Instituto Superior de Engenharia do Porto

Interim Report

Autonomous Sailboat

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Abstract

In todays world the ocean suffers greatly with the ever-growing population and disasters that occur over the world. A maneuverable ocean exploring monitoring system has been a state of the art subject for several years, its advancements can be used in several market sectors and advanced overtime. This can monitor the oceans for research and development while maintaining desired energy efficiency. Horizons Sails is developing a Autonomous Sailboat, Kantian, to sail the oceans and capture data without the act of human interaction. The product will be marketed on several platforms for several industries in a growing market. Many technical aspects have to be studied or developed, especially concerning the fact that the “Kantian” is a product that will be subjected to adverse weather conditions.

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1. Introduction

“Talent wins games, but teamwork and intelligence win championships.” - **Michael Jordan**

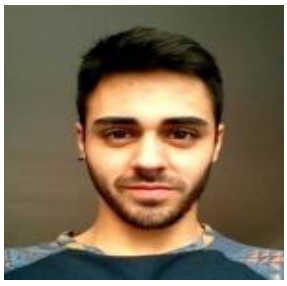
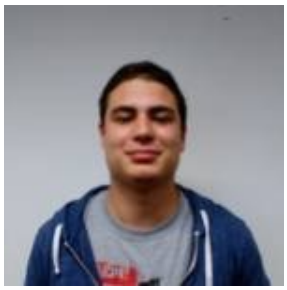
1.1 Presentation

Our team consists of six multinational, interdisciplinary student members who have undertaken the European Project Semester program 2015 at the Instituto Superior de Enganharia do Porto otherwise known as ISEP. The program commenced on the 23/02/2015 and it will last four months, finalizing on the 26/02/2015. The semester is based on a group project, “Autonomous Sailing Boat”.

The program also offers additional classes such as Team building, Project Management, Communication, Marketing, Sustainability and Ethics & Deontology all of which are designed to aid the project completion.

1. Our Crew

Table 1: Presentation of Team Members

Roberto Giordano	Italy		Management in Engineering
Gizem Ozturk	Turkey		Mechanical Engineering
Gary Jonathan Rabone	Scotland		Mechanical Electronic Systems Engineering
Marc Navarrete Hill	Catalonia		Industrial Design and Product Development
Imre Asztalos	Hungary		Electrical Engineering

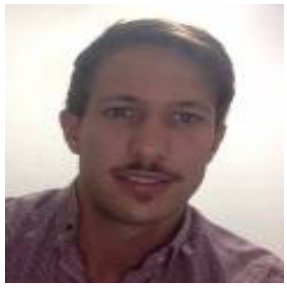
Thies Gunther	Germany		Sales and Purchase in Engineering

Figure 1 displays our first idea of a sailboat.

Figure 1: First impression design

1.2 Motivation

The decision to select a suitable project, which covered all our skill sets, was a difficult one out of the 15 project proposals. The final choice was to design, manufacture and deliver an autonomous sailboat to a client who specializes in the field of autonomous systems. The motivation for our team decision is based on several conditions, listed below:

- **Team Contribution**: It takes a lot to make people a winning team. Everybody's contribution is important and this is vital in achieving our combined goal.
- **Innovation**: For good ideas and true innovation, you need human interactions, conflict, argument and debates. This is something we all possess as a team and through thick and thin we will achieve new heights with this project.
- **Challenge**: Overcoming a problem takes time and effort but more importantly team support. The cooperation each member plays in our team will contribute to our overall success and each individual will be supported throughout to overcome any challenges faced.

<u>Team members also had their say:</u>

- **Roberto Giordano:** "*I selected this project to better understand an ancient but still modern mode of transportation, traditional and common but also exciting. With this project I can improve my practical skills and work on something tangible and that can be useful for everyday life*."

- **Gizem Oztruk:** "*I choose this project because it was really interesting to build a boat and it will provide me a different perspective, as an introduction to unmanned vehicle technology. Moreover, i will see many*

different pieces working in harmony. It will improve my qualifications as an engineer and it proves that we can work together as a team and achieve new limits."

- **Gary Jonathan Rabone:** "*I chose the project due to its challenge and relevance to my field of study, furthermore its appeal was grown by working with an accomplished institute in the autonomous control system sector*."

- **Marc Navarrete Hill:** "*I selected that project because I immediately recognized that I could implement all the design skills that I have currently studied during my advanced education and moreover because the sea is one of my passions and always wanted to design a naval mode of transport*."

- **Imre Asztalos:** "*Every summer I go sailing so this project was very attractive since it is one of my favorite hobbies. I'm looking forward to using my sailing and electronic knowledge in this project. I think this project is not easy, but it will be a very good experience for all of us in the team*."

- **Thies Gunther:** "*The project was appealing I had the feeling that in our interdisciplinary team everybody could contribute to the project. Due to the fact the technology of the autonomous sailing is relatively new, we all can benefit from the knowledge of new technology*."

1.3 Problem

Although none of our members is specialized in naval engineering, we felt that there is a strong market need for autonomous sailing boats. There is a high interest in doing research missions in all different water environments and doing this autonomously would enhance our possibility in the market. Therefore we have to first think about the actual mission that the boat has to fulfill. Based on this we need to define the dimensions of the boat and select the best and cost efficient material. Meanwhile we have to research the best possibilities to design the hull and start off with calculations as well as simulations to ensure safety and stability of the boat in its diverse environments. Doing so, we will take into account the size of the sail and the total weight of the boat to ensure the maintenance of buoyancy in any rough water surrounding. Lastly there is the aspect to guarantee a steady power supply to be autonomously and accomplish its long-term missions.

1.4 Objectives

The objective of this project is to build a boat that has the ability to store and collect data in a changing environment. The boat shall be able to stay in a prior defined area for a extend periods of time. The environment can be any possible body of water such as ocean, lakes or river. The focus is to design a boat that is extremely stable and reliable when completing its various missions. It is key for the modular design of a control system that is adjustable for different sensors or even cameras. The sail shall consist of a rigid wing-sail and the boat shall not exceed the dimensions of 3 meters. Due to an easier navigation it only consists of one rudder. Furthermore we have to find different power supply solutions to ensure a constant functioning of all electrical components. Besides we will have to do a market research to find prospective clients and purposes that our boat will be able to fulfill. Our target is to design a boat that is, in respective to sustainability, environmentally friendly.

1.5 Requirements

There are a number of requirements that the boat must be adhered to:

- The boat has to withstand adverse environmental conditions while in operation.
- It must be unsinkable and retraceable if damaged.
- Backup motor system fro zero wind conditions.
- Capable of venturing on missions for extensive periods of time.
- The boat must comprehend and accommodate autonomous components such as sensors for wind, depth, current and location.
- Single rigid sail and single rudder boat.
- The boat must operate in a certain area.
- Sustainable methods of power through the environment. (wind, solar, current)
- A 1:1 scale model must be designed, **(1)** Styrofoam prototype **(2)** Final product.

Comply with the following EU Directives:

1. Machine Directive (2006/42/CE 2006-05-17);

2. Electrical Safety: Low Level Voltage Directive (2006/95/CE 2006-12-12);

3. Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive (2002/95/EC 2003-01-27);

Mandatory adoption and use of the International System of Units (The NIST International Guide for the use of the International System of Units).

1.6 Functional Tests

The model and final product will be subjected to a variety of tests to ensure its integrity in its requirements to for fill the desired roles of the client. The main tests that will be undertaken are buoyancy for the hull and lift on the sail. We are also going to test the boat as a whole to ensure these functional test cooperate to allow the boat to be fully functional. It is a necessity to have to check if all the

used components are correctly positioned and assembled during these tests to avoid inaccurate data.

1.6.1 Buoyancy Test

Conducting this test will validate our boat design from geometry and weight predictions from materials and components. This test we will use the water tank in the LSA laboratory. The main idea is to see if we balanced our boat the right way and if the material used is causing appropriate buoyancy. The boat will have a prefixed maximum capacity of 'X'kg, to ensure our boat is viable in this test we will fill the boat with 'X'kg+5kg as a tolerance, this will validate that the boat will float when exceeded weight is applied. This test will ensure if the boat will accept any future upgrades to components of unexpected weight. The keel and hull have to be calculated and designed the right way as our learning outcome of the state of the art chapter taught us.

1.6.2 Sail Lift Test

This test will consist of the rigid wing-sail stalled in position with a variety of weights applied to a pulley. The lifting force will be calculated from the amount of weight it can lift off the ground. The driving force will be a fan obtained form LSA to adjust the lifting force in particular angles and positions, the fan will be positioned to cover the maximum surface area for the initial test. This will ensure the rigid sail is functioning correctly and also giving the boat an appropriate velocity. We have to make sure that this is done in a secure area so we do not lose the boat or it will be destroyed in the first place.

1.6.3 Boat/Sail Maneuverability

This final test will validate the product to the customer and shareholders as a success. The test will consist of the assembly of hull and sail finalizing the boat, it will be subjected to a body of water and controlled via fans positioned in different areas. The boat must maneuver through a subject area without deviating from the path to be considered successful. This test will take a vast

amount of preparation and teamwork to be achieved. The help of LSA will be greatly appreciated as a expert body to oversee our test.

1.7 Use Cases

Figure 2 Storyboard I

Figure 2: Requirements

Figure 3 Storyboard II

Figure 3: Use cases

1.8 Project Planning

Figure 4 displays our alternative Gantt chart

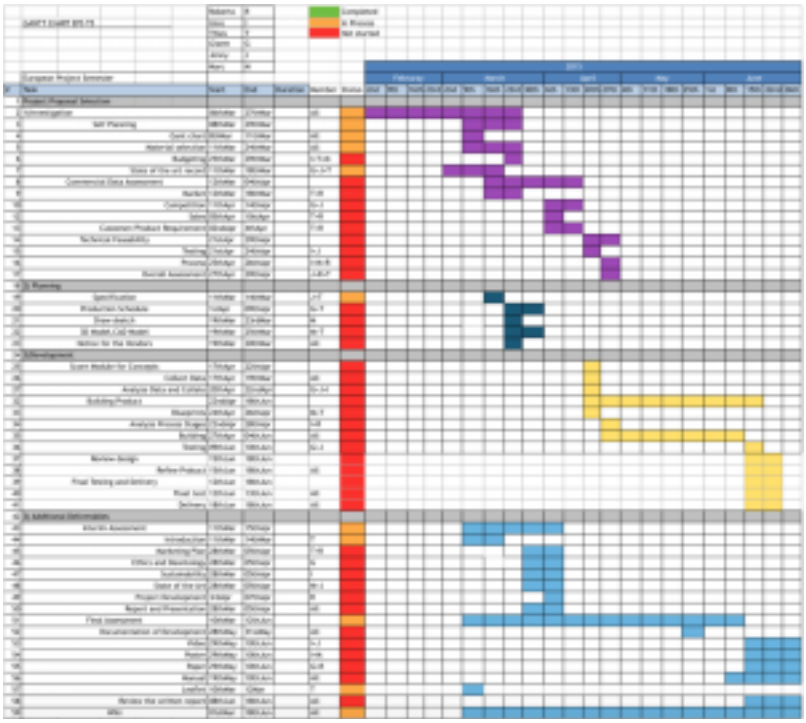


Figure 4: Activities to be carried out

Table 2: Task Allocation

Task	Responsible
Gantt Chart	Thies, Imre
Leaflet	Thies
Research materials	Jonny, Marc, Gizem and Roberto
State of the Art	Roberto, Marc, Jonny, Imre, Thies
Project Management	Jonny
Marketing Plan	Thies, Roberto
Logbook	Jonny
Sustainability	All
Ethical and Deontological Concerns	Thies
Project Development	Thies

Investigation	All
Team Presentation	
Final Presentation	
Interim Report	
Final Report	
Development	
Functional Testing	

1.9 Report Structure

Table 3: Report Structure

Task	Description
Introduction	Consists of a team presentation and the motivation for choosing the project. Furthermore it states the objectives, planning, requirements and the problem that we face.
State of the Art	Should give an overview of the mechanical principles and design basis for constructing a sailboat.
Project Management	In this chapter we will outline the planning of the project ensuring a successful ending.
Marketing Plan	This chapter will consist of an analysis of potential market segments to guarantee a long lasting and profitable surviving in the market of autonomous sailboats
Eco-efficiency Measures for Sustainability	We will try to manufacture eco-efficient and sustainable for protecting the environment. Therefore we concentrate in this chapter in finding the best solutions for doing so.
Ethical and Deontological Concerns	We want to operate ethically correct in terms of setting up a business and therefore we will analyze how to achieve this goal.
Project Development	This part of the report will describe the development of our project throughout the semester.
Conclusions	Summary of our learning outcomes and the final prototype.

2. State of the Art

2.1 Introduction

In this chapter we are going to build the basis for understanding and proceeding with our project. We will point out the main ideas and concepts of sailboats and there design. Firstly we will concentrate on the different components of a sailboat such as the hull, mast, sail, keel and the rudder. This will be done by a comparison of the mainly used types and explanation of the principles how these components work on a sailboat. Later in this chapter we focused on the mechanical principles of a sailboat with its hydrodynamics, aerodynamics and equilibrium in both a static and dynamic environment. Our knowledge is based on books on yacht design principles and scientific papers found online. The end of this chapter will contain a conclusion summing up our investigation outcomes and providing design solutions for our project.

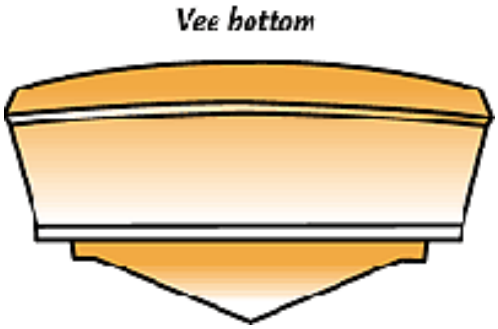
2.2 Boat Components

2.2.1 Hull

A hull is the watertight body of a ship or boat. Above the hull is the superstructure and/or deckhouse, where present. The line where the hull meets the water surface is called the waterline. The structure of the hull varies depending on the vessel type. Traditional sailboats are monohulls, but multi-hull catamarans and trimarans are gaining popularity.

Hull types

Table 4: Hull designs

Type	Description
Flat Bottom Boat 	Flat bottom boat - These boats are generally less expensive to build and have a shallow draft (the part of the boat that's under the water). They can get up on plane easily but unless the water is very calm they tend to give a rough ride because of the flat bottom pounding on each wave. They also tend to be less stable and require careful balancing of cargo and crew. Examples of flat bottom boats might be Jon boats, small utility boats, and some high-speed runabouts.
Vee Bottom Boat 	The vee bottom tends to have a sharper entry into the water that provides for a smoother ride in rough water. They do, however, require more power to achieve the same speed. Many runabouts use the vee-bottom design.
Round bottom boat 	These move easily through the water, especially at slow speeds. They do, however, tend to roll unless they are outfitted with a deep keel or stabilizers. Many trawlers, canoes and sailboats have round bottoms.

Multi Hull-Boat 	Catamarans, trimarans, pontoon boats and some house boats use a multi-hull design. The wide stance provides greater stability. Each of the hulls may carry any of the above bottom designs.
Cathedral Hull Boat 	Boats with cathedral-hulls has a distinct modification of the "V" bottom that are called tri-hulls and cathedral hulls. Examples: modern boats usually power driven. This popular hull style has two or more hulls attached closely together for more stability without extra width. The air pocket between the hulls can also help the boat get on plane more easily. Cathedral hull gives a rougher ride in choppy water because of the increased surface at the bow. The side hulls can cause pounding, resulting in a lot of spray.

With these considerations, and after visiting the Sport Clube Do Porto, and in particular the 2.4 metre sailboat we can say that the majority of sailboats have a Vee bottom Hull or Round Bottom Hull with some adjustments for hydrodynamics.

Figure 5 displays the hull of the 2.4 meter sailboat

Figure 5: Hull design of the Paralympic boat

Hull Features

The hull can be described by dimensional quantities as length, beam and draft, or non-dimensional like prismatic coefficient or slenderness ratio:

1. Length overall (LOA) the maximum length of the hull.

2. Length of waterline (LWL) & The length of the designed waterline (DWL).

3. Length between perpendiculars (LPP). The forward perpendicular (FP) is the forward end of the designed waterline, while the aft perpendicular (AP) is the centre of the rudder stock.

4. Rated Length. The single most important parameter in any rating rule. Usually L is obtained by considering the fullness of the bow and stern sections in a more or less complex way.

5. Beam (B or Bmax). The maximum beam of the hull excluding fittings, like rubbing strake.

6. Beam of waterline (BWL), The maximum beam at the designed waterline.

7. Draft (T), The maximum draft of the yacht when floating on the designed waterline. Tc is the draft of the hull without keel.

8. Depth, The vertical distance from the deepest point of the keel to the sheer

line. Dc is without the keel.

9. Displacement could be either mass displacement (m), or the volume displacement (V). It is the weight of water equivalent to the immersed volume of the hull.

10. Midship section. For ships, this section is located midway between the fore and aft perpendiculars.

11. Maximum Area section, the maximum area section is usually located behind the midship section. Its area is denoted Ax (Axc).

12. Prismatic coefficient (Cp). This is the ratio of the volume displacement and the maximum section area multiplied by the waterline length, Cp= Vc/ (Ax*Lwl).

13. Block coefficient (Cb), The volume displacement is now divided by the volume of a circumscribed block Cbc=Vc/(Lwl*Bwl*Tc).

14. Centre of buoyancy, the centre of gravity of the displaced volume of water. Its longitudinal and vertical positions are denoted by LCB and VCB respectively.

15. Centre of Gravity, The center of gravity must be on the same vertical line as as the centre of buoyancy.

16. Sheer line, The intersection between the deck and the topside.

17. Freeboard, The vertical distance between the sheer line and the waterline.

18. Scale factor, The scale factor is simply the ratio of a length at full scale to the corresponding length at model scale.

Figure 6 shows the main dimensions measured of a hull.

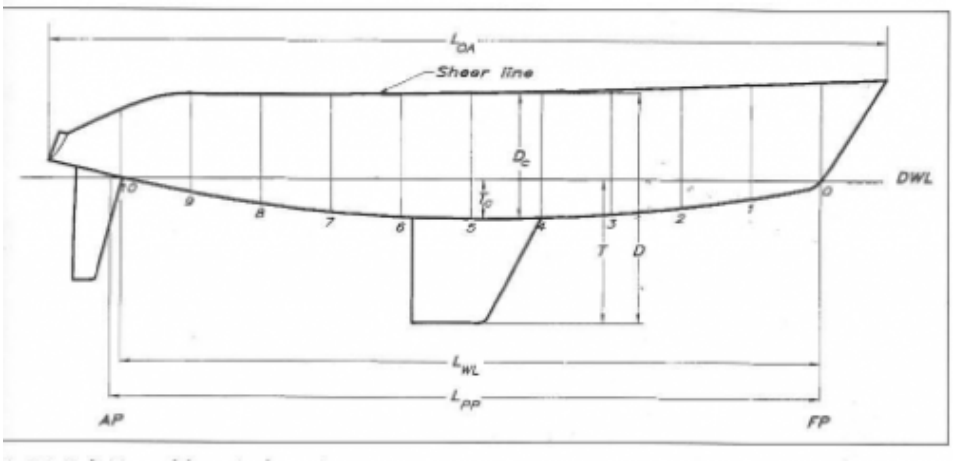


Figure 6: Hull measurements [Priciples of yachts design, Larsson Rolf and Eliasson, 2000, pag.5]

Main Forces

When the hull is driving through the water, a resistance is developed. Under equilibrium conditions, when the yacht is sailing at constant speed, in a given direction, the resistance has to be balanced by a driving force from the sails. Unfortunately, this cannot be created without at the same time obtaining a aerodynamic side force, which in turn has to be balanced by a hydrodynamics side force. The heeling moment from the aerodynamic force is balanced by the righting moment from the buoyancy force and the weight. In Figure 7 the apparent wind a fat arrow marks direction. This is not the true wind direction, since the wind felt onboard the yacht is influenced by its speed through the air. The wind created by the yacht speed is opposite to the arrow shown as yacht speed in the figure.

