits into a car trunk or qualifies as checked airline baggage, which one can take to a trip with themselves. Sail sizes vary from 2 m to 5.5 m and are made from dacron sail fabric. Sails are reinforced with fibreglass battens and polyester film. Masts are divided into sections which fit together [2].

**Whike** is a company based in the Netherlands. They produce a pedal- and wind-powered land vehicle for leisure time and to raise awareness on natural green energy [13]. Whike features a lightweight tricycle with the steering system, gears and three mechanical brake disks. The vehicle comes with two sails, which can be switched, packed and carried on the tricycle. There is one 1 $m^2$ storm sail

and one 1.6 $m^2$ mainsail, both are made of polyester film [12]. Frame and sails are designed and developed by the company themselves [11].

**The Greenbird** was a UK based project. Its aim was to build two wind-powered vehicles, one meant for driving on land and another one on ice. Both of those had one common goal - to break the speed record of a wind-powered vehicle on a given surface. On March 26, 2009, their land yacht set a new speed record of 203,1 km/h. [9]. The Greenbird has a rigid sail which is adjusted by a tail attached to its back. The goal is to achieve higher speeds, without a more strong wind. That is done by minimising the drag and maximising the lift. For that, The Greenbird used the resultant of a manmade wind, which is created when an object moves forward, and the true wind, which is a natural breeze. Adding those two winds to the ride, the feeling is somewhere between those two - the apparent wind. Using this perk, The Greenbird team was able to reach speeds 3 to 5 times higher than the wind itself [10].

### 2.2 Marketing

The team decided to create a land sailing car intended for people who are interested in land sailing, both the experienced and the ones who are just starting to take up and experiment with the sport. The main aim is for customers with average or higher income because our product cannot be considered as a cheap one. The goal for the team is to stand out on the market by differentiating the product from the competition.

Our potential customers are: (*i*) beginners, who are interested and curious in taking up land sailing; (*ii*) intermediate land sailors, who want to try new technology; and (*iii*) experienced land sailors, who want to sail faster than with a soft sail.

**Adapted Marketing-Mix** While the 4 Ps appear to be more marketer-oriented, the 4 Cs focus on the client or consumer or customer. That is why the team chose to build the adapted marketing mix strategy based on 4 C's: (*i*) Customer/Consumer value; (*ii*) Cost; (*iii*) Communication; and (*iv*) Convenience.

### 2.3 Sustainability

The team chose to use quality materials in the construction of our product. The intent is to produce a quality product that would last and at the end of its life cycle, many of the used materials could be repurposed or recycled. The sail car is to be eco-friendly during the manufacturing process and during its usage time.

**Resources** The team will use wood for the ribs in the sail, steel frame, rubber wheels, PVC for the sail glued with silicone. This, of course, is not very sustainable but the team intends to make up for it by repurposing the used materials at the end of the life cycle of the product. Steel will allow us to construct a durable and firm frame for the car; it can be remelted at the end of its use. PVC is durable and lasts for a long time, it is also recyclable, as do the other materials used in the project.

**Manufacturing** would be done in Portugal. It would be more expensive, but more eco-friendly to have the production in Portugal than for example in China because then the product would ship from China over long distances, which causes more pollution in the supply chain. The manufacturing process has to be efficient as not to waste any materials, this the project is more cost-efficient.

**Storage** The team will partner with a well-known logistics company which will take care of the logistics and storage, for example DHL. The team will find a central warehouse for our product from where we could ship globally the most effectively.

**Retail** Customers will only have the option to order our product online and not buy it directly from a store. This would mean lower costs, because the team does not have to run a retail shop with workers.

**Transportation** Shipping from Portugal to most of Europe one would have to use land transportation options. This would be more polluting but would save money on costs and a lot of time. Most of the clients want the product delivered to their doorstep and in order to achieve that, the best option is to use land transport.

**Use** The customer can use Sailo on flat terrain, preferably on the sand like a beach or the desert. All the customer has to do is sit in the car and sail. It has been made possible by the self-correcting sail technology.

### 2.4 Ethics and Deontology

The team will follow the Code of Ethics for Engineers by National Society of Professional Engineers while advancing in the project. While marketing the product the team strives towards an honest and transparent attitude and aim to be ethical towards the customers and also competitors. For the environmental point of view, the weight could be on power, which makes the vehicle move - the wind. The product has no emissions and the ecological footprint is small.

The product will comply with the following European Commission standards:

**The Machine Directive** In the product, there are not many components from the machinery field, but it is essential to ensure, that piloting and steering the car, while on the move, is safe [3].

**The Electromagnetic Compatibility Directive** It is used for the companies to make sure that their products are safe and match the requirements of CE certification marking. Since the team does not produce the components themselves, it is mandatory to make sure, that the suppliers comply with this directive [5].