Figure 7

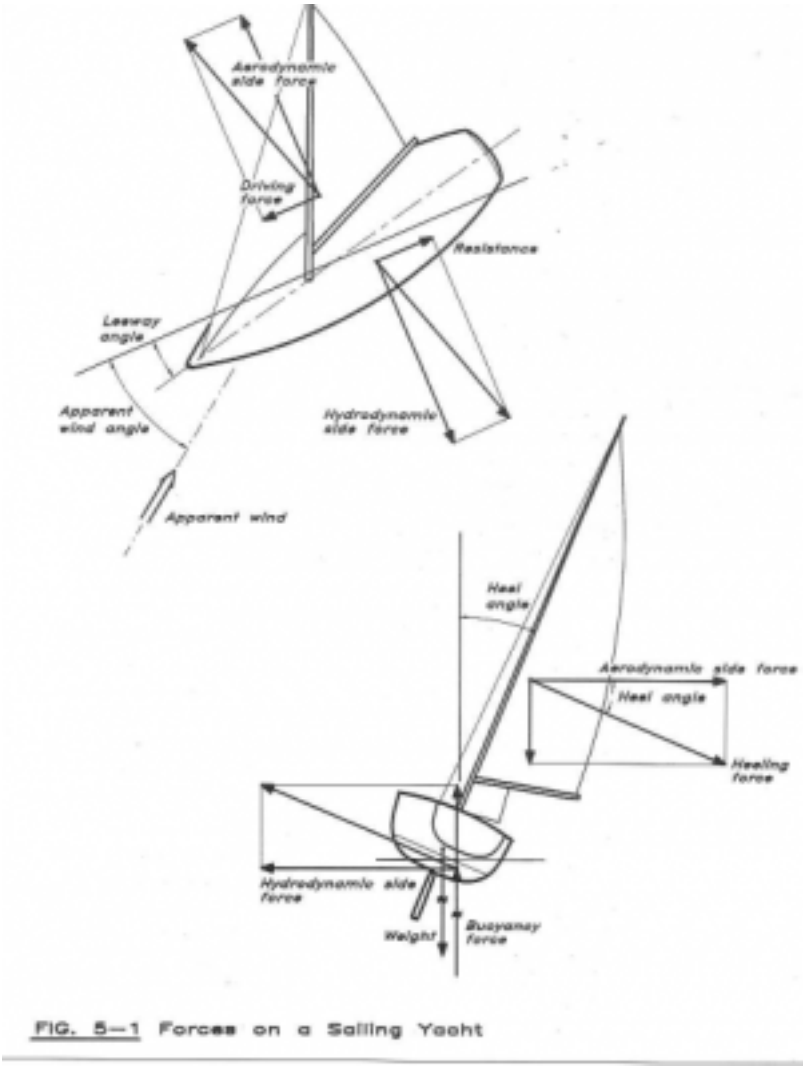


Figure 7: Forces on the boat[Priciples of yachts design, Larsson Rolf and Eliasson, 2000, pag.17]

Resistances

At low speed the dominating component is the viscous resistance due to frictional forces between the hull and the water. The friction gives rise to turbulence of different sizes, which contain energy left behind the hull in the wake. This component increases relatively slowly with speed, as opposed to the second component, the wave resistance, which occurs because the hull generates waves, transferring energy away. The sum of viscous and wave resistance components are the upright resistance.

- Viscous Resistance

The molecular forces between the hull and the water are strong enough to stop the relative motion in the innermost water layer. The part of the flow within the hull and the point in which the water velocity have the ship speed is called boundary layer. Near the bow the flow within the boundary layer is smooth. The velocity in one layer is slightly larger than in the layer just inside. After a certain distance from the bow disturbances start to occur, and shortly thereafter the flow structure breaks down into a seemingly chaotic state: turbulence. The boundary layer is now characterized by eddies of different sizes and frequencies. The fluctuating velocities caused by eddies are, however considerably smaller than the mean velocity at all points in the boundary layer, so the flow is moving backwards. A special region can be distinguished in the inner part, called the viscous sub layer. It plays an important role, particularly in connection with surface roughness. In the viscous sub layer the flow is mainly laminar, but is sometimes disturbed by turbulent bursts, located at isolated spots, moving downstream with the flow. The region where the flow changes from laminar and turbulent is called the transition region and is very short. The viscous resistance can be divided in three parts:

1. The direct friction on the smooth surface
2. The pressure imbalance between the fore and after bodies
3. The increase in friction due to surface roughness

The frictional resistance can be calculated by:

$$R_f = c_f * 0.5 * \rho * V^2 * S_w$$

$$where\ c_f = \frac{0.075}{(Log(R_n)-2)^2}$$

V is the velocity of yacht in m/s, v is the kinematic viscosity and Sw is the wet surface. A slightly lower pressure is found at the stern, giving rise to the resistance component, which is indirectly caused by friction, through the boundary level. It is in the range 5-10% of the direct frictional force. This value depends on the slope of the diagonals that need to be about 25°. In order to minimize the viscous resistance the hull should have a shape like a cod, but very slender. The Cp should be less than 0,5 and the LCB should be positioned in front of the midship section. We can assume the viscous pressure is 10% of the friction, which is a reasonable figure.

- Wave Resistance

When a boat is into the water create a wave system with well-defined properties, called the Kelvin wave system, and is due to a traveling point disturbance on the water surface. There is a very simple relation between wavelength and traveling speed for surface waves. Since the wave system travels with the yacht, at the same in the longitudinal direction, the length of the generated waves will depend on the yacht speed.

$$wavespeed = \sqrt{((g * \lambda)/2\pi)}$$

where λ = wavelength. After this the wave resistance can be calculated with a coefficient table depending on water plane area, displacement, length on waterline and beam on waterline.

2.2.2 Mast

To begin: the area of the fore triangle is not greater than 1.6 times the area of the mainsail. The sail area is greater than the righting moment divided by 128 times the heeling arm.

1. To calculate the rig we begin calculating the righting moment RM at 30° of heel in fully load condition.
2. From the formulae we get the transverse load values of T_1, T_2, Thead, Tboom.

Where, a1 =

$$T_1 = R_m/a_1$$

$$T_2 = R_m/a_2$$

$$T_{head} = 0.40T_2$$

$$T_{boom} = 0.33T_2$$

$$T_{hu} = T_{head}d_1/(d_1 + d_2)$$

$$T_{bu} = T_{boom} * BD/l_1$$

1. With this values calculate the dimensioning forces F1, F2, F3 depending on on the number of spreaders, in Load case 1 and in Load case 2.
2. Calculate the tensions of the shrouds in Load Case 1.Pd1, Pd2, Pv1, Pv2, Pd3.
3. Calculate the tensions of the shrouds in Load Case 2.Pd1, Pd2, Pv1, Pv2, Pd3.
4. Choosing the maximum value we get the dimensioning shroud forces: Pd1,

Pd2, Pv1, Pv2, Pd3.

5. Get the dimensioning forces Pfo and Pa.

6. Knowing the material of the mast and the way it's stepped, Calculate for each panel's transverse moment of inertia Ix.

7. Calculate the required longitudinal moment of inertia Iy.

8. Entering values we get the requirements for the boom's section modulus.

9. Entering values we can pick the relevant shrouds, stays and rig component, and the dimensions.

All the formulae are provided in the book " Principle of Yacht Design" and are referred to a normal sail. However they could be adapted for our Wing Sail.

2.2.3 Sail

For the design of our boat we decided to use a rigid sail. One of the benefits of using a single sail is the easier control by a micro-controller. Additionally the increased controllability has the effect that the boat can safely stay for a long time alone offshore. As a result we searched for different rigid wing sails to understand the newest technologies and decide upon the most profitable for our boat. We have attached some examples of these sails below:

The AC72 Catamaran (Oracle Team USA)

The rigid wing sail of this catamaran is 130 feet (40 meters) tall. Flaps on the trailing edge provide lift and consists of multiple segments to shape the wing in order to match the wind and control the power. [32] These classes of catamarans "AC72" or its smaller versions "AC45" are using a special design for their wing sails, which enables them to achieve top speed up to 1.6 times the speed of the wind sailing downwind. This is possible because the increasing speed lifts the catamaran out of the water. As the drag through the water reduces as well, the boat will hardly touch the surface of the water anymore. [33]

Figure 8 displays the oracle catamaran sail

Figure 8: AC72 Catamaran sail

Wally Omer Wing (WOW)

- High performance in terms of boat speed and heading angles.
- Ease of handling by one person only, whatever its dimension is.
- Lowering and reefing characteristics.
- Reducing and simplifying the boat structures thus improving the interiors.
- Simple, safe and reliable.

The WOW Sail increases the performance by 10-30 per cent in any condition, depending on the displacement of the yacht: the lighter the boat is, the more efficient the wing sail is.[50]

Figure 9 shows the WOW Sail

Figure 9: WOW sail

X-Wing Wingsails

These sails are made of foam reinforced with sheet aluminum and plywood and are covered with clear heat-shrink plastic. The forward piece has an aluminum spar inside and a custom base with blocks for wing adjustment. The aft section has a T shaped control bar on the bottom that is used to trim the wing and a block beneath for the mainsheet. The top of the forward wing section has a knob toward the aft edge and the aft wing section has a tab with a hole that rests over the knob. It is secured with a pin and bolt at the bottom. A single line rigged as a continuous loop controls the angle between the two wing sections. Release the cleats and pull on one side while easing the other and the aft wing section will move relative to the forward section, establishing the overall shape of the wingsail.[51]

Figure 10 pictures the X-Wingsails

Figure 10: X-Wingsails

Harbor Wing Composite

The design was realized using a variety of composite materials selected to combat the harsh marine environment and minimize weight. High-modulus HR40 carbon fiber material was selected for the stub axle to provide maximum tensile stiffness. The wing sail and tail parts are each fabricated in one-piece, on male mandrels, using E-glass wet out with epoxy resin and are cored with either Corecell styrene acrylonitrile (SAN) foam or aluminum honeycomb. Aramid fiber was incorporated into the wing leading edges for added impact resistance, and some carbon fiber was used in locations that required extra stiffness. The bulkheads are flat carbon fiber/epoxy plate stock, which is CNC-machined to shape. The wing tail arms are simple carbon/epoxy tubes. Secondary bonding was accomplished using epoxy.

Figure 11 displays the Harbor Wing Composite

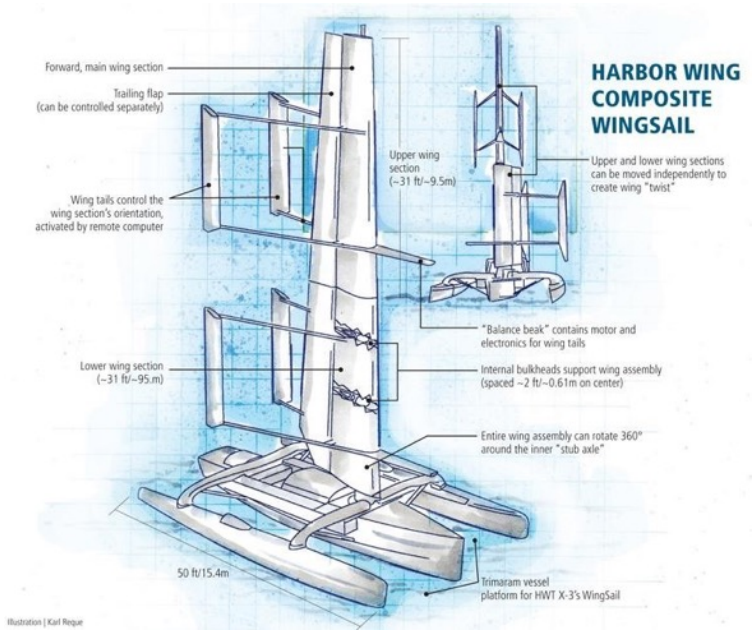


Figure 11: Harbor Wing Composite

How a rigid sail works? Figure 12

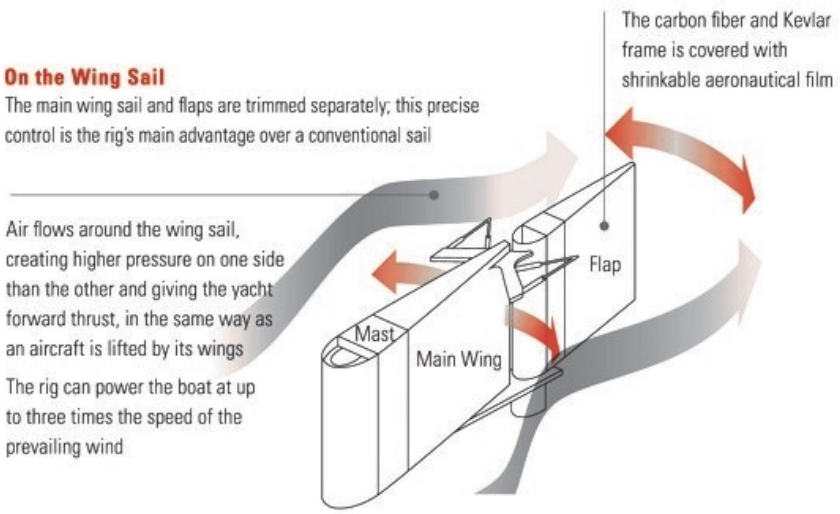


Figure 12: Functioning of a rigid sail

2.2.4 Keel

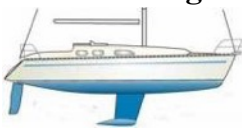
Table 5: Keel designs

Type	Description	Advantages	Disadvantages
Long or full keels 	These types of keels are built as a part of the boat's hull, which make them extremely robust. These boats usually are slow and need a large spread of sail to move, especially in light winds. However, these boats have a comfortable motion in a seaway and track readily.	A sailboat with a full keel tracks more easily through the water, moving forward with less swinging off course due to wind gusts and wave action. A full-keel boat generally also has a more sea-kindly motion.	Full-keel boats are slower to turn when the rudder is moved and may be difficult to tack (turn across the eye of the wind) in light wind. Because the larger surface area below the waterline causes more drag, full-keel boats are also usually somewhat slower than boats of the same size with a fin keel.

Encapsulated fin keels 	These types of keels greatly improved maneuverability due to the separation between it and the rudder.	With less wet surface and drag, fin keelboats are usually faster than their full-keel counterparts. With less keel length to resist the turning action of the rudder, a fin-keel boat turns more quickly and usually tacks easily. Most racing sailboats have fin keels (or a centerboard that is similarly shaped).	Because the shorter keel provides less resistance to forces that act to throw a sailboat off course, such as wind gusts and waves, a fin-keel sailboat does not track as well as a full-keel boat and requires more attention to the helm. Its motion may not be as sea-kindly.
Deep fin keels 	These types of keels are so quite efficient to windward, creating more lift and reducing leeway. These keels produce an area of low-pressure flow on one side of the foil and high pressure on the other, so the keel tends to move into the low pressure area, reducing leeway and dragging the boat up to windward.	Deep fin keel is normally considered to have a better grip of the water, and to provide more leverage to balance the rig, therefore is stiffer. It has less wetted surface area than fuller keels and drafts more. The deeper draft makes the boat sail great. In general, the deeper a sailboat drafts, the faster she is.	Less access due to limited depth and grounding.

Retractable keels 	These types rely on ropes and pulleys, or hydraulic rams in some cases, to retract a steel centerplate into a keel housing. Some types operate vertically and others pivot around a pin at the forward end. It provides deep draft offshore and shoal draft when navigating in shallow waters. Another much heralded benefit is the ability to dry out upright, particularly when partnered with a twin rudder design. Nevertheless the added complexity and possibility of failure could outweigh all other advantages.	The centerboard can be raised to decrease displacement to allow the boat into shallower water, and it should swing up and back if it hits the bottom when sailing with it down. In addition, it can be raised for faster downwind sailing or can be partially raised if needed to provide better boat balance.	Provides no (unweight board) or less (weighted board) ballast, compared to a fixed keel, to resist capsizing and ensure recovery from capsize and is less effective than a larger fixed keel at preventing leeway (sideways movement of the boat). The centerboard trunk takes up space in the boat's cockpit or cabin and the pivot and control line involve moving parts those can jam or break.

Twin or bilge keels 	These types are two keels that emerge at an angle from the hull of a sailboat, at or near the bilge. The angle allows the boat to have a shallower draft while still allowing for minimum leeway while sailing. The placement of the twin keels also allows the boat to stand upright when out of the water without additional support.	Twin keels are meant to make sailing safer and easier in shallow or extremely tidal waters while preserving the stability and performance of deep-keel vessels. When sailing upright, twin-keeled boats have shallower draft while, when heeling, twin-keeled boats increase their draft and usually have half their ballast directing downward pressure. These are also said to be safer in downwind conditions as they are more resistant to rolling, and hence should not broach as easily. (Broaching can occur when a boat "surfs" down a wave and its stern gets lifted and pushed by the wave, causing the vessel to turn sharply, and is then rolled over by the wave).	Twin keels are often shown to provide better theoretical performance on paper, and, in realty, are only slightly slower performing when compared with single keels on identical vessels.

Keels with bulbs or wings 	These types of keels are usually made with a high aspect ratio foil that contains a ballast-filled bulb at the bottom, usually teardrop shaped. The purpose of the bulb keel is to place the ballast as low as possible, therefore gaining the maximum possible amount of leverage and thus the most righting moment. It reduces draft whilst minimizing an effect on stability.	The bulb provides more ballast weight without the keel having to go deeper, thus these boats may be sailed in shallower waters. The wings at the trailing edge of the keel provide additional hydrodynamic stability. The greatest advantage of the winged keel is when one is sailing upwind. The greater stability and the side force produced by the horizontal foil allow a racing boat an advantage in conditions that are not ideal to the sail force.	The wing keel has disadvantages for the cruising sailor, to offset that superior shallow draft performance. When a wing keel boat heels, the draught increases and this takes away one of the options available to the skipper who has run aground, deliberate heeling to reduce draught. Another problem with flat bottom wing designs is the tendency for the boat to stand precariously upright when drying out.

[52]

Keel Selection

The main requirement that our boat has to supply is to be as much stable as possible so the keel that we need for our design will be which provides the most floatability to the boat, downing the gravity centre and avoid that it capsizes. To get this there are two different ways. The first one is designing a deep keel, what work against the forces that affect to the sail and downs the centre of gravity increasing the buoyancy, but the problem is that if that keel is too deep the boat will has limitations on sailing near the beach. The second option is to put some weight at the end of the keel, what puts so down the gravity centre without being it so deep a letting the boat navigates everywhere. Furthermore, is really important to don't make the boat too much stable because, in this case, it will be so slow and will have a lazy navigation.

For those reasons, we have decided to put a bulb keel on our boat, with a certain length, which will allows the boat to sail fast everywhere and turn better.

2.2.5 Rudder

Usually symmetrical shapes for the rudder are used to ensure when going straight, that there are no pressure differences between the two sides. If we go with the rudder at a certain angle there will be an asymmetric profile, this angle between rudder and fluid flow is called angle of attack. If we assume a fluid that flows at constant velocity that collides with the rudder, we firstly have two points to mention. These are the stagnation points where the velocity of the fluid is zero. The location of these points depend of the foil section and angle of attack in respect to the flow. To illustrate this you can see these stagnation points "S1" and "S2" in the following figure.

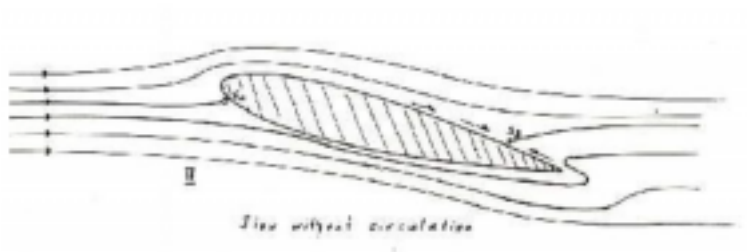


Figure 13: Stagnation points of the rudder

However, when sailing at higher velocities the flow at the trailing edge of the rudder will break away and cause a vortex to arise. This vortex will be between the stagnation point and the trailing edge. The rotation of the vortex will be always against the rotation that develops around the hull of the boat and depending on the viscous forces that are involved in this process. By holding a certain angle of attack, the vortex will break away and the stagnation point of “S2” will move towards the trailing edge. By doing so the velocity differences of the upper and lower stream around the rudder are equalized at this point. There will be no more vortex and the stable flow will cause a lifting force. Figure 14 displays the occurrence of vortex.

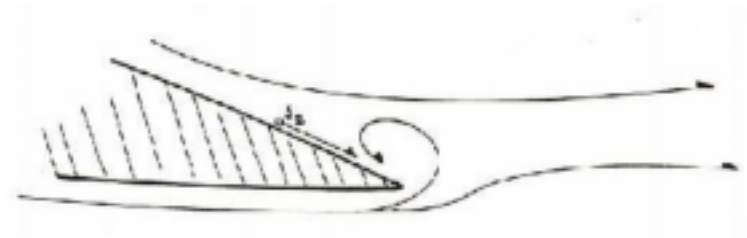


Figure 14: Vortex at the rudder

Figure 15 displays the lift force of the rudder

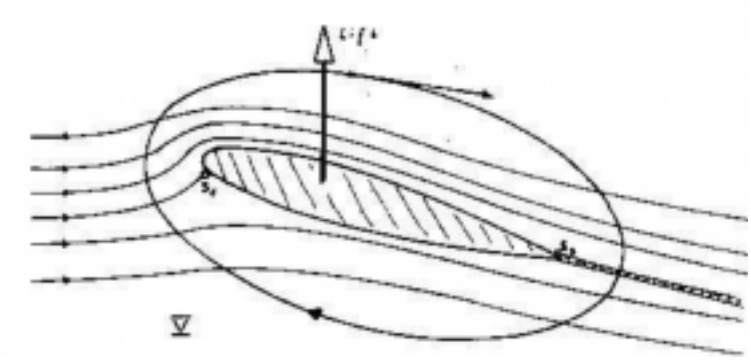


Figure 15: Lift force

This lift force consists of two forces. One that is trying to move the boat in a certain direction and one that slows the boat down, due to acting backwards. The necessary physical basis for creating a lift is, that the upper stream of the fluid particles have to be faster that the ones that flow over the lover surface in order to reach the trailing edge at the same time. Furthermore we have to state that the higher the aspect ratio rudder is, the greater will be the lift created and faster the respond to a change in the angle of attack.

Another force to mention, that effects the performance of the rudder is called drag. Form drag always occurs when a fluid passes a solid object, as a resistance in the flow. This resistance is highly dependent on the shape of the rudder and will be minimized the thinner and smaller the rudder is. Apart from the form drag, we have skin friction. This is caused by surface irregularities of the rudder that slow down the flow of the fluid. To generate a smooth flow, called laminar flow, it is highly deepened on the angle of attack, the skin friction, shape of the rudder, velocity and the density of the fluid. At a certain point the flow will become turbulent which affects the lift created. The point at which the flow becomes turbulent is called transition point and is caused by a slow down in the velocity of the fluid flow around the rudder. The fluid will only accelerate until the suction point and loses momentum along its way.

Figure 16 displays the turbulence and different points causing drag.

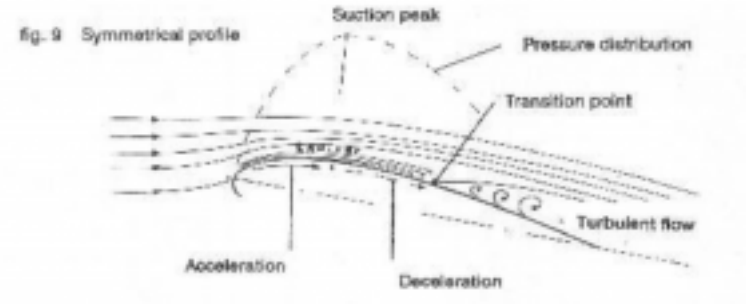


Figure 16: Drag of the rudder

As a conclusion we can state that the longer the laminar flow can be held, the less drag is caused. On the other hand a greater the laminar section of the rudder the earlier it tends to stall. The tendency of greater laminar sections to stall earlier but create a higher lift in small angles of attack can be seen in the following graphs (B has a greater laminar section). C_L is the lift coefficient (y-axis) and the x-axis is the increase in the angle of attack. [18][19]

Figure 17 displays the lift and point where the rudder tends to stall (max. point)

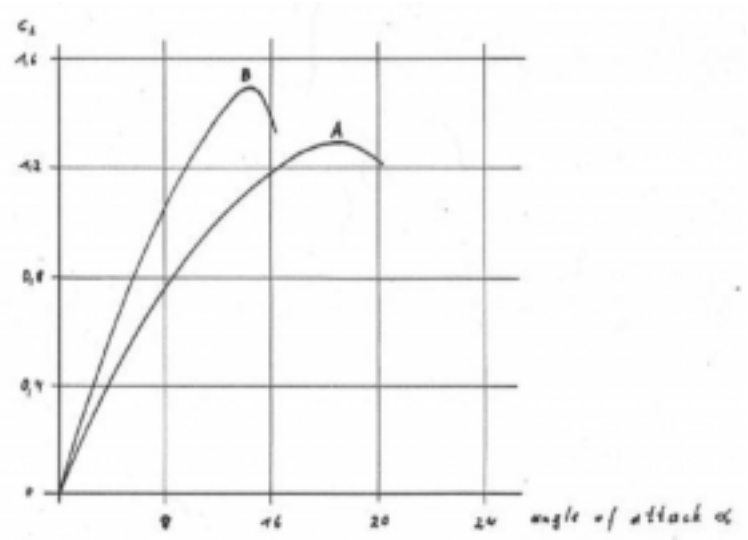


Figure 17: Graph on the lift of rudders

Table 6: Rudder designs [42][43]

Type	Description
Full Keel Rudder 	This type of rudder is directly connected to the keel. It is a continuous surface with the keel. If the boat has a propeller, it is positioned between the keel and the rudder. Positive: The rudder is protected in this shape; the forces on the rudder are better distributed. Negative: It takes more energy to move the rudder, because sideway forces of the water are behind the pivoting point.
Spade Rudder 	The spade rudder is the most frequently used type of rudder. It goes straight down after the hull. It allows rotating the rudder entirely to both sides and pivots around the post. Positive: The force of the water is not only on one side of the rudder when turned. It requires less energy to steer it. Negative: Is more vulnerable towards objects in the water. If the rudderpost gets bent, the rudder may jam and become useless.
Skeg-Mounted Rudder 	It is similar to the full keel rudder and has the same advantages and disadvantages. Mostly used is this type of rudder with the shape of a spade rudder but offering the protection or safety of a full keel rudder.

Outboard Rudder 	The outboard rudder is mounted outside of the hull. Mostly the outboard rudders are steered by a tiller than a steering wheel because it doesn't have a rudderpost. Positive: It doesn't require a hole through the hull, which makes it easier to be mounted. It can be easier removed when damaged or service needed even if the boat is still in the water. Negative: It is easier to be damage by objects in the water i.e. nets, rocks or when running on the ground. The force of water will be always on one side of the pivot point and it will require more energy to turn.
Michalak Kickup Rudder 	Mostly used by small and homemade boats. The designer was Jim Michalak. It is very easy to build and use. It is useful for shallow water because you can turn the rudder upwards, so it will not get damaged. It is good if you sail towards the beach and start there as well, due to the function of the rudder to go upwards.
„Sandwich“ Kickup Rudder 	Designed by Ken Abraham. The blade is in a kind of sandwich between two other boards. It has a pivot bolt through the sandwich layers and the blade.

Rudder Conclusion

As a conclusion about the rudder design we want to use a symmetric spade rudder that is designed after the principle of “NACA0012”. The „NACA0012“ will provide high stall angle and the stall characteristics is gradual because it is less likely to cause cavitation and vibration. Furthermore the symmetric design will guarantee a equal working on the different angles of attack. As the rudder and the keel are working together, the rudder will contribute the necessary side forces for the keel and also will enable the boat to maneuver und all conditions.

The rudder design will have to concentrate on the maximum side force required. This force is proportional to the product of the maximum lift coefficient and the plan form area. The nose of our rudder should be constructed like the purposed a) in the following figure. The graph is showing that the drag is increasing whether the nose is made blunter or sharper. Furthermore the shape a) will give the boat more lift which is essential for turning.

Figure 18 displays the rudder nose

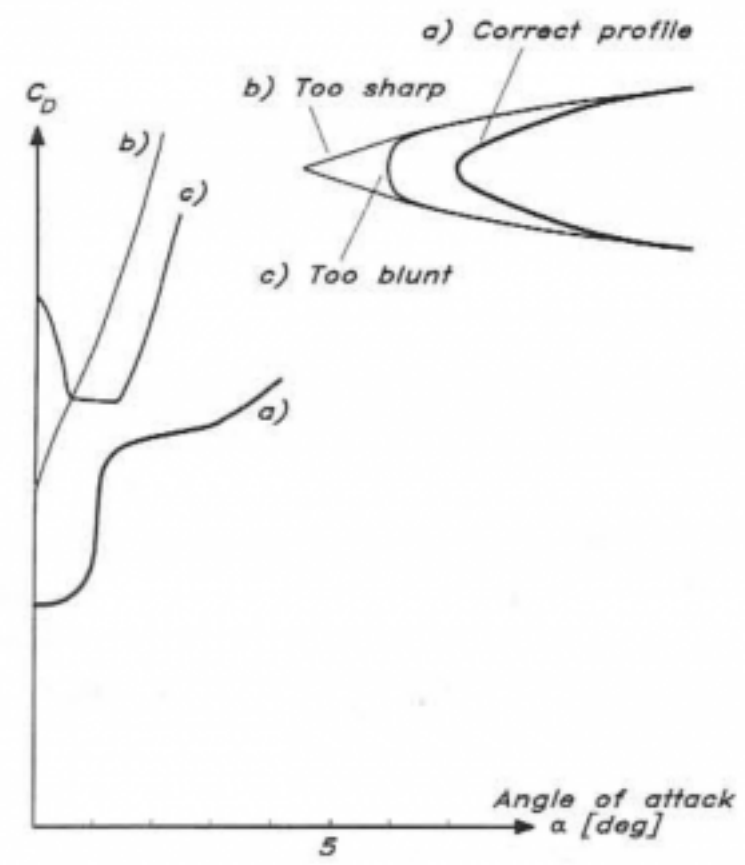


Figure 18: Optimal rudder nose

2.3 Mechanical Principles

2.3.1 Hydrostatics

Hydrostatics considers the conditions of fluids in an equilibrium state, thus when fluid velocity is equal to zero. In these conditions the submerged surface area of the hull is put throughout to different pressures, which are depended on the depth and the weight of the fluid. The hull is not only under pressure from the fluid but due the our spherical planet subjects the hill to a gravitational force from above, this variable changes inversely as the square of the radius from its centre. This variation has a maximum of 0.6%. We therefore neglect the variation of gravity and account it as 9.807m/s2. A special case occurs while dealing with a hydrostatic condition, the acceleration and viscous terms are ignored, and pressure is only dependent on gravity and density due to zero flow or flow at constant velocity. The boat hull has forces applied from above and below. The force from above is gravity forcing the boat down and vice versa from below is the force in a upwards direction is the up thrust created by a higher pressure at a greater depth and finally the weight of the boat is a factor.

The equilibrium of a boat can be analyzed in two steps. Firstly to understand the equilibrium in water, we describe the static equilibrium and from there onwards we will show what dynamic equilibrium means in relation to our autonomous sailboat. The equation has defined of a submerged or floating object has two laws governed by a principle discovered in the third century, they are as follows:

(1) Archimedes' Principle: *"Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object."*

(2) Archimedes Principle: *"Any floating object displaces its own weight of fluid."*[Clifford A. Pickover, 2008]

2.3.2.1 Buoyancy

Archimedes' principles in practice indicate that there is a buoyant force exerted in the bottom surface which lifts the boat up, while the mass of the boat times the gravity are working against it. Imagine if we have a boat floating on the water without wind, tides or currents nor any other distracting environmental circumstance, then the following equation describes the relation between boat and water:

$$M \times g = V_{total} \times \rho_{boat} \times g = V_{water} \times \rho_{water} \times g$$

$$V_{total} \times \rho_{boat} = V_{water} \times \rho_{water}$$

$$\frac{V_{total}}{V_{water}} = \frac{\rho_{water}}{\rho_{boat}}$$

$$\rho_{water} > \rho_{boat}$$

To explain this equation we know that the weight of the boat is a downward force, which acts at the center of mass. Collinear to this force is the force of buoyancy acting upwards on the center of buoyancy. The mass of the boat is equal to its total volume times the mean density of the boat times the gravity. This part of the equation has to be equal to the volume of the displaced water by the boat times the density of the water time's gravity. It is important to mention that the density of the boat is the mean of all different materials used.

For a floating of the boat the density of water has to be always greater than the respective density of the boat to ensure the equation equals 0. If this is not the case the boat will sink. If you imagine to put some weight unevenly on one side of the boat, the boat will sink deeper on one side, which will cause an increase in buoyancy force and equilibrium is retained. The buoyancy force will chance because the center of buoyancy is changing and this causes a greater moment. The condition in which the boat always moves back to is called stable

equilibrium and the movement is called righting moment or positive stability moment.[20]

Therefore, Archimedes' Principles **(1&2)** indicates that the volume of the displacement of fluid is equal to the volume of the boat surface volume that is submerged in the fluid; this also indicates identical weight in both fluid and boat.

Figure 19 displays the forces of buoyancy and weight of the boat at each centers when the vessel is in stable equilibrium.

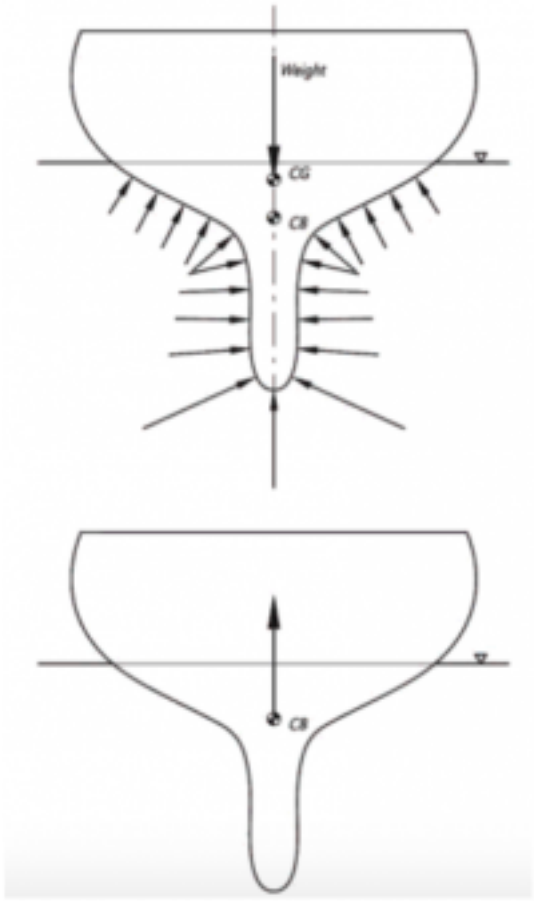


Figure 19: Static Equilibrium

Figure 19: Aero-hydrodynamics and the Performance of Sailing Yachts:The Science Behind Sailing Yachts and ther Design;Fabio Fossati;2009S.324

Water Environment Density and Specific Weight

In our circumstances the boat must be able to be deployed in any environment and for this all water environments must be considered. Due to liquids being nearly incompressible we can neglect the variation in density and assume it a constant in hydrostatic calculations.