**The Low Voltage Directive** The product will be working with a voltage between 5 V to 10 V [6].

**The Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive** It bans the use of ten materials, but probably the most known and also the most likely material, that could end up in the product in and, is lead (Pb). Lead is used in the soldering process of electronic components. Since again, the team does not solder the components by them-

selves, it must be ensured, that the suppliers follow the RoHS directive and use lead-free substances in their processes [4].

## 3 Design and Development

The proposal for the project put the team up for a task to "Design, build and test a light sail car, following sustainable and ethical practices. The purpose, target user segment and the full set of device requirements are to be defined by the team based on the state of the art, marketing, sustainability and ethical analyses" [7].

The requirements for the project are [7]:

- Wind propelled;
- Use or reuse low cost hardware solutions;
- Use open source software;
- Adopt the International System of Units (NIST International Guide for the use of the International System of Units);
- Comply with the 2006/42/CE 2006 05 17 0517 0517 , 2004/108/EC 2004 - 12 - 15, 2014/35/EU 2016-04-20, 2014/53/EU 2014-04-16 and ROHS EU Directives.

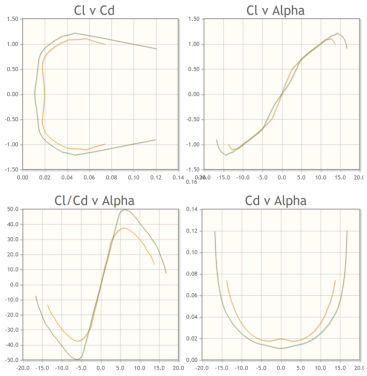
### 3.1 Design

The analysis made with the self-trimming wingsail is subcategorized into electronics and mechanical sections. The electronic analysis consists of the power transmission, hardware, servomotor, sensor and code design. The mechanical analysis is based on the design of the product using static and dynamic analysis to make preliminary design decisions. Afterwards, construction of the prototype of a real scaled model to test and validate the data made initially. Fig. 2a displays a structural drawing of the final prototype.

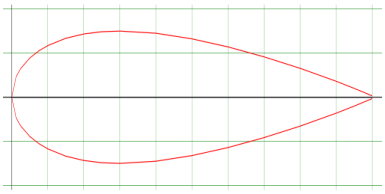
**Robotic analysis** The mast of self-trimming wingsail is free rotational, meaning that no control is needed in this aspect. However, the control over the mainsail comes from the actuation of the trim tab controlled by a servomotor is directly linked with the angle of attack of the mainsail. The ideal $\alpha$ (angle of attack) to produce the most useful force is around 10° to 15° from the apparent wind. Fig. 1a displays the coefficients for the lift and the drag. It can be seen how important the angle of attack is. If the angle is too high the flow becomes turbulence and breaks off. So, an angle above 17° is counterproductive. The most lift can be generated with an angle of 14° and the maximum lift compared to drag ($C_L/C_D$) can be generated with an angle of 6.25°, thats the most efficient angle.

**Mechanical analysis**

*Wingsail* The wingsail is the component that will provide the forces needed for the sail car to move, while the tail controls the direction of the wingsail for maximum angle of attack. Symmetrical airfoils were necessary because the wingsail was required to generate lift while at both positive and negative angles of attack. Using the airfoil catalogue provided from airfoiltools.com, NACA 0015 (see Fig. 1b) was the selected airfoil due to the highest lift to drag ratio with a maximum thickness of 15 % at 30 % chord. Moreover, calculations were made to determine the size of the wingsail (see Fig. 3a) considering: (*i*) angle of attack; (*ii*) atmospheric properties; (*iii*) coefficient of drag and lift; and (*iv*) reynolds number.



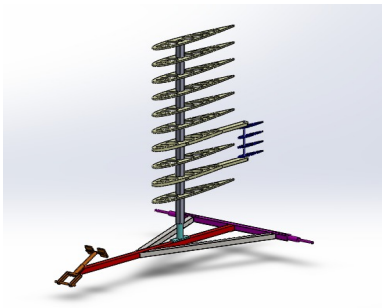

(a) Airfoil diagrams



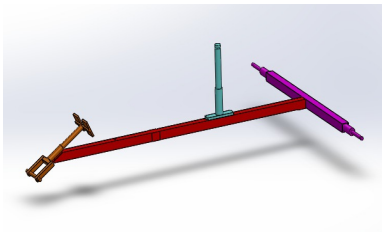
(b) NACA0015 airfoil

Fig. 1: Airfoil characteristics

*Frame* First, it was needed to establish the dimensions of the sail car by calculating the external forces acting on the whole object using the balancing equation on excel. This ensures the balance of the sail car when a strong wind acts on it and will not tumble. Fig. 2b displays structural drawing of the base structure of the project.



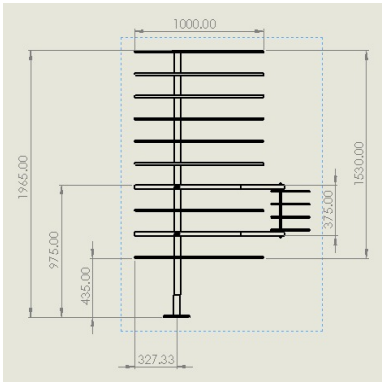
(a) Structural drawing of prototype



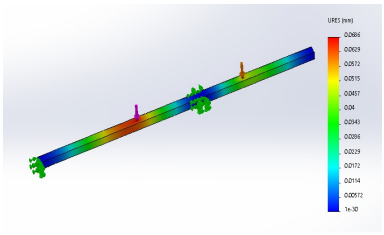
(b) Structural drawing of the base structure

Fig. 2: Sail Car design

The design and tests for the frame were made based on the prototype because this project was developed only for academic purposes with a limited budget, time and production. Having that in mind, the selection of materials and the actual production is not the most efficient, but is the most appropriate considering all the aspects mentioned above. Not only that, there are other important parameters to have in consideration as well, such as lightweight structure, good mechanical resistance, good weldability and easy to produce. These features can be found on structural steel S235 with a 50x50x3 mm profile. Fig. 3b displays the simulations carried out on the frame profile chosen by the team.




(a) Dimensions of the wing and tail



(b) Square profile 50x50x3 mm

Fig. 3: Characteristics of the details

*Other components* The sail car requires (see Fig. 4) three 10″ wheels (3), two at the back and one in the front stirred by the feet which control the direction of

the moving sail car. Although the methods of braking and parking are not the most efficient, it is enough to do tests on the prototype. So, when the person wants to break a simple mechanism was implemented using some rope/ strings to actuate (1) and when it is needed to stay immobilized, a locking door system (2) was added to the frame (4) because the wheel model has orifices that allow the shaft pass through.

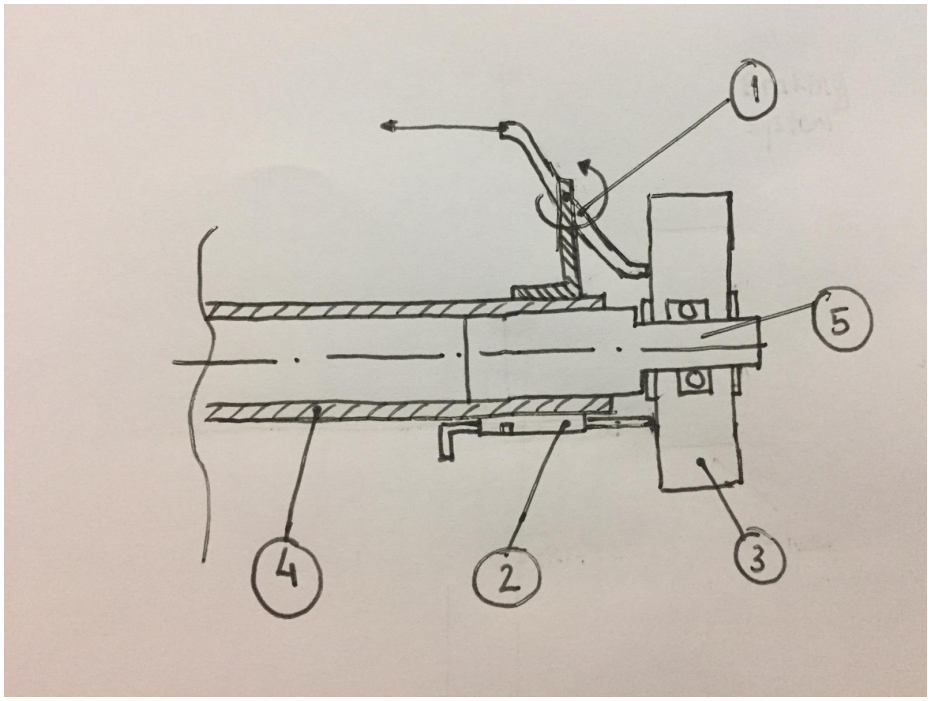



Fig. 4: Parking brake system

### 3.2 System Architecture

The internal system in the project, which operates the self-correcting system is controlled by an Arduino UNO unit, which operates with a voltage of 12 V. The microcontroller gets its information from a wind sensor placed on the top of the mast. The wind sensor will be built by the team, using a rotary encoder. Based on the data, the Arduino unit gives out commands to the servo motor, which operates with a tail attached to the back of the wing. By moving the tail, the wing also turns to the desired direction.