Table 7: Task Allocation

Environment	Average Density (kg/m3)	Specific Weight (N/m3)
Sea Water	1020–1029	10,050
Water	1000	9,790

Introduction to Hydrolog. Department of Geography, Okanagan University College., 11 June 2001. (SEA WATER)

2.2.3.2 Stability

After understanding the basics of static equilibrium we now want to focus on forces that we have to take in consideration in a actual environment. Firstly there are forces that could cause a moment along the longitudinal x-axis of the boat. This might be caused by weights unevenly added to one side of the boat or i.e. due to wind and waves. The force(s) will result in a heel of the boat and it will lose its static equilibrium. If the sum of the moments becomes zero, the boat will retain equilibrium at this angle. Furthermore the center of buoyancy will change, due to a change of the mass of the boat under water. See figures: 19 and 20

Figure 20 shows a change in the center of buoyancy

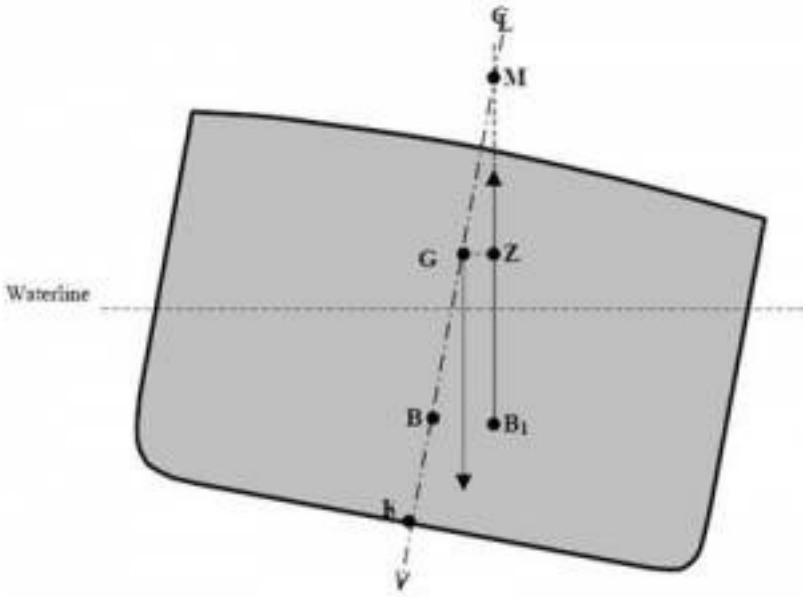


Figure 20: B is the center of buoyancy,

B_1 is the new buoyancy center, G is the center of gravity, and the horizontal line between G and Z is the resisting moment caused by the angle of heel and M the metric center that will be explained later in this chapter

Figure 21 displays the moment along the longitudinal x-axis of the boat

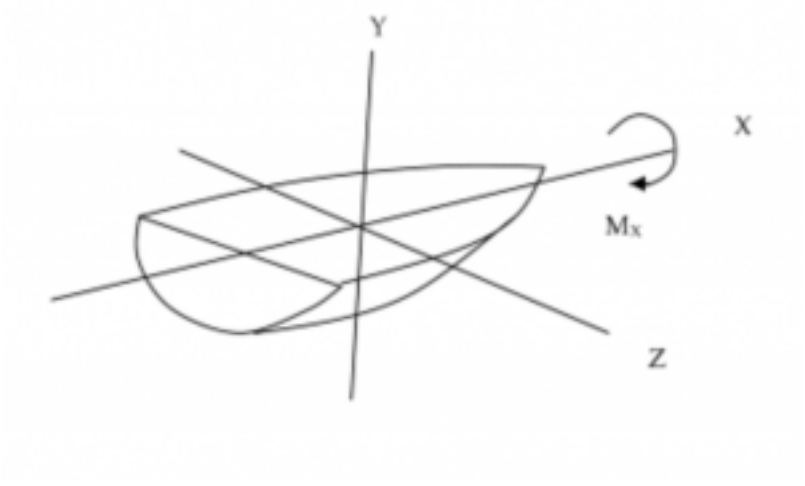


Figure 21: Moment along the longitudinal x-axis

In conclusion we can say there is equilibrium if the forces G and B are equal to zero and the moments along the x-, y-and z-axis are zero too.
If those three equations are satisfied the vessel will always float [21]:

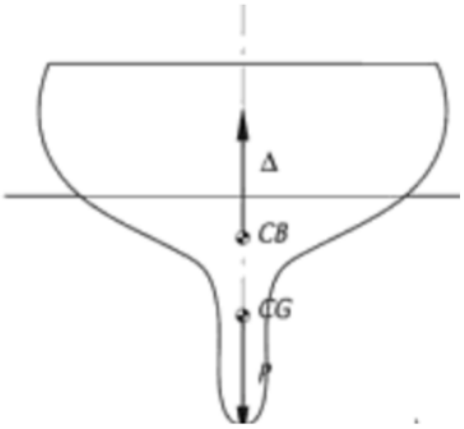
$$\Delta - W = 0$$

$$M_x - M_R = 0$$

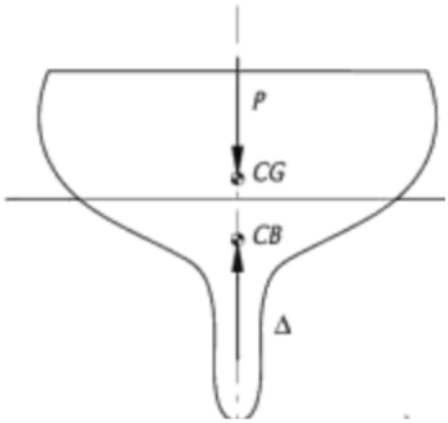
$$M_z - M_P = 0$$

2.2.3.3 Centre of Gravity

Next we want to point out the importance of the centre of mass being as low as possible compared to the center of buoyancy in case of our boat. This refers to the last paragraph about the moments. It is needed to ensure stability and not capsizing as the target is to project a boat that fulfills its long term missions offshore.
If we compare the two possibilities: In Figure 22 we have the center of gravity under the center of buoyancy.



And in Figure 23 we have the center of gravity above the center of buoyancy.



If we now imagine the possibility in Figure 23 that the center of gravity is above the center of buoyancy and the boat will be put under side forces. This will undoubtedly cause that the boat will start to heel as well. At position c) we can still see that the angle of heeling is not big enough so the boat still tends to go back in its original position. If the forces become bigger and situation d) is present, we can see that both centers are in a collinear line. In this position equilibrium is retained again. At this position it is nearly impossible to get the boat back in the sailing position. After this position, with an increasing side force, the next position e) is only temporal. Pretty quickly the boat will lie upside down in the water, see position f).

Aero-hydrodynamics and the Performance of Sailing Yachts:The Science Behind Sailing Yachts and their Design;Fabio Fossati;2009;Page 327-328

Figure 24 pictures the roll of the boat when side forces increase.

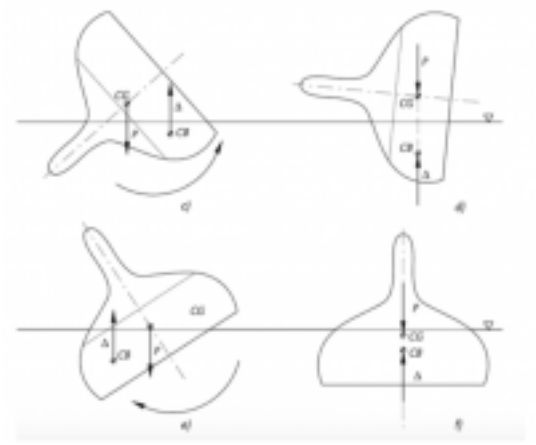


Figure 24: Stadiums of the boat rolling caused by side forces

Underlining this movement we can see in the following figure two graphs. Number one displays the situation when the center of buoyancy is above the center of mass/gravity and it is the other way around in graph number two. If we now compare the stability in a relation between the moment of resistance and the heel angle we can see that the first option is much more stable than the second one. The heel angle is the angle between the waterline of the boat and the surface of the water after the movement towards side. [22]

Figure 25 is the graph on the stability of boats depending on the centers of gravity and buoyancy.

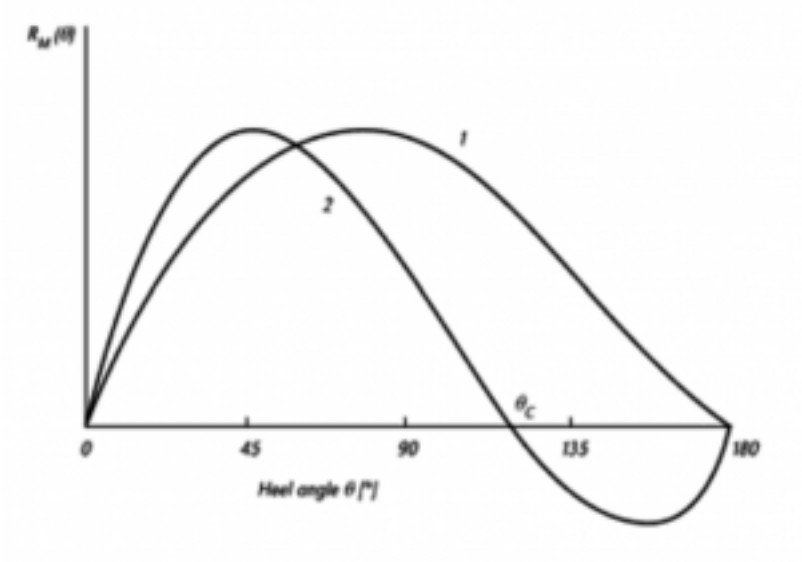


Figure 25: Graph displaying the stability of a boat
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This Figure shows, that the second option is very unstable and tends to capsize faster than the first option. In fact if the R_m is crossing the y axis, than the center of mass and the center of buoyancy are collinear. As shown in the graphs, after option 2 has crossed the y-axis, the moment of resistance is negative. That means the boat has no resistance when totally capsizing it actually enhances turning upside down.

To explain why a boat is capsizing we need to define the term of the transverse metacenter, which is often stated as simply metacenter.

The significant effect of the metacenter is that if it is above the center of gravity, the momentum will right the boat to its former stable upright position. If the metacenter is below the center of gravity the momentum will result in the capsize of the boat.[23] As shown in Figure X the point of the metacenter is at

the intersection of the line of BG and the line of the new center of buoyancy B´. As the righting arm, the distance from G to Z is getting bigger; the larger becomes the distance from G (center of gravity) to M (metric center). For heeling angles not greater than 10 degrees the metacenter remains near constant. The distance of G to M at such small angles is called the metacentric height.[24] „The higher M is above G, the greater will be the value of GM, the metacentric height, and the righting arm, and consequently the greater will be the tendency of the log to right itself when slightly inclined from the upright position.“[25] The closer the metacenter is to the center of gravity, the ship will change its stable equilibrium to a neutral equilibrium, see Figure 26.

In Figure 26 we can see the position of the meta center.

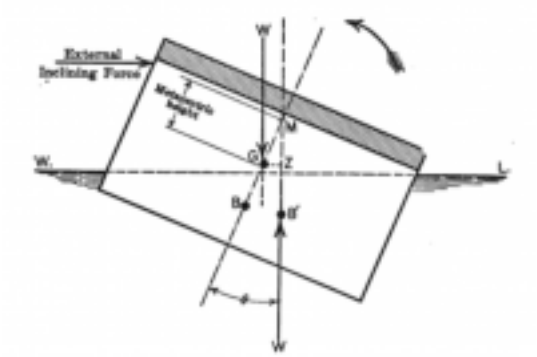

Figure 26: Metacenter

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Figure 27 displays the positions of the meta center and the stability of the boat.

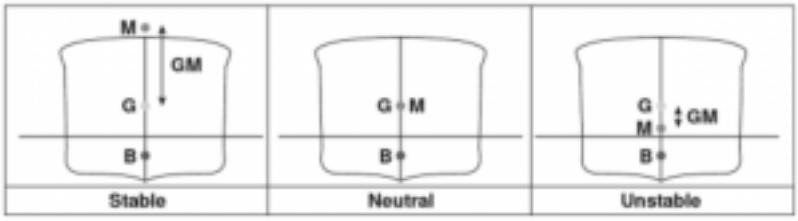


Figure 27: Meta center 2

Reeds Vol 13: Ship Stability, Powering and Resistance; Jonathan Ridley,Christopher Patterson;Page 51;2014

2.3.2 Aerodynamics

The sail is the sustainable driving force of the boat, through the conservation of motion of wind to the sail. The sail controls many aspects of the boat thus vital in the design to ensure correct operation, balance and stability, while controlling both velocity and direction. Primarily the aerodynamic forces apply from differences in air pressure causing normal stress, which act perpendicular to the sail, and air viscosity that causes a parallel shear stress on the entire sail surface. The boat is subjected to six degrees of freedom listed in the next section. The sail is subjected to lift and drag, shown in the figure below:

Figure 28

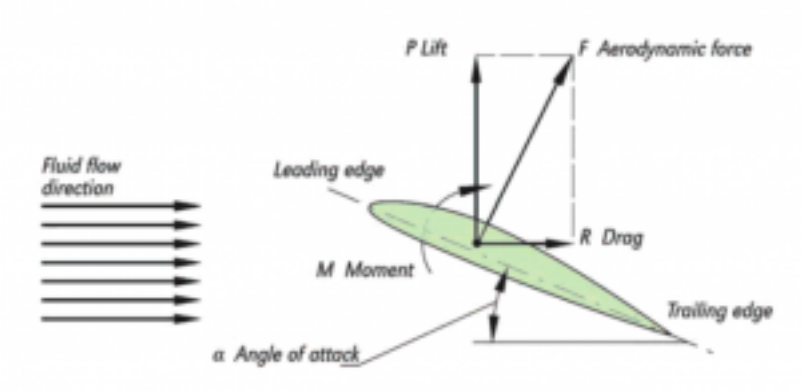


Figure 28: Forces of the sail

Aero-hydrodynamics and the Performance of Sailing Yachts: The Science Behind, Fabio Fossati, Pg31

The image shows indicates all forces applied to a symmetrical section that acts as a wing-sail. It can operate for angles of attack ranging from 0-90o, where lift and drag propel the boat as air pressures pass the winged section. This requires high levels of accuracy from the National Advisory Committee for Aeronautics (NACA) now formally known as NASA, was the leading aeronautics experts who published wind tunnel analysis's of winged section over 60 years.

The NACA wings vary in size and geometry through the years of testing has distinguished sizes by allocating numbers. NACA, if the first two digits 00 indicate the aerofoil is symmetrical and the last two, for example 12, or 12% indicates the maximum thickness of the wing 15% behind the nose. These can vary from 6% to +24%. These NACA aerofoils will vary in our selection for the final design as testing and calculations must be carried out before finalizing a stable wing for the boat.

These aerofoils produce a large quantity of drag but conversely a larger lift coefficient, this lift coefficient or Ct, is in relation to the angle of attack. This can be depicted below for a NACA 0012: Figure 29

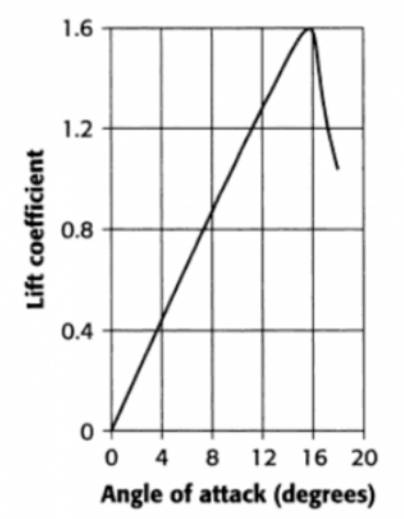


Figure 29: Forces of the sail graph

Aircraft Flight: A Description of the Physical Principles of Aircraft Flight By R. H. Barnard, D. R. Philpott pg 363 31/03/2015

The graph shows a rise and fall of the lift coefficient to a maximum angle of attack up to 16 degrees. This wing gives values of 3 different Reynolds numbers for each section of the wing due to roughness. In this area the wing has an optimum effectiveness at 16 degrees. Although wing sails can operate when it is deeply stalled, the coefficient of lift vs. angle of attack for the range 0 to 90 degrees.

To ensure aerodynamic stability the wing must move freely in the required direction, an additional symmetrical wing stabilizer can be installed on the wing. This allows the wing to balance and stabilize is wind direction and wing orientation changes. The aerodynamic forces are exerted onto the pivots and this brings two forces and moments into existence. These forces must have equilibrium with the stabilizer providing an upward force to balance the combined moments on the wing and on itself and to do this it must make an

angle of attack in the same direction as that of the wing.

The wing and control vane in our circumstance the rudder is capable of producing a force to drive the boat and is simple to switch to change tacks. If mounted on ball races it can respond to slow changes in wind direction. It is then a wing-sail. The wind-sail interacts with the wind to produce lift and drag to drive the boat as the orientation can be changed to accommodate wind forces applied, the wing-sail is much less cumbersome in comparison to a soft sail for our design.

It is possible to calculate the force applied on a wing-sail at any point of sailing if the ratio of lift to drag is assumed, the effect of this ratio can be shown below:

$$ratio = \frac{Lift}{Drag} = \frac{L}{D} = \frac{cl}{cd} = \frac{1}{\tan(a)} = \frac{d}{h} = \frac{distance}{height}$$

It can be seen that lift and drag are both separate equations, firstly the **(1)** Lift Coefficient (Cl) and secondly **(2)** Drag Coefficient (Cd) are both determined on complex dependencies of shape, inclination, and some flow conditions. Both coefficients have been tested extensively which has produced a vast array of Reynolds Numbers for certain airfoil dimensions in wind tunnel conditions.

$$(1)\quad Cl = \frac{2 \times L}{p \times V^2 \times A}$$

$$(2)\quad CD = \frac{D}{\rho \times A \frac{V^2}{2}}$$

These calculations are used to find the driving force of the boat that can be incorporated into the next section of dynamic equilibrium, where the correct scales and dimensions must be ensured for the boat to float and not capsize. When designing the wing it must be noted that there can be no net moment produced by the wing-sail because it is free to rotate on its bearings. The physics behind wing-sails allows it to be a viable concept. We will use the symmetrical NACA 0012 concept as our wing-sail as its concept is considered available. Only the certain modification of the wing for our boat will be required to ensure a more efficient product.

2.3.3 Dynamic Equilibrium

After understanding what equilibrium means in terms of a vessel and what the forces are that prevent a vessel from capsizing, we now have to analyze the equilibrium when wind, currents and tides etc. are taking influence on the sailboat. Whenever the boat is in motion and other external forces are influencing the stability of the boat and it is preserving a point of equilibrium, we call it dynamic equilibrium. If you imagine a boat in the sea when it gets windy and the waves are rising, you actually see that boat rather moving along all directions. It tends to go upwards and downwards, from left to right. Putting those movements into description we can define them as following:
Figure 30 displays what the forces on the boat cause

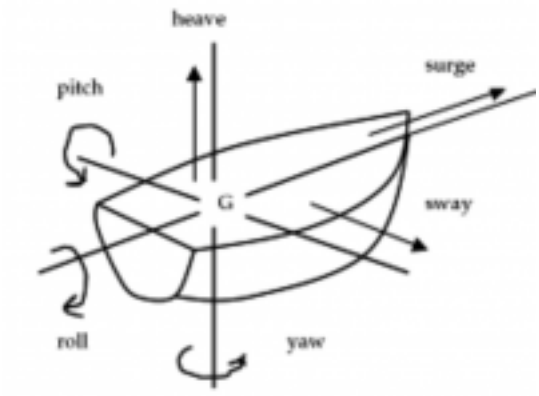


Figure 30: Movements of the boat

So what we can state is that the dynamic forces arise from the relative motion of the boat such as wind and water. Firstly we have the force of the wind which will be called F_A in Figure 32. This force applies directly to a point called centre of the sail plan or aerodynamic center of effort. To make it easier, we say that the center is the geometrical center of the sail, which is not always correct because it highly depends on the direction of wind and the trim of the sail. There are lots of variables to take into consideration. The force has a big component in the direction perpendicular to the wind direction and a small component towards the wind direction.[26] Apart from the aerodynamic forces we have the hydrodynamic forces. These forces occur under the water and are called F_i in Figure 32.

F_i applies to the center of lateral resistance. For simplify reasons it is in the center of the longitudinal center of the submerged part of the boat. If we imagine the boat in motion in water, it the center of lateral resistance will depend on many variables i.e. the position of the rudder and trim of the sail. V_A is the wind speed at and acting angle of ß. This is the course that the sailboat would intend to sail. The speed of the boat is assumed to be V_S.

Figure 31 shows the hydro- and hydrodynamic forces on the boat

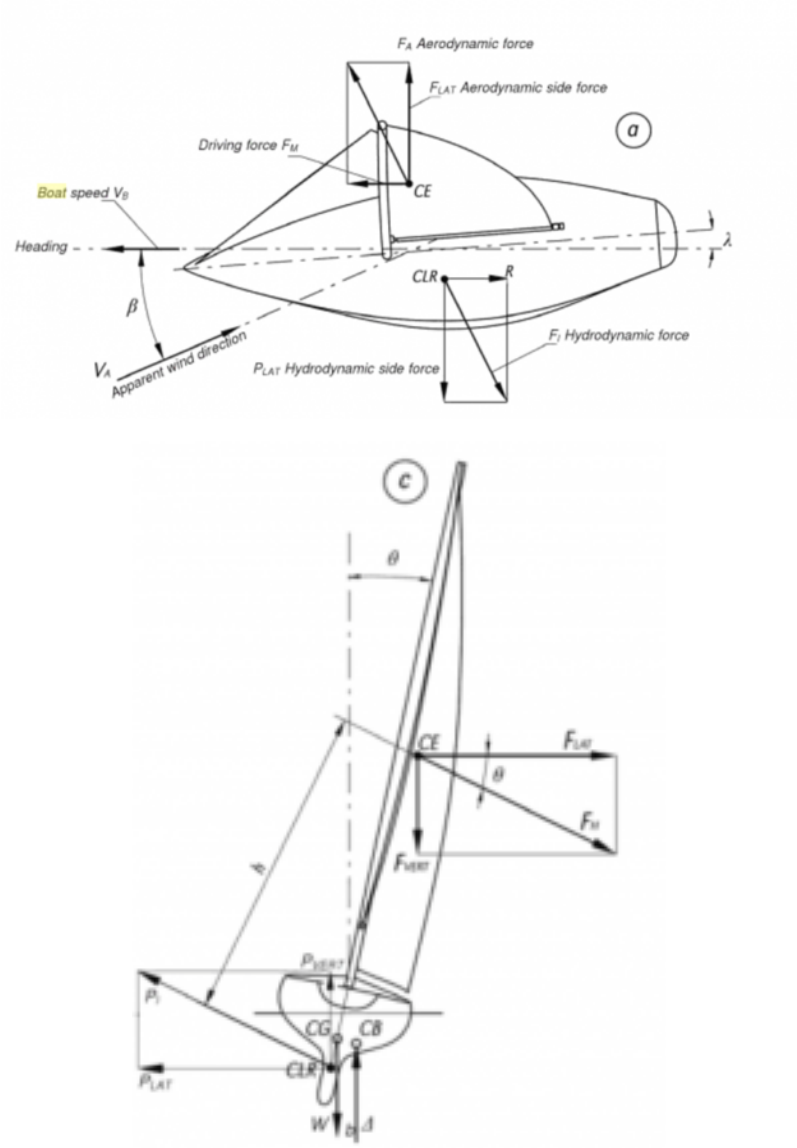


Figure 31: Forces on the boat

The angle of the sail has the purpose to generate the biggest lift and minimize the drag of the boat, depending on the wind speed and angle. When combining the lift and drag force you get the total aerodynamic force as shown in Figure 32. The total aerodynamic force can be divided into the driving force F_M and the aerodynamic side force F_{LAT}. This force F_{lat} is the heeling force. To get equilibrium the hull has to generate an equal force in opposite direction. To get this we can use the rudder and create an angle of attack (Lambda). In conclusion to the dynamic equilibrium we have the forces of the aerodynamic part, the hydrodynamic and the forces acting on the center of gravity and center of buoyancy. To create an overall dynamic equilibrium we have to ensure that:

$$\sum F_x=0 \quad \sum F_y=0 \quad \sum F_z=0 \quad \sum M_x=0 \quad \sum M_y=0 \quad \sum M_z=0$$

2.4.1 Batteries

Batteries can store and provide electricity. Batteries can contain any number of cells, which has a chemical unit inside. There are many types of batteries with different capacities. A battery's capacity is the amount of electric charge it can deliver at the rated voltage in Ampere-hour (Ah) or Watt-hour (Wh).The battery is best suited for our project, due to its capacity. It will store energy generated by solar, sea and wind. Although these forms of natural energy will not be developed in this project they will be fully considered to ensure the boat is fully self sufficient in both sustainably and eco-efficient aspects.
Table 8 shows different types of batteries.

Table 8: Comparison of battery types

	V	Energy Density Wh/ Kg	Charge time (hrs)	High Temp Perf.	Cold Temp Dis. (-17 °C)	Adv	Disadvantages
Lead Acid	2 V	35	8	Good	Good	• Inexpensive and simple to manufacture • Mature, reliable and well-understood technology • Capable of high discharge rates.	• Cannot be stored in a discharged condition • Low energy density • Allows only a limited number of full discharge cycles • Environmentally unfriendly

Ni-Cd	1,2 V	45	1,5	Good	Good	• Fast and simple charge • High number of charge/discharge cycles • Good low temperature performance • Available in a wide range of sizes and performance options	• Relatively low energy density • Memory effect • Has relatively high self-discharge • Environmentally unfriendly
Li-Ion	3,6 V	167	2-6	Average	Average - Good	• High energy density • Relatively low self-discharge • Low Maintenance	• Requires protection circuit • Subject to transportation regulations • Expensive to manufacture
Li-Poly	3,6 V	110	2-6	Average	Average - Good	• Very low profile • Flexible form factor • Light weight • Improved safety	• Lower energy density • Expensive to manufacture

The best battery type for our boat is the Li-Ion battery. It has high energy density, a good lifespan, and less charging hours than the other battery types. [12] [13]

2.4.2 Solar Panel

Solar Panel is a device, which can convert the sun generated electromagnetic radiation to electrical energy. Solar panel is a collection of solar cells, and these cells works together to produce electricity. There are three main solar cell types: Amorphous, Mono-crystalline, and Polycrystalline solar cells.

Table 9 shows different types of solar cells.

Table 9: Comparison of solar cells types

	Picture	Average efficiency	Best efficiency	Warranty	Price	Additional details
Amor		6-8%	13%	10-25 years	0,62 €/W	• Low availability on the market • Cheap • Thin design
Poly		13-16%	20%	25 years	0,56 €/W	• Oldest cell technology • Most widely used
Mono		15-20%	25%	25 years	0,67 €/W	• Less silicon waste in the production process • Most expensive

The best solar cell for our boat is the polycrystalline solar cell. This is the most widely used type, and it has a good energy efficiency, and not too expensive. [8] [9] [10] [11]

2.4.3 Sensors

Sensors are one of the most important measuring elements in the electronics. We use them for different measurements in the control engineering, but nowadays we use it in the consumer electronics too. This measurement is a comparison

between the measured and etalon. There are many types of sensors, but we need only these three sensors: wind sensor, compass sensor, and GPS receiver. [6] [7] [14]

2.4.3.1 Wind Sensor

A wind speed sensor is part of an instrument that is used to measure the speed of the wind and determine wind direction. Depending on the wind sensor we choose, the sensor can also generate electrical energy as a backup supply

Table 10 shows different types of wind sensors.

Table 10: Comparison of wind sensor types

	Picture	Measurement method	Remarks
Cup anemometer		Related to rotation speed of cups	• Proven, robust, reliable and inexpensive • Difficult to extrapolate in complex terrain • Maintenance intensive
Propeller vane anemometer		Related to rotation speed of propellers	• Faster response time than cup anemometer • More expensive than the cup anemometer
Sonic anemometer		Related to time of flight of sonic pulses between transmitter and receiver	• Doesn’t contain moving parts • Capable of measuring wind velocity • Calibration is difficult • Needs strong energy source • Very expensive
AMS AS504X encoders		Related to rotary position (0°-360°)	• Doesn’t contain the connection between the device and the wind • Also useful to measure sail and rudder rotation • Supported by Arduino • Inexpensive

The best wind sensor for our boat is the AMS AS504X encoders. It is very small and cheap, and supported by Arduino.

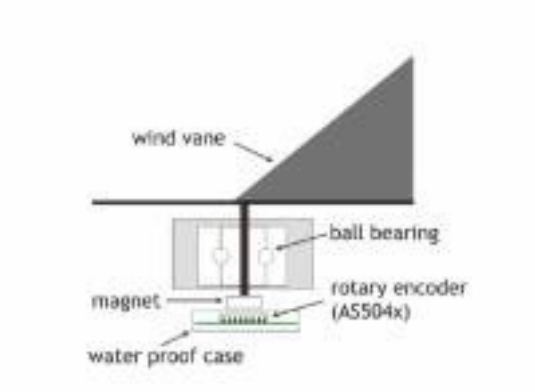


Figure 32: An application of AMS AS504X wind sensor

Figure 33: The wind sensor in real

2.4.3.2 GPS Receiver

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. GPS receiver

compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map. [38] Table 11 shows different types of GPS receivers.

Table 11: Comparison of GPS receiver types

	Pictures	Sensitivity	Supply Voltage	Power consumption	Accuracy	Price
A1084-A		- 159 dBm	3,3 V	85,8 mW	2,5 m	~ 16€
u-blox LEA-6H		- 162 dBm	2,7 - 3,6 V	117 mW	2,5 m	~ 75€
Adafruit Ultimate GPS Breakout		- 165 dBm	3 - 5,5 V	100 mW	3 m	~ 40€
SparkFun Venus GPS		- 165 dBm	2,7-3,3 V	67 mW	2,5 m	~ 45€

2.4.3.3 Compass Sensor

The compass sensor device can be used to determine direction refer to magnetic north. Just like real compass, a compass sensor can be affected by large metallic objects and magnetic interference caused by motors and computers.

Figure 34 displays a compass sensor.

Figure 34: Compass sensor

Honeywell HMC5883L: Triple Axis Compass Magnetometer Sensor Module for Arduino. This is a surface-mount, multi-chip module designed for low-field magnetic sensing with a digital interface for applications such as low cost compassing and magnetometer.

Features and benefits:

• 3-Axis Magnetoresistive Sensors

• Includes 12 bit ADC converter

• Built in self-test

• Low Voltage Operations (2.16 to 3.6V) and Low Power Consumption (100 μA)

• Sensors Can Be Used in Strong Magnetic Field Environments with a • 1° to 2° Degree Compass Heading Accuracy

• Compatible for Battery Powered Applications

• Price: ~ 3€

2.5 Related Work

2.5.1 ASV Roboat

The ASV Roboat is a nearly 4 meter long boat with a 60kg keel ballast to achieve that it is unsinkable. In the year 2008 the ASV 'Roboat' became the first world robotic sailing champion at an event in Austria. It has a 800MHz/512 MB Mini-ITX computer controlling and the software uses Java and C++.
Furthermore it has GPS data for the positioning and can estimate the speed of the boat. Also on board are sensors like ultrasonic wind speed and direction data, tilt-compensated compass, humidity, air and water temperature and water depth. Furthermore the boat has a three-stage communication system combining WLAN, UMTS/GPRS and an IRIDIUM satellite communication system for navigation and tracking. For the energy supply they added solar panels which makes the boat mostly energy independent. As a backup they used a direct methanol fuel cell. [40] The battery bank, solar panels providing up to 285 W of power, a direct methanol fuel cell delivering 65 W for backup power. The sail area of mainsail and foresail together is 4.5 m2.[41]
This project of the ASV Roboat is the closest compared to our project this semester. As their approach was to build an unsinkable boat as well and also won championships with it, we can orientate our project along this boat.

Figure 35 displays the ASV Roboat

Figure 35: ASV Roboat 1

2.6 Conclusion

There is great deal of detail in this section that has been quantified and specified to find solutions for our boat design, it will be further developed in **7.0 Project Development** section. The State of the Art has allowed us to derive the best possible design for the boats requirements, below is a list of features the boat will have as an end product.

- **Sailboat**
- Hull ⇒ Vee/Rounded bottom
- Keel ⇒ Bulb keel
- Rudder ⇒ Spade rudder
- Wing-sail ⇒ Airfoil NACA 0012
- **System**
- Sensors
- Wind ⇒ AMS AS504X Encoders
- Compass ⇒ Honeywell HMC5883L

- GPS ⇒
- Battery ⇒ Li-ion
- Solar Panel ⇒ Polycrystalline solar cell

Although some of these are not getting taken into consideration it is vital to highlight the possible components for future upgrades, which is dependent on product improvement and the client. The system that we will adopt on our boat is a wind, battery and solar panel. These components will allow the sailboat to function at he simplest level on its own accordance. The next chapter will see our skills in project management put to the test from task allocation to budgeting, where several of these products will be scrutinized and removed according to costs. The aim is to manage our valuable time and resources over the entire duration of the project.

3. Project Management

3.1 Scope

The scope for our project is a autonomous monitoring system which is deployed for extensive periods of time in aquatic environments. The project concentration will be solely lie in the development of a functioning sailboat for the autonomous system platform. The boat will be deployed in several environments, to ensure this and a high quality product, we must:

- Fully sustainable, using negligible resources to function.
- Complete user manual.
- Safety for both user and animal/marine life it may impact when deployed.

In addition, the following deliverables have to be developed, documenting the project´s process and achievements: This report, a paper, a leaflet, a poster and a video.

The user manual will incorporate the use of the hull and sail, as our main focus is on this although the finished products will a fully functioning autonomous monitoring system so this must be taken into full consideration when the boat is being designed.

The prototype must succeed in all requirements and functionalities to be deemed successful, allowing it to work and be controlled unmanned is not our objective but as stated before all considerations must be made for this factor. The detailed technical requirements towards the prototype are listed in section **1.5 Requirements**. It is tried to fully comply with the requirements during chapter **7.0 Project Development**.

3.2 Time

Time management is a key matter for the project. It accounts for the deliverables to the clients and incorporates the entire team to achieve the end goal. Shown below the deadlines for deliverables, which were predetermined by the EPS coordinators:

Table 12: Report Structure

Deliverables	**Deadline**
Hand in list of materials	27-03-2015
Upload interim report and presentation	05-04-2015
Interim presentation	09-04-2015
Upload the Final Report, Presentation, Video, Paper, Poster and Manual	12-06-2015
Final Presentation, Individual Discussion and Assessment	18-06-2015
Make final corrections to the report and wiki, according to received feedback	26-06-2015

In addition to these deadlines the team has prepared additional deliverables for our client:

Table 13: Deliverables and Deadline

Deliverables	**Deadline**
Storyboard	12-03-2015
3D Computer Model	23-03-2015
Styrofoam Model	11-05-2015
Prototype/Finalised Model	12-06-2015

Based on these deadline tables, a outline can be portrayed for the quantity of work must be done for the project. The work assignments have been specified and categorized according to the deadline and durations of the deliverables. These tasks are subject to change as computing an accurate plan for such a long duration is demanding; therefore the Gantt chart has been repeatedly revised as the project proceeded.

3.3 Cost

Controlling the project budget is vital for the success or failure, this parameter must be strictly monitored throughout the project. The budget for this project is 500 € and is provided by LSA. The project includes direct and indirect costs, shown below:

- **Direct** – The model and prototype expenses through materials, these will be researched and chosen strictly to maintain a large safety margin and quality design.
- **Indirect** – EPS cover these working condition costs which incorporate facilities and staff such as technicians, professors and supervisors salaries.

The list of materials is yet to be chosen due to a delay our tasks because of calculation considerations have yet to be made in the project. Although the materials have not been selected a projected value of 80 € has been selected and a projected value for the prototype is ranged between 240 €-280 €. This equates to the total approximated amount of money required for materials is at 360 €. This allows for a safety margin of 120 € to be spend on unexpected materials

3.4 Quality

Quality is essential in throughout a products life cycle, from planning to manufacture it contributes several variables to the satisfaction of customers, stockholder, investors and even employee's.

- It begins with innovative designs that we will find the basis of in ISO 12215:2002. The ISO standards ensure a quality product on an international platform this reduces cost and allows the product to enter new markets overseas. Quality control measures will be implemented, both human and technical aspects will be input to the entire process, in particular the manufacturing stage, as inspections will make sure products are finished to the highest procession.
- Group meetings will take place on regular occasions to address any problems that arise over the coming months of the project from over and under allocated tasks to cost management problems.
- Testing the products in the functional tests will certify and validate the quality for the customer and the market. The testing procedure will commence ongoing through the product development, testing circumstances will be strictly monitored to guarantee accurate results and figures. The testing stage will either confirm or de-confirm if the product was successful in completing all requirements for the client while finding solutions to these requirements.

3.5 People

The academically integrated and international Team 5 opted for allocation and delegation of tasks suited to individual strengths within the project. The team members are shown below, followed by a task allocation list:

Roberto Giordano ⇒ Gizem Ozturk ⇒ Gary Jonathan Rabone ⇒ Marc Navarrete Hill ⇒ Imre Asztalos ⇒ Thies Gunther

Figure 36

1	**Sailing Boat**	
2	Control and Monitoring	
3	**Investigation**	
4	**Ideation**	
5	State of the Art	Gizem Ozturk[50%];Jonny Rabone[50%];Thies Gunter[10%]
6	Storyboard	Marc Hill[50%]
7	**Self Planning**	
8	Market	Roberto Giordano[50%];Thies Gunter[20%]
9	Costumer/Product req.	Gizem Ozturk[20%];Jonny Rabone[50%]
10	Sales	Roberto Giordano[50%];Thies Gunter[50%]
11	Competition	Roberto Giordano[50%];Thies Gunter[50%]
12		
13	Gantt	Entire Team[10%]
14	Material selection	Entire Team[10%]
15	Budget	Imre Asztalos[20%];Thies Gunter[50%];Marc Hill[20%]
16	**Boat Building Principles**	
17	Mechanical Principles	Entire Team[10%]
18	Boat Geometry	Entire Team[10%]
19	**Technical Feasability**	
20	Testing	Imre Asztalos[20%];Jonny Rabone[50%]
21	Manufacturing Process	Imre Asztalos[20%];Marc Hill[50%];Roberto Giordano[50%]
22	Overall assessment	Jonny Rabone;Roberto Giordano;Thies Gunter[70%]
23	**Planning**	
24	Specification	Jonny Rabone[20%];Thies Gunter[20%]
25	Production Schedule	Gizem Ozturk[50%];Thies Gunter[10%]
26	Customer talks	Entire Team[20%]
27	Draw sketch	Marc Hill[20%]
28	3D Model, CAD Model	Marc Hill[20%];Thies Gunter[10%]
29	Notice to material vendors	Entire Team[20%]
30	Task allocation	
31	SWOT analysis	
32	WBS	
33	Gantt chart	
34	**Development**	
35	**Score Module for Concepts**	
36	Collect Data	Entire Team[10%]
37	Analyze Data and Collate	Gizem Ozturk[50%];Imre Asztalos[30%];Jonny Rabone[50%]
38	**Building Stage**	
39	Blueprints	Marc Hill[20%];Thies Gunter[10%]
40	Building	Entire Team[50%]
41	Analyze Process Stages	Imre Asztalos[10%];Roberto Giordano[50%]
42	Testing	Gizem Ozturk[50%];Jonny Rabone[50%]
43	**Review design**	
44	Refine product	Entire Team[5%]
45	**Final Testing and Delivery**	
46	Float test	Entire Team[20%]
47	Delivery	Entire Team[10%]
48	**Additional Deliverables**	
49	**Interim Assessment**	
50	Introduction	Thies Gunter[10%]
51	Marketing Plan	Roberto Giordano[50%];Thies Gunter[20%]
52	Ethics and Deotology	Gizem Ozturk[20%]
53	Sustainability	Imre Asztalos[60%]
54	State of the Art	Marc Hill[20%];Jonny Rabone[20%]
55	Report and Presentation	Entire Team[20%]
56	**Final Assessment**	
57	Documentation of Development	Entire Team[10%]
58	Video	Imre Asztalos[20%];Jonny Rabone[50%]
59	Poster	Imre Asztalos[80%];Marc Hill
60	Paper	Gizem Ozturk;Roberto Giordano
61	Manual	Entire Team[10%]
62	Leaflet	Thies Gunter[10%]
63	Review Report	Entire Team[10%]
64	Wiki	Entire Team[10%]

The work distribution has been allocated singularly, pairs and in some circumstances the entire team due to severity of the task. The severity of the task is dependent on the workload and the deadline date. Distributing these tasks among several members of the team will allow the team to make deadlines and if additional assistance is required members can be shifted to complete all tasks on time.

3.6 Communications

Communication in teamwork conditions can define success or failure from oral, written and nonverbal communication, everyone must be involved. Each individual member of our group has a particular way of connecting and transferring information.

(1) Primarily our communication is orally, during face-to-face meetings where agendas and targets are clearly highlighted as topics of interest. In these circumstances healthy discussions and debates can take place and this usually overruns the meeting times but a clear goal has been achieved afterwards. Meetings take place in ISEP facilities and also in other locations pending to member's attendance.

As a group, Team 5 attends weekly meetings with the EPS supervisors. Preparation is required for the meetings, usually questions that are uploaded prior to the meeting time. One member of the team is selected as the speaker to ask these questions to the supervisors. The meeting is recorded via audio and written, later these are collated into the group logbook. Post meeting discussions can be arranged if either the meeting overruns or questions have yet to be answered.