The driver of the sail car will also have an option to control the sail manually, using the data provided by the wind sensor. In order to do that, there is an

override switch in the system, which gives control over the servo over to the driver, who can operate the motor using a joystick. The system will be powered by a 12 V battery. Fig. 5 displays the detailed schematics of the project.

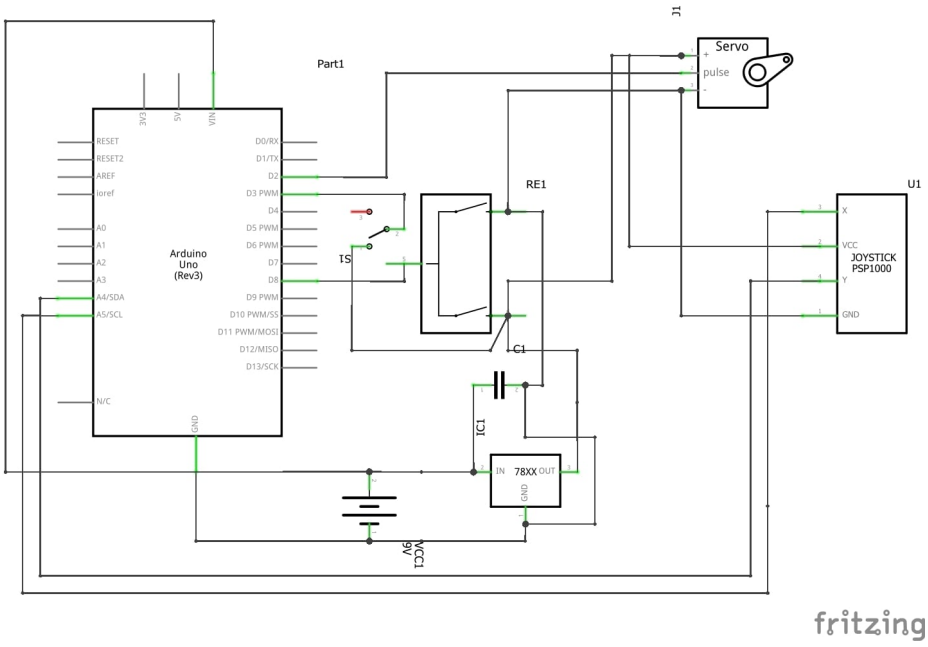



Fig. 5: Detailed schematics

## 4 Tests and Results

The next steps in the project development will be building the prototype and carrying out the needed functional tests with it.

The functional tests the team is planning to carry out:

**Electronics**: (*i*) wind sensor and servo motor connection; (*ii*) controlling the servo with a joystick; and (*iii*) microcontroller and servo motor connection.

**Frame**: (*i*) simulations on SolidWorks; (*ii*) steering; and (*iii*) balance calculations.

**Forces**: calculations for friction, acceleration, thrust, Lift and Drag.

**Wheels**: simulations on SolidWorks.

**Wing**: (*i*) free rotation; (*ii*) calculations Lift, Drag and Result Force; (*iii*) steering the tail; (*iv*) rotation of the tail.

## 5 Conclusion

The goal for this project was to design and develop a wind-powered land sailing vehicle. One, that could be easy to drive, self correcting towards the wind and offering thrilling attributes to both, beginner and experienced land sailors. By developing the sail car the team aimed to raise awareness among the people, that there is a great option to have an thrilling and interesting hobby, which is at the same time sustainable and eco-friendly.

The more general aim of the programme was to offer a project-based learning experience to all of the participating students. Help to develop technical, scientific and communicating skills. The participants were placed in a multicultural environment, where they had to work as a team to achieve one common goal. All of this included planning, paying attention to the deadlines, respecting the team members, dividing the work and trusting others. The members of the team shared their thoughts about the EPS experience.

*Really nice opportunity to learn new things. It's interesting to see how other students solve problems with a different fields of study, and culture.*

*EPS is a great opportunity to learn about different cultures and mindsets. It teaches us to think outside the box and to be creative in any subject.*

*European Project Semester is a really mind opening experience. There is a great opportunity to learn by building a project and apply all of the things absorbed to the development. It teaches to respect teamwork, trust others and not to let down the people, who rely on your work. Definitely a totally different semester that would be recommended to every engineering student.*

*EPS has been an eye opening experience, I have learned so much from the people that I work with and that surround me. ERASMUS and EPS are both experiences that I am grateful for experiencing and they will stick with me for the rest of my life.*

*EPS was both a personal and an academical journey. Studying Business Engineering I always wondered how and what my role would be in a technical team. That is why EPS helped me to understand more about what I want to do in the future and realize how important is every resource in this kind of project, especially the team itself.*

*EPS is a great experience. Work in a team with international students from different fields of study and see how they solve problems is really interesting. Furthermore, you can learn a lot from other fields and expand your own knowledge outside your field of expertise.*

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