(2) Written communication is used mainly in unsocial hours, when team members or advisors are unable to meet and must contact over the following platforms, from the EPS standpoint and for our clients LSA.

- **EPS**

Table 14: EPS

User	Platform	Operation
Team Members	Whatsapp/ Facebook/Text	Inform the group about meetings, tasks and deadlines
Team Members	Dropbox	Share documents
Supervisors (Fernando)	Email	Arrange meetings for any queries
Supervisors	Wiki	Work progression
Teachers	Email	Submit work and answer student queries

- **Client**

Table 15: Client

User	Platform	Operation
Customers (LSA)	Webpage/ Internet	Showcase the product to attract customers
Customers (LSA)	Leaflet	Showcase our brand and what we aim to achieve
Customers (LSA)	Poster	Show our final solutions to the problem at hand
Customers (LSA)	User´s Manual	Step-by-step guide for use and maintenance of the product

(3) Finally, nonverbal communication is used mainly in team meetings where a team member is confident and trusts in each member, as it is an obligation to complete the tasks for each deadline. This is a usually conveyed in-group meeting when member are disconnected from the matter at hand.

3.7 Risk

Risk management is the act or practice of dealing with risk. It includes planning, identifying, analyzing, responding strategies, and monitoring and controlling the risk factors. Risk should be closely coupled with key project processes, including but limited to: overall project management, scope, schedule, quality and time. (Project Management: A Systems Approach to Planning, Scheduling, and Controlling By Harold R. Kerzner)

Below are the possible risk factors we might face during our project:

Table 16: Risk factors

Risk	Probability (L/M/H) & Impact	Feedback Response
Floatation/ Buoyancy problems	**(H)** If the boat design is not sufficient to float and the hull is not sealed properly water may come inside the body of the hull.	Perform a floatation test with weights exceeding the required weight capacity of the boat. Also seal the hull with a waterproof sealer and test in a body of water.
Sail/Hull design is unacceptable	**(H)** We are developing a wing-sail/hull and have little experience in the aerodynamic/ naval a sector. It is possible that our design doesn't work as expected.	Inspect all possible failures of the wing-sail/ hull with every available expertise. Try to develop an advanced wing-sail/ hull with available materials.
Styrofoam Model does not work	**(M)** The 1:1 scale Styrofoam model is incompatible due to design and features incorporated	Refine design of hull using calculations and ensure pristine testing circumstances
Team work ethic due to absences	**(L)** Depending on illness and recovery time allocated tasks cannot be performed.	If it is a serious situation, the person´s tasks will be redistributed among the remaining team members.

Late for Deadlines	**(L)** Late problems may arise and our team mark will be downgraded.	Ask the supervisors for an extension after explaining the problem that occurred.
Materials are not as expected	**(M)** Calculations were incorrect thus incorrect materials were selected for the Prototype.	Prototype cannot be developed in planned format.

3.8 Procurement

The development and manufacture of a sailboat includes a vast array of components and materials to which we have the responsibility of sourcing quality suppliers for the design. A quality to cost comparison must be made and a final material or component must be selected that will fit the bill of our project. Due to restrictions we were only allowed to use local Portuguese shops and websites however, our client Eduardo Silva from LSA, has stated international purchases may be acceptable but only after his authorization.

Figure 37 displays the dimensions for Project Management

Figure 37: Procurement; http://www.avance-tech.com/uploads/image/Procurement.jpg

Once on a international market, the autonomous sailboat can be developed at lower costs due to higher demands thus affordable supplier demands. This will improve revenue in our company by reducing costs over time while growing our quality exponentially. This must all coordinate with the compliance of the product to the customer, for filling all requirements on every product delivered.

3.9 Stakeholders management

Stakeholder management is the process of managing the expectation of anyone that has an interest in a project or will be effected by its deliverables or outputs. In our project we have several stakeholders, with different expectations. We try to analyze in this section the expectation of every stakeholder. Stakeholders are all the teachers of the EPS, all the supervisors, our client Eduardo Silva and the team members.

Table 17: Stakeholder table

Stakeholder	Role	Possible Expectation
Team members	Project Development	Improve our skills; know new cultures having international team mates.
Fernando Ferreira	Project Advisor	A good knowledge of the mechanical principles as the basis for boat design.
Alberto Pereira	Project Management	Accurate use of the technical for project management.
Luis Filipe Caeiro Castanheira	Energy and Sustainability	A good know of the sustainability principles involved in the design and in the development of the project.
Ana Barata	Communication and Portuguese	Good understanding of basic Portuguese language and how correctly communicate our results to other stakeholders.
Alberto Peixoto Pinto	Team Building	Correct division of the roles inside the team, good understanding of everyone strengths and weakness.
Luis Càndia	Ethics & Deontology	Consciousness of the basic principles of ethics & deontology at the bottom of engineering projects.
Supervisors	Follow and supervise project steps	Respect the deadlines, doing a successful project.

Eduardo Silva	Client	Develop a prototype in respect of some constraints.

3.10 Conclusion

Provide here the conclusions of this chapter and introduce the next chapter.

4. Marketing Plan

4.1 Introduction

Oceans cover 71% of our world surface. For many years the sea was mainly navigated and explored, but nowadays humanity possesses the technology to analyze the sea and find resources for energy and research functions. This new approach of investigating offshore about the sea´s diversity and its unforeseen fortunes is a great opportunity for unmanned sailboats. In the process of a continuous development, the demand for accurate ocean sampling is continuously growing in order to provide a better understanding of the complex sea environment. An autonomous sail boat can satisfy the needs of many companies in this way, with several sensors for several needs. Our goal of the marketing plan is to find a potential market by analyzing competition, market segments and potential customers for our product. The key for a successful product implementation will be to find a niche or spot in the market that has not been fulfilled yet and on the other hand will create a for the customer recognizable benefit.

The easy way to display a marketing process is shown in Figure 38

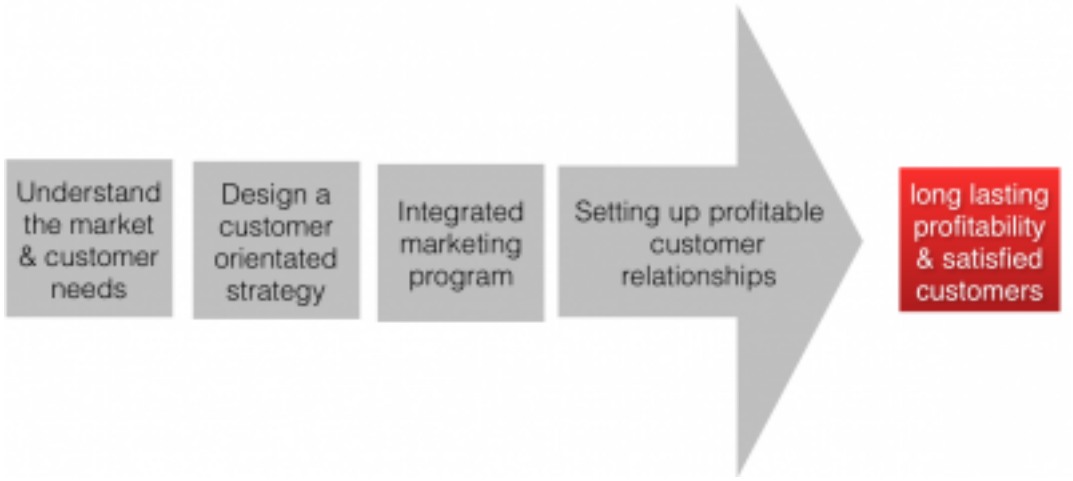


Figure 38: Marketing process

To have a successful marketing process and strategy we will have to understand our product itself. Our boat will fulfill different purposes offshore and will be capable to use a great variety of sensors and cameras. To specify the effectiveness of our segmentation and positioning later on as well as our potential customer analysis, we have to bear in mind all different product dimensions. It is important that the customer recognizes the personal benefit. “The main target of marketing is that the selling process is redundant. The object is that you understand the customer and their needs in a way that the developed product matches perfectly with these and will sell itself.”[Peter Drucker] The next figure will display what kind of product dimensions we have to take into consideration while analyzing the customer needs.

Figure 39

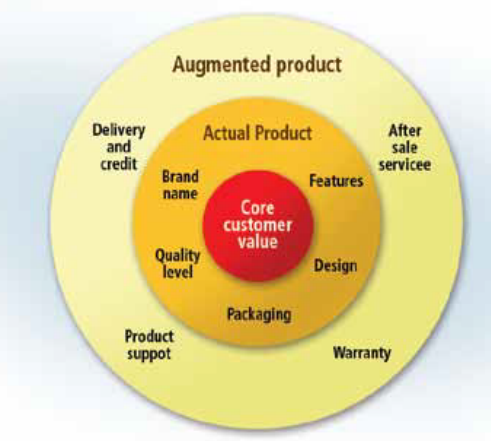


Figure 39: Product dimensions

The dimensions of the product that we have to keep in mind for any marketing strategy are containing aspects of the boat that can be offered to any customer apart from just the boat itself. The core product or core customer value we sell is a sailboat that can sail autonomously and stay in a specific region for a defined amount of time. Apart from this we also have to take into consideration to think about the necessity of design aspects, which is part of the actual product. It might be important for our customers to have a special kind of design. Mainly

because our product will be operating in the name of the business and could cause public interest. Furthermore we will have to ensure a unique and high quality. This is important because our customers will have to rely on the product, as it will be not in direct contact with humans. Next we need to manage to build up a certain brand name to attain loyalty and bonding towards our products. As business-to-business is a hard market with a low number of customers we need to attain good relations. Lastly it is in terms of the augmented dimension it is important to offer a good after sales service. All these aspects are essential for a good marketing campaign.

4.2 Market Analysis

"A market is a virtual or real place where the offer of a product meet with its demand which concludes in a price." (Homburg/Krohmer; 2009; Page 2)

4.2.1 Macro Environment

The macro environment is composed by the major external and uncontrollable factors that influence an organization's decision making, and affect its performance and strategies. We can study the macro environment of our product with a P.E.S.T analysis, composed by political, economic, social and technologic factors

Figure 40

Figure 40: PEST

4.2.1.1 Economical Environment

We focus on this chapter on economical background of Europe and Portugal in particular, due to the fact that Portugal is the country in which our brand and company will born. The European Crisis was the background of the Great Recession on Portugal, which was a debt crisis during 2010-2014 that led the country led to the county being unable to repay or refinance its government debt without the assistance of third parties. We can see in the graph one of the results of crisis, the fall of the gross domestic product.

Figure 41

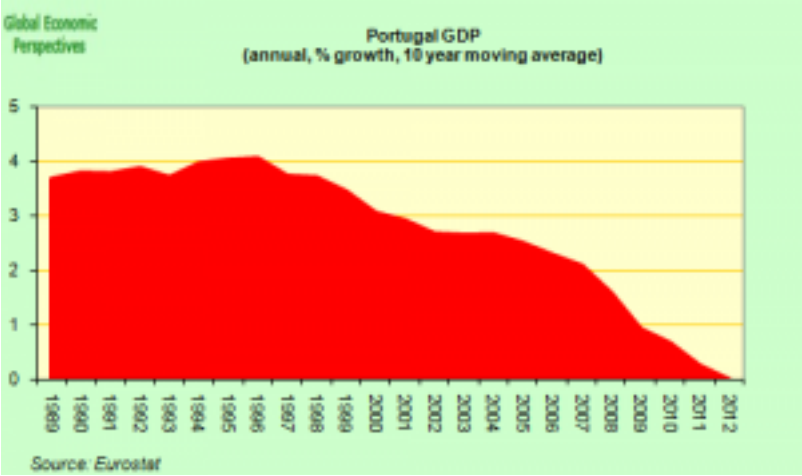


Figure 41: GDP Portugal; http://fistfulofeuros.net/afoe/portugal-please-switch-the-lights-off-when-you-leave/ [15]

Instead of the crisis, Portugal has expanded its research and innovation system over the last decade, increasing its investment in research at a remarkable average annual real growth rate of 7 % between 2000 and 2007. However, R&D intensity in Portugal decreased by an average of 0.16 % from 2008 to 2011. [44] In the table below we can see Portugal performance in research, innovation and competitiveness. The indicators relate knowledge investment and input to performance or economic output throughout the innovation cycle.

Figure 42

	Investment and input	Performance/economic output
Research	*R&D intensity* 2011: **1.50%** (EU: 2.03%; US: 2.75%) 2000-2011: **-0.16%** (EU: +0.8%; US: +0.2%)	*Excellence in S&T* 2010: **26.45** (EU: 47.86; US: 56.68) 2005-2010: **+4.23%** (EU: +3.09%; US: +0.53%)
Innovation and structural change	*Index of economic impact of innovation* 2010-2011: **0.38** (EU: 0.61)	*Knowledge-intensity of the economy* 2010: **41.04** (EU: 48.75; US: 56.25) 2000-2010: **+3.18%** (EU: +0.93%; US: +0.5%)
Competitiveness	*Hot-spots in key technologies* Food, agriculture, fisheries, Biotechnology, Materials, Environment, ICT	*HT + MT contribution to the trade balance* 2011: **-1.2%** (EU: 4.2%; US: 1.93%) 2000-2011: **n.a.** (EU: +4.99%; US: -10.75%)

Figure 42: Research, innovation and competitiveness

In addition to this is the Research and Development intensity projection Figure 43

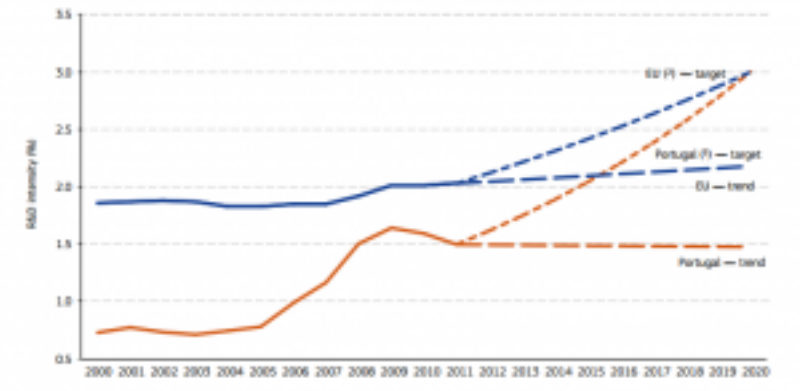


Figure 43: Research, innovation and competitiveness

Focusing in the energy production, according to the European Renewable energy council, the installed capacity in 2009 was approx. 250 MW. This included La Rance in France that has an annual production of 550 GWh. In terms of electricity production generated by the sector, ocean energy estimates the following: 0.62 TWh in 2010, 8.94 TWh in 2020, 150 TWh in 2030, 549 TWh in 2040 and 645 TWh in 2050. Focusing on Portugal in October 2011 Principle Power deployed a full-scale prototype WindFloat 5km off the coast of Aguçadoura.

4.2.1.2 Technologic Environment

Two factors are included in the technologic environment of an autonomous sailboat. The marine technology background, and the improving robotic background is our gain in technological industry. As seen above the first is expanding thanks to human needs to find resource. For the second, according to the international federation of robotic, in 2013, robot sales increased by 12% to 178,132 units, by far the highest level ever recorded for one year.

4.2.1.3 Political environment

Political backgrounds influence organizations in many ways and are able to create strengths and opportunities for organizations.

EU provides an integrated maritime policy to provide a more coherent approach to maritime issues, with increased coordination between different policy areas. The Blue growth is the long-term strategy to support sustainable growth in the marine and maritime sectors as a whole. Seas and oceans are drivers for the European economy and have great potential for innovation and growth. It is the maritime contribution to achieving the goals of the Europe 2020 strategy for smart, sustainable and inclusive growth. The strategy consists on three components:

- Develop sectors that have a high potential for sustainable jobs and growth.
- Essential components to provide knowledge, legal certainty and security in the blue economy.
- Sea basin strategies to ensure tailor-made measures and to foster cooperation between countries.

In June 2014, The European Council adopted a Maritime Security Strategy for the global maritime domain. The objective of this strategy is to provide a common framework for relevant authorities at national and European levels to ensure coherent development of their specific policies and a European response to maritime threats and risks. The second aim of such a strategy is to protect EU's strategic maritime interests and identify options to do so. Such a framework will provide the context and ensure consistency amongst different sector specific maritime policies and strategies. Most importantly it will significantly strengthen the link between internal and external security aspects of the maritime policy of the EU and civil and military cooperation.

The economical/technological environment has been supported further with advanced research and development. Even if the on-going European crisis, for

the period between 2014 and 2020, 21.46 billion euros were intended to Portugal by European Union, with the aim to improve the economic competitiveness and innovation.

4.2.1.4 Social Background

In 21st century the interest for green energy, for food and climate change have become a part of the general public, society at large, not only for big companies. For this reason our product could be useful to take oceans data for methereologists, or taking data to understand the quality of the water in which we fish or we breed the fishes that we eat.

4.2.2 Micro Analysis

The Microanalysis, is the analysis of the immediate environment that impacts a business. the micro environment includes considerations related to competitors, customers and suppliers.

4.2.2.1 Competitors

We can segment our competitors in two groups:

- Similar products, but not already in the market.
- Different products, already in the market with similar functions.

FASt Autonomous Sailboat

Figure 44

Figure 44: FASt Autonomous Sailboat

FASt is a 2.5 m LOA (length overall) autonomous sailing boat developed in the Department of Electrical and Computer Engineering of the University of Porto, Portugal. The project started in 2007 as an activity of an extra-curricular group of students, to enter the series of international competitions organized in the scope of the MicroTransat initiative. [45]

ASV Roboat

Figure 45

Figure 45: ASV Roboat 2

The ASV Roboat is a Robotic sailboat and has been in development by a INNOC research team since 2006. Robotic sail boats perform the complex maneuvers of sailing fully automatically and without human assistance.[46]

Saildrone

Figure 46

Figure 46: Saildrone

Saildrone Inc. uses basic sailing principles, but combines state-of-the-art carbon fiber composites with ultra-efficient aero and hydro dynamics to create an incredibly robust and efficient sailing machine. [47]

AMS Data-maran

Figure 47

Figure 47: Saildrone

Autonomous Marine Systems delivers a global platform for ocean observation using a global platform for ocean observation using intelligent sensor networks powered by Data-maran.[48]

Data Buoys

In the market are present a big variety of data buoys with different sensors for different uses.

- Satlantic's LOBO (Land/Ocean Biogeochemical Observatory) is a complete turnkey data buoy monitoring system in sensitive and diverse ecological areas such as estuaries and inland waters.
- TRYAXIS is a data buoy that can measure waves and currents
- MetBuoy can monitor, record and display wind speed & direction togehter with meteorological data.
- Turbibuoy can monitor, record and display turbidity data in support of water quality monitoring or dredge monitoring operations.

4.2.2.2 Potential Customers

We see our main potential customers in a "Business to Business"(B2B) relation with us. The main characteristics of a B2B market are explained in the following:

Figure 48 displays the main characteristics of business markets.

Business markets
Fewer customers, often geographically concentrated, with a small number accounting for most of the company's sales
Larger amounts of money involved
Longer decision cycles
More reliance on personal selling
More-rigid product standards

Figure 48: Business markets

Despite the preexisting autonomous boat market, our purpose in this section is to identify potential costumers in different sectors of the market.

- Oil rigs and Oil companies. There's a variety of methods to find oil: Ships can use sensitive gravity meters to measure tiny changes in the Earth's gravitational field that could indicate flowing oil, as well as sensitive magnetometers to measure tiny changes in the Earth's magnetic field caused by flowing oil. They can detect the smell of hydrocarbons using sensitive electronic noses called sniffers. Finally, and most commonly, they use seismology, creating shock waves that pass through hidden rock layers and interpreting the waves that are reflected back to the surface. Our boat could be improved with several of these features to help finding oil.

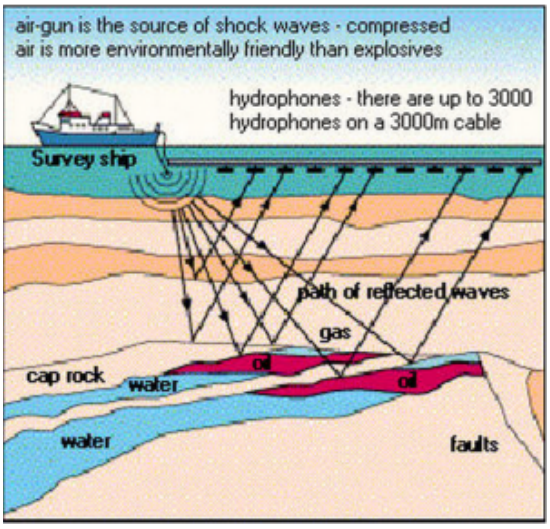


Figure 49: Oil location

By now are actives about 900 offshore oil rigs in Europe, most of these in the North Sea owned by Great Britain companies, and in Italy.[16]

- Off-shore wind farms. Here a list of the biggest 5 European offshore wind farms and the Portuguese Wind Float

Table 18: Windfarms

Name	Position	Total Power (MW)
Blekinge Offshore	Sweden	2,500
Moray Firth	United Kingdom	1300
Creyke Beck A	United Kingdom	1200
Creyke Beck B	United Kingdom	1200
East Anglia (formerly Norfolk Bank)	United Kingdom	1,200
Wind Float	Povòa de Varzim,Portugal	150

- Meteorologic and oceanography industry. For example The National Oceanography Centre (NOC) undertakes integrated ocean research and technology development from the coast to the deep ocean. It provides long-term marine science capability including: major facilities; sustained ocean observing, mapping and survey; data management, and scientific advice. Marine science national capability is provided to the Natural Environment Research Council (NERC).[17]
- Nation governments. Seas are often the more easy way for clandestine immigration. This happen for example in Italy, with lot of north-African people trying coming to the Sicilian coasts. This means poor travel conditions and high-risks for their safety. Lot of incidents happened in last years, with barges sunk and lot of deaths. In 2013 a barge sunk near Lampedusa with the death of 366 North Africans. For this reasons a continuous monitoring of the coasts is important. In this case, policy provided the use of helicopters, reconnaissance aircrafts and Predator B drones, which could be seen as competitors.[49]
- Port surveillance. Port areas as well as ships docked in ports are vulnerable to numerous hazardous scenarios and are targets for theft and terrorist attacks. Given the vast size of the perimeters of most port areas, manual

inspection of all potential points of entry is infeasible. Currently, a number of port facilities are equipped with video surveillance systems. Our boat could improve a surveillance system giving a continuous monitoring of a selected area.

- Fish Farms. In Europe, aquaculture accounts for about 20% of fish production [European commission]. Lot of Fish Farms use chemical as hygiene products for disinfection or for environmental control, as antifouling agents for fish cages and medicinal products, divided into chemotherapeutic agents for therapy or prophylaxis of disease which act on the invading organisms, and pharmacological drugs which act on the target animal. Is fundamental in this field an appropriate chemical analysis of the water in which fish grow.

4.3 SWOT Analysis

S.W.O.T. is an acronym that stands for Strengths, Weaknesses, Opportunities, and Threats. A SWOT analysis is an organized list of our business's greatest strengths, weaknesses, opportunities, and threats. Strengths and weaknesses are internal to our team, opportunities and threats are external, they are out there in the market. New businesses should use a SWOT analysis as a part of their planning process.

Figure 50

Figure 50: SWOT

4.4 Strategic Objectives

To reach a good position on the market, every start-up business has to define strategic objectives in a limited duration.

Market objectives for the first 5 years:

- Gain experience on the first year.
- Establish company, policy, logo and name
- Participate to MicroTransat challenge to test and advertise our product.
- Sell the first prototype to a company.
- Build other 5 products.
- Sell 5 products to different companies.
- Reach the break-even-point and a little profit to continue to produce.
- Enter on the international market thanks to the costumer confidence and advertise.

4.5 Segmentation

Due to the fact that our product is mainly operating as a data collector and will stay for a long term mission in certain water areas, we are opting on a Business to Business (B2B) market or the possibility of a tackling two markets , Business to Government (B2G).

The segmentation is one of the essential marketing processes. It is the basis to decide upon what kind of market segment we want to focus our campaign on and try the position ourselves along the competition. One approach to explain what segmentation and its ongoing steps are is the following:

Figure 51

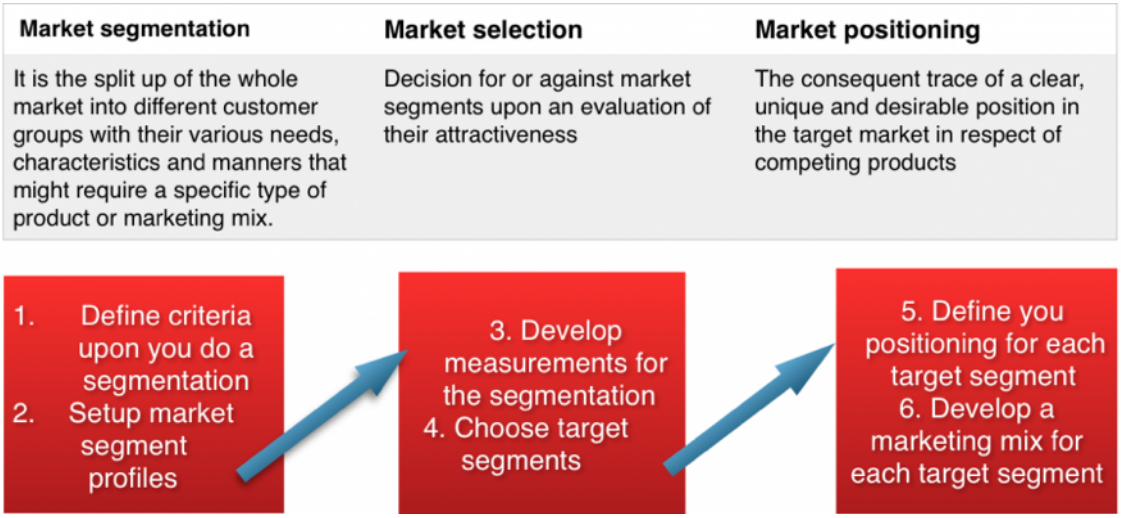


Figure 51: Segmentation, Selection and Positioning; Grundlagen des Marketing;Pearson Studium; Auflage: 5., aktualisierte Auflage (1. August 2010)

If you want to start off with your segmentation you firstly have to think about how you want to approach your customers at the end. There are different ways to do so.

- Firstly there is mass marketing. This means you do not differentiate for specific segments in your marketing campaign. Your marketing will be focus on the slogan “one size fits all”.
- Next you can do a niche marketing, which is a specific definition of you, product and marketing mix for small sub segments.
- Micro marketing in a “one-to-one” marketing where you focus on individualized products and marketing mix.
- Lastly there is the target marketing that will be our approach. This means that we will adapt our marketing mix and product to a wider defined segmentation. [27]

After understanding these basics we can continue with our segmentation of the market that can be done by various aspects. We firstly want to break it down into the these four criteria:

Figure 52

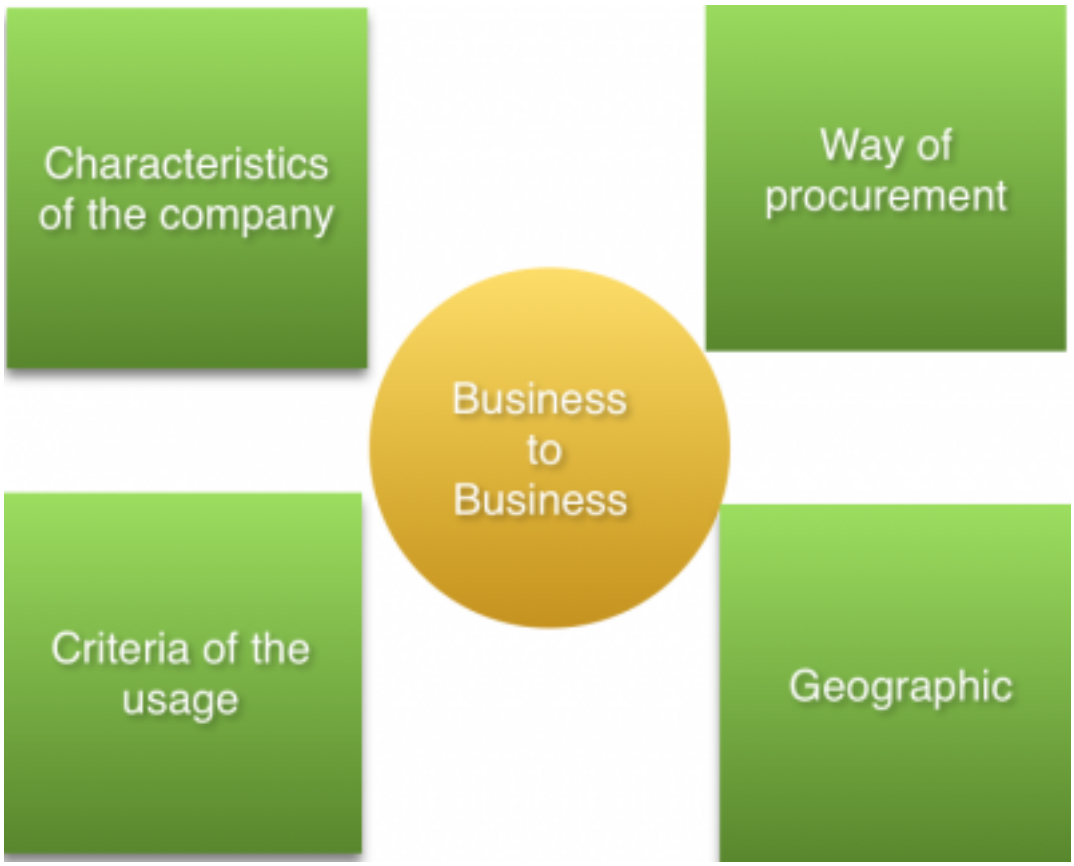
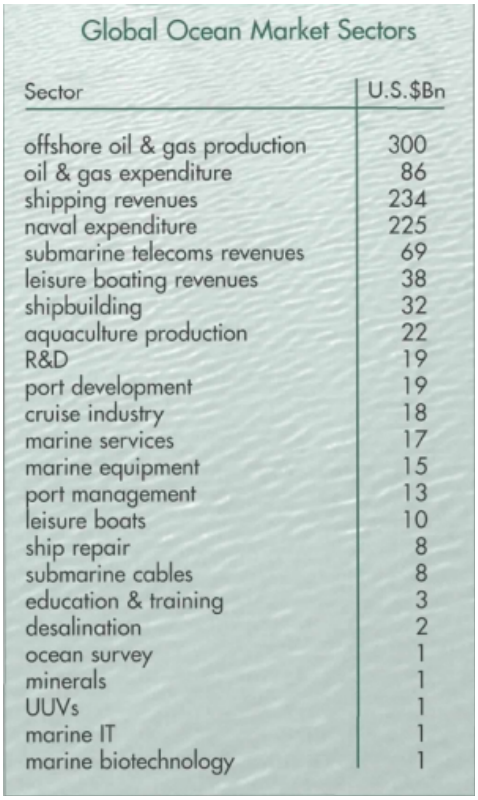


Figure 52: Market segmentation criteria

4.5.1 Characteristics of the companies

To start off we want to give a basic overview of the global ocean market and its various industries. From the table you can see the biggest market segments in terms of overall worthiness in a year. It includes investments and returns depending on the segment. Furthermore we added a table to demonstrate where this global ocean market takes place in the world.

Figure 53



Global Ocean Market Sectors

Sector	U.S.$Bn
offshore oil & gas production	300
oil & gas expenditure	86
shipping revenues	234
naval expenditure	225
submarine telecoms revenues	69
leisure boating revenues	38
shipbuilding	32
aquaculture production	22
R&D	19
port development	19
cruise industry	18
marine services	17
marine equipment	15
port management	13
leisure boats	10
ship repair	8
submarine cables	8
education & training	3
desalination	2
ocean survey	1
minerals	1
UUVs	1
marine IT	1
marine biotechnology	1

Figure 53: Segments of “ocean market”;Year 2000; http://www.tos.org/oceanography/archive/14-3_westwood.pdf

Figure 54 displays the expenditures for the R&D sector in terms of maritime investigations

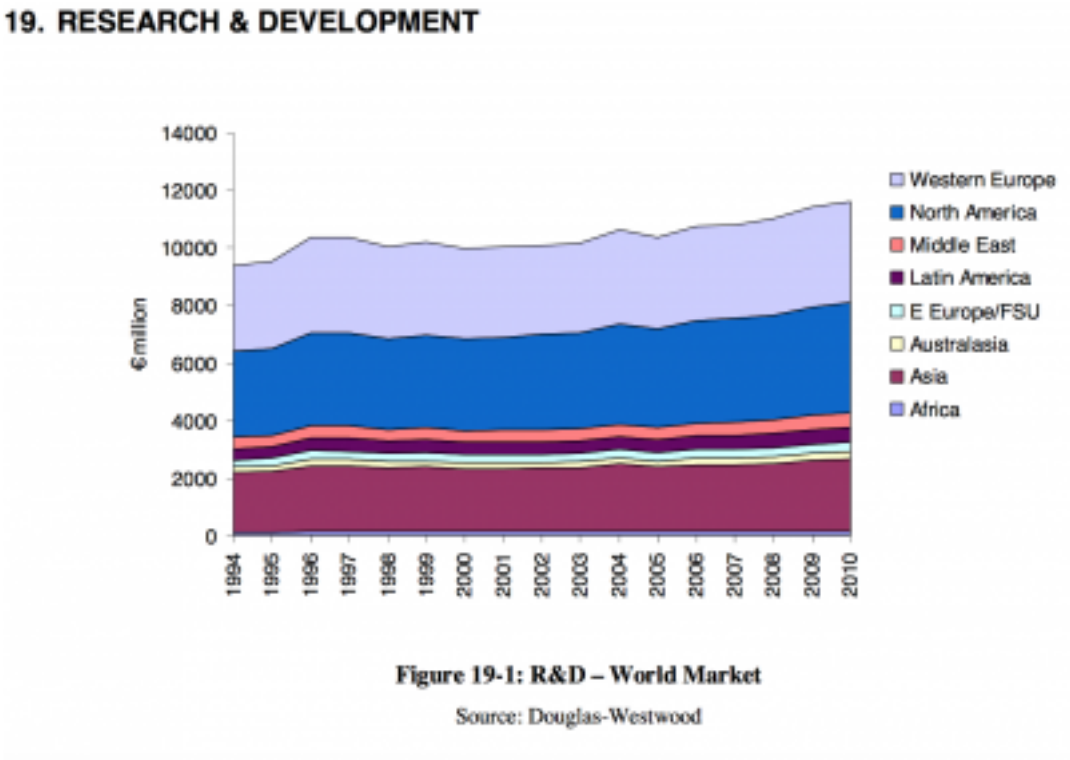


Figure 54: R&D Expenditure ;Year 2005; http://www.schleswig-holstein.de/MJKE/DE/EuropaOstseepolitik/Meerespolitik/Download/studieWorldMarine__blob=publicationFile.pdf

From this Figures we can extract some important information. The total market for ocean related businesses was in 2000 747 Billion US Dollar . This means that there is a huge monetary potential in the market. The biggest sector is the oil and gas production but also interesting for us is the amount spent on R&D (19Billion US Dollar). Additionally we can extract that ocean survey expenditure is with one billion US$ also really high and underlines our approach for implementing a research and monitoring sailboat.

4.5.2 Geographic Segmentation

Geographic segmentation is a criterion we chose because we want to know the physical location of the potential and actual customers. We would like to get information about where our products is being sold or can be possible to get sold in order to increase our advertisement and sales in these regions. Our criteria for this segmentation are: investments on research, quantity of potential costumers and employees with naval education background, location of the city/ business.

Figure 55

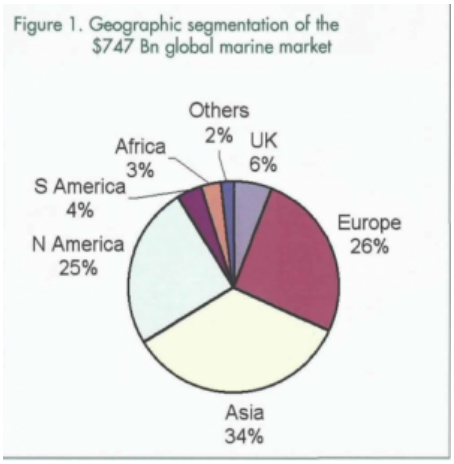


Figure 55: Global investments overview; Year 2000; http://www.tos.org/oceanography/archive/14-3_westwood.pdf

Figure 56 shows the percentage of expenditure for the continents in 2005

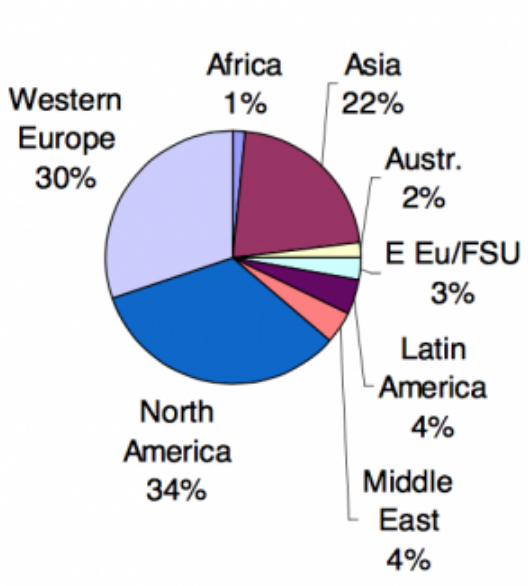


Figure 56: R&D Expenditure continents ;Year 2005; http://www.schleswig-holstein.de/MJKE/DE/EuropaOstseepolitik/Meerespolitik/Download/studieWorldMarine__blob=publicationFile.pdf

From this data we can extract that Europe and Asia are the biggest markets in terms of the worthiness of marine businesses and the highest financial forces are in the segments related to offshore and gas production but also interesting for us is the Research and Development (R&D) segment with 19 Billion US Dollar. On basis of this knowledge about the market we want to concentrate on Europe as the members of our team come from Europe as well and have a profound knowledge about cultural and language aspects.

Continuing with the geographical segmentation we focused on the fact that we build a sailboat and we have some regional limitation. As a matter of fact it is more likely that our potential customers are located close to the sea, a lake or a river. By investigating on this we focused on seas or big lakes as the need for research boats will be rather interesting for bigger areas that can't be easily monitored. On basis of the location limitation next to the see and the size of the city we searched for the biggest cities in Europe fulfilling these criteria.

Table 19: http://www.jpi-oceans.eu/news-events/news/how-blue-your-country

Number	City	Size	Investment
1	Iceland/Reykjavik	121.230	25
2	Ireland	1.110.627	29
3	London	8.500.000	189
4	Oslo	925.228	230
5	Stockholm	1.372.565	200
6	Helsinki	1.159.211	19
7	Kopenhagen	1.181.239	30
8	Hamburg	1.800.000	300
9	Amsterdam	821.702	125
10	Antwerpen	510.610	52
11	Genoa	586.180	100
12	Marseille	850.726	306
13	Barcelona	1.620.943	121
14	Lisbon	545.245	7
15	Istanbul	9.000.000	37

Figure 57 displays the relation between population of the city and the expenditure of the country in naval research

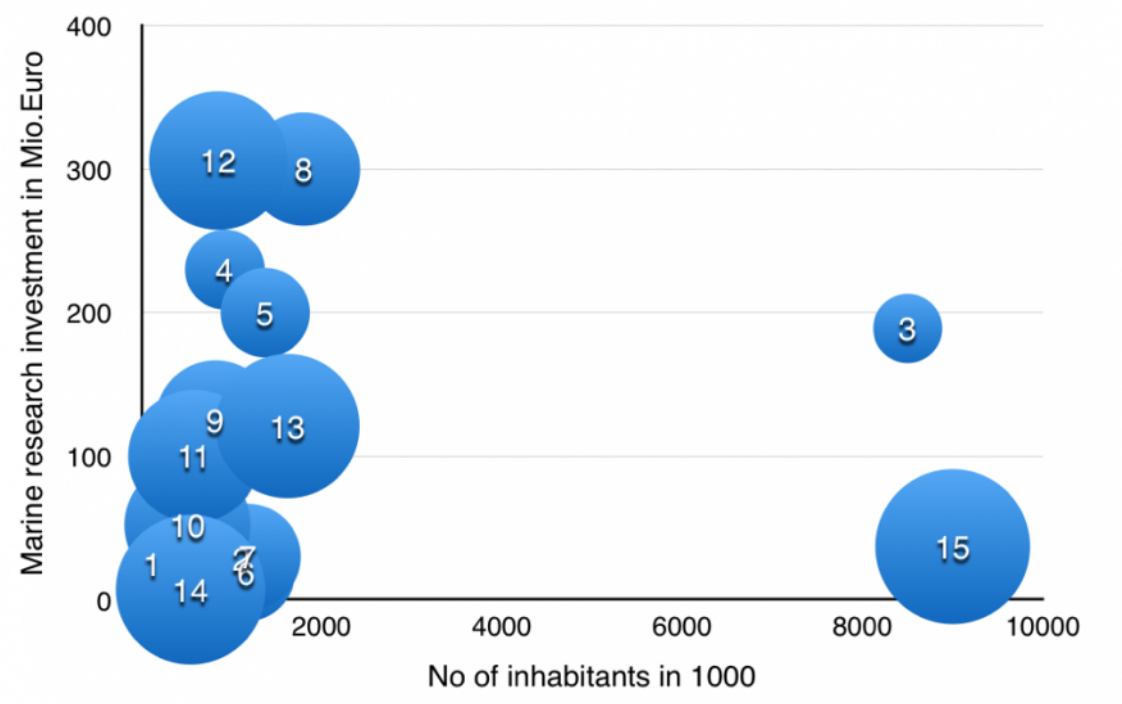


Figure 57: Country investment and population in relation

Taking in these into consideration, we focused also our list on countries by their research and development spending's.

Table 20: Country expenditures on R&D http://www.battelle.org/media/global-r-d-funding-forecast

Rank	Country	Expenditures on R&D (US billion dollars)	Expenditures on R&D Per-capita (US dollars)
1	United States	405.3	1275.64
7	United Kingdom	38.4	602.78
4	Germany	69.5	861.04
39	Hungary	1.7	171.61
12	Italy	19	316.70

As we can extract from the ongoing tables and figures, our target market will be considerably in European countries. Possible cities are Hamburg, London or other cities/countries that have a high expenditure in maritime research. Germany for example spends a lot of money on R&D and in R&D respectively for maritime purposes. Furthermore Hamburg has a high population and many big companies. Undoubtedly Hamburg offers a good connection to the North Sea, has a long maritime tradition and offers a great logistic network. Underlining this we can see that we have a big international airport, a good railway system in Germany, many trucking companies located in Hamburg and furthermore one of the biggest harbors worldwide. In our opinion when expending our first choice would be the German market. We will chose new countries because the product we offer is a very specialized one that is mainly interesting for research institutions or big companies that are investigating offshore. Therefore the basis of potential customers is limited in Portugal. Conclusion of geographic segmentation:

- Target markets geographically after Portugal will be Europe.
- We are European, and we know languages and cultures of costumers.
- Research and development funds are high in European countries, second in respective to the US.

We can also say that the interest of the exploitation for example of offshore wind plants is growing in Europe. Due to the fact that the amount of land used is very high the result are strong limitations for the installation of onshore wind farms. Today the offshore operating wind power is 12 MW, with two wind farms in Denmark and one in Netherlands; it starts to be significant (0.6%) in terms of the onshore power, 2000 MW in Europe. In the world the onshore installed wind power is already exceeding the 4000 Mega Watt (MW). However, there has not

been done much so far in terms of the offshore area outside Europe. The European four year forecast on the prototypical offshore wind farms looks significantly promising and suggests to promote a similar approach in many densely populated coastal countries in the world with high electricity demand. [Gaetano Gaudiosi, 1996]

4.5.3 Way of procurement

In terms of the way of procurement we mean that we want to analyze how our potential customers in the target market segments are processing their buyings, what is there interest in buying, what causes their intention to buy? As a matter of fact Business-to-Business is mainly done by procurement teams, in our case we focus on decentralized procurement. These teams have certain exceptions on a product and evaluate the product in the buying process upon defined criteria. This means that we will have to convince our customers by quality and functionalities of the product and the process of buying will be larger than normally with private customers. To picture this process we have in the following a typical process of buying a higher monetary product.

Figure 58 displays the stages of procurement when buying B2B

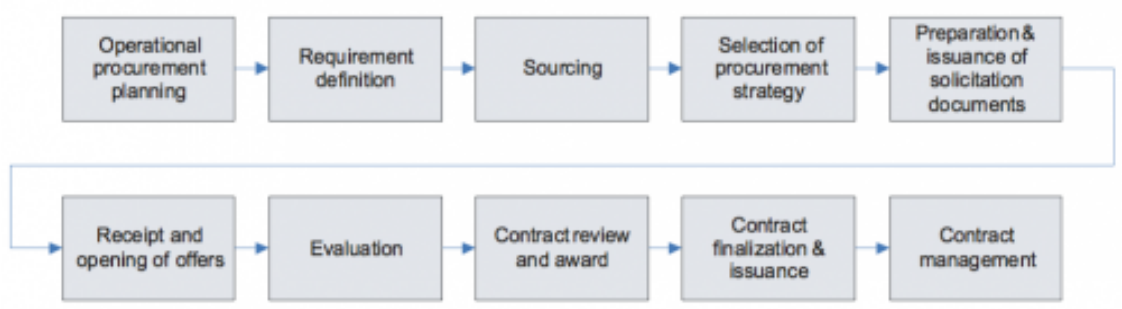


Figure 58: Procurement process

As we can see, the way of procurement is highly objective and at the stage of receipt offers we will compete with other products who serve the same need. That means that our product dimensions or their purchasing criteria will have to

focus on objectively quantifiable and functional dimensions rather than on packaging design for example. Furthermore after sales services are important in this terms because other companies will expect from us to deliver good quality and to hold us responsible when problems occur. The amount of order will be more likely to be small. There is not a high chance of selling big bundles of sailboats to one customer at the same time.

Next we need to analyze the interest they have to buy our product and how they approach us or we get need to approach them. The main interest of the potential customer in the segment of R&D and maritime monitoring (for example oil platforms, wind farms etc) will be the functionality of our product. For this we need to approach them by demonstrating the qualities of the boat and convince them about the necessity of it. For example the Research and Development market segment for maritime products has a total investment volume of 19 Billion US Dollars, as already mentioned. This is divided into the following percentages:

Figure 59

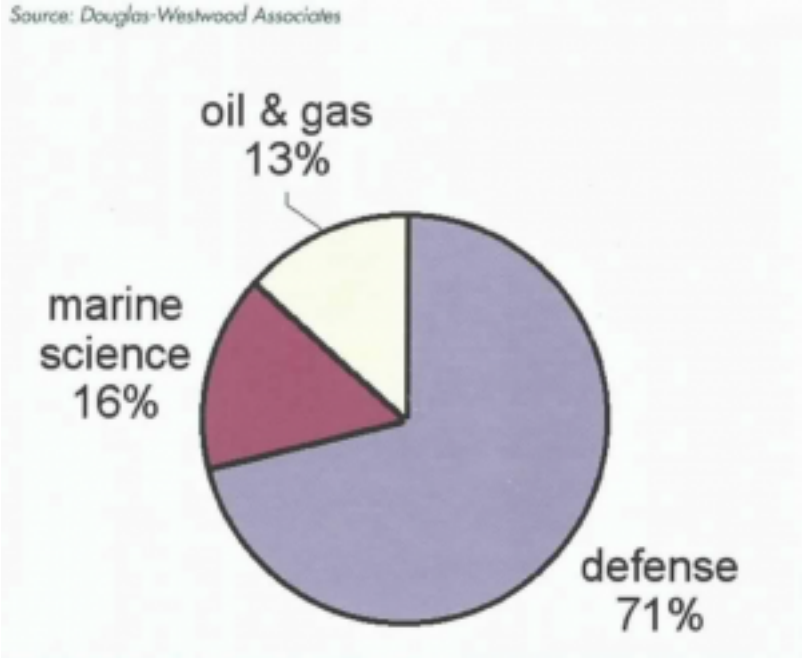


Figure 59: R&D investments; Year 2000; http://www.tos.org/oceanography/archive/14-3_westwood.pdf

Although the defense part of the investments is the biggest component, we can underline the interest of our company in approaching the markets of marine science and oil & gas.

4.5.4 Criteria of usage

For the criteria of usage we have to focus on the technologies that the potential customers may focus on and that we need to address our strategy to. Another aspect is the question if the buyer is the actual user or not and what kind of qualifications our users have. This means that we might have to explain our product and functioning in detail or not.

To begin with, we already mentioned that the main focus of purchase would be in the functionality of the product. It has to have a high value for the customer rather than a solution that we sell. Our customers are basically also the users, which means that we will have a direct contact to them. The next open question

is if we should address our product to customers that need a lot or less supportive services. As the following figure will display, we will focus on value buyers. That means that the main interest of the buyer will be the added value for him. We expect that these costumers do not need to get an intensive support service from us. However, to maintain good customer relationships and as defined a high “customer lifetime value”, which is the overall expected value a customer has for the whole existing of its business, we try to offer best services and maintenance of the boats.

Figure 60

Figure 60: Customer needs segmentation model; Marketing Presentation ISEP Spring 2015

4.5.5 Conclusion

Summing up our analysis, we come to the conclusion that our target market segments will be in the Research & Development sector which can be institutions investigating on maritime organisms or structures as well as searching for new soil resources. Furthermore potential customers are in the segment for monitoring offshore installations such as wind parks and/or oil platforms etc. For the possible missions that we think our boat can fulfill please

check the storyboard. As we mentioned there are high potentials in these segments and we are keen in exploiting these. For doing this the best way, we will analyze in the following chapter the best positioning strategy.

4.6 Strategy/Positioning

The target of a good positioning strategy is to adjust the strengths and the requirements and opportunities of the market or its segments with each other. Therefore you follow certain defined steps. Firstly you identify the customer groups towards which you have a unique and special advantage in comparison to your competition. After this you will position your product in the market and the perception of the customer. At the end of the process of positioning and differentiation the customer has to know why he should buy our product.

To explain what positioning is, we could say that we will try to pursue a clearly defined, unique and desirable position in our target market in comparison to our competition. The strategic options for positioning ourselves are to strengthen our current position, find a unfilled position or repositioning. In these terms and as we are a new company in the market we will need to find a new position in the market and differentiate us from the competition. The steps to follow the positioning on will be:

- Identification of possible competitive advantages
- Choose the right competitive advantages
- Develop a positioning strategy
- Communicate our strategy on the market

To start with to find our possible competitive advantages we can analyze the product itself or our services offered to the customer. Our product with its function is not available in the market. Although there are already autonomous

sailboats, they mainly focus on the participation in tournaments. Most of them are made to be fast and sail from a defined start to a finish point. The basic value our product is satisfying is unique in this way. We did not find any autonomous sailboat that is made to stay in a defined region for a longer amount of time and collect data. For this data collection our boat will be modular designed. This enhances adjustments in terms of sensors or cameras to fulfill each purpose and mission. Some possible competition can be other stationary products like buoys that collect data but our main advantage is the flexibility of a boat and even if there are boats to collect data, they use fuel or need humans on board. Although there are many prototypes of autonomous sailboats in the market we can still call our product innovative in terms of its functioning. These two aspects are the biggest competitive advantages we see for us and we need to concentrate on this in our positioning. Additional to the product differentiation we see a huge chance to take benefits for additional customer services. As the existing autonomous sailboats are mainly concept boats from institutions or universities we can exploit the chance in offering services for our business customers when selling. For innovative and technical products there is most of the time the need of explanation. Therefore we want to offer trainings for users and also to build a long term bounding to our customers in offering services and maintenance, as already mentioned in the previous sub chapters. Also there will be the recycling aspect of old and not usable boats. Our company will take care of the recycling and give discounts for new procurements of the customer. Our bargain will be to reuse parts of the boat and also improve the customer service. More differentiation aspects can be made by our employees, which we refer to our chapter of social sustainability with our approaches to enhance the commitment and satisfaction of them. Our benefit will be a better public relation and reputation in the society. [28] At the end of this so-called benefit segmentation we can sum up that:

Table 21: Benefit segmentation

Benefit criteria	Description
1) Modular design	Easily adjustable for different purposes. Cameras or sensors
2) Flexibility	Navigable to stay in a certain defined region
3) Environmental aspect	No use of fuel, recycling by our company
4) Customer service	Maintenance of the boat, trainings and service hotlines
5) Labor costs	No humans needed on the boat

Our approach to get a by the customer recognized unique position is to be quite different from other businesses. By enhancing the mentioned benefit criteria it is possible for us to present a product that does not exist this way in the market. Our purpose is to reach the costumer bonding by their understanding of needs and being flexible to react on changes of their needs. There are fundamentally three approaches to achieve a good business and a good relationship with costumers that could be summarizes in a triangle:

Figure 61

Figure 61: Business triangle

The “Lock-in” approach is based on a linkage between costumer and supplier. This means that by using the product, the customer cannot easily go to another company for services or similar products. Although this is a good way to guarantee regular income and a long-term relation with the customer it might tend to create disapproval and customers will not buy the product in the first place. We can better achieve our goal with the antithesis of the “Best Product” strategy, or rather the “Total Costumer solution”. This approach is based on looking for a deep understanding of the costumer that allows us to develop customized value propositions for each that can create a link.

4.7 Adapted Marketing-Mix

In this sub-chapter we are going to define how we are going to approach our target market and attract the customer for our product. The previous stages that we described are for this decisions upon the marketing mix essential in order to invest your time and money in the most profitable way and ensure efficiency. What we did so far is displayed in the following figure. It mainly pictures the process we did so far in order to find out about the target market.
Figure 62 displays the process from analyzing the macro environment up to our target market and the meaning of marketing mix.

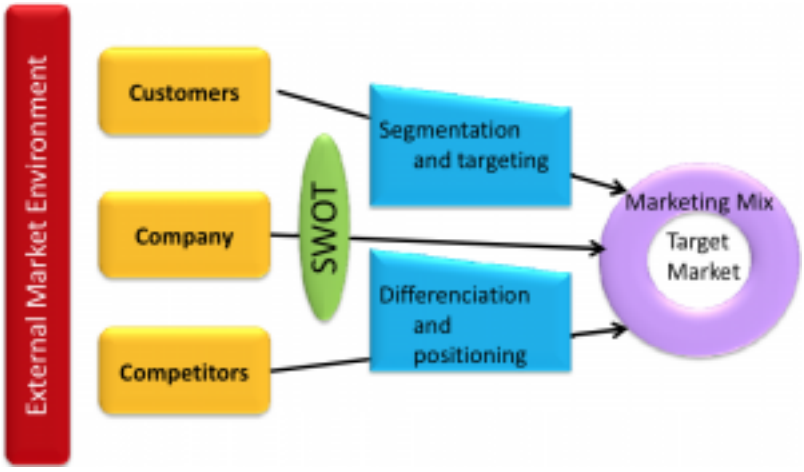


Figure 62: Analyzing the marketing process

After analyzing the market environment we focused on the potential customers and competitor in the market. Then we proceeded with our swot analysis and

did the segmentation and positioning in the market. To understand now what the target of the marketing mix is we can state that we need to understand the consumer behavior and trigger his desire to buy our product. Doing so we define our product and services with the concept of the „4P´s“ which are: product, place, price and promotion. These criteria are meant to create a relation between our company and the customer. It is a stimulus that will result in a response by the customer.

Figure 63

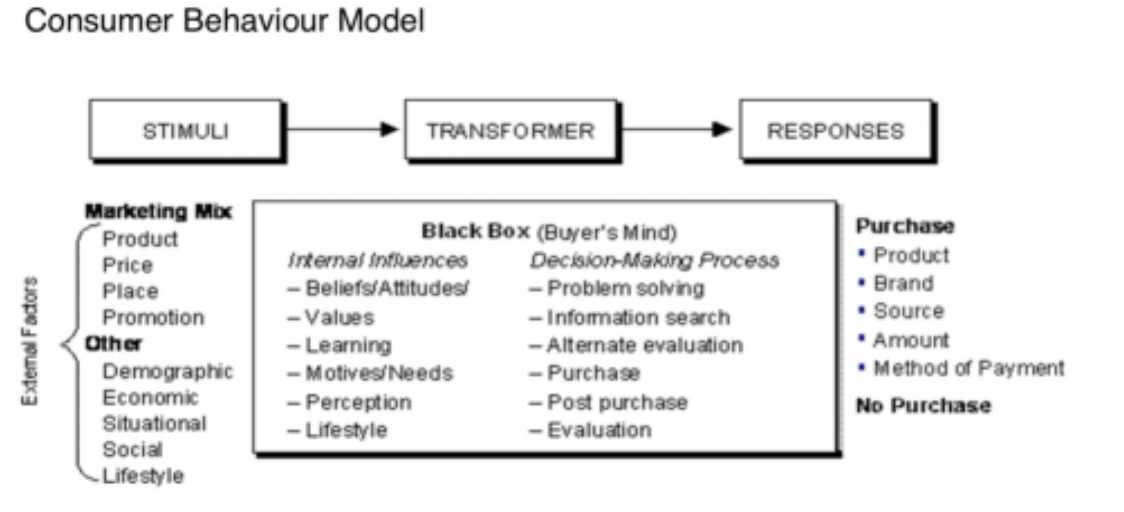


Figure 63: Consumer Behavior Model

This concept is often used to explain the process of our action and the reaction of the customer. Apart from the stimuli of the „4P´s“ we also have situational factors like demographics, economic, situational, social and lifestyle that are affecting their decisional process.

Now we want to define what the meaning of each element of the „4P´s“ is and how we want to strategically use this aspect to attract potential buyers.
Figure 64 displays the dimensions of the marketing mix and a brief description of there meaning.

Figure 64: Marketing Mix

To start off we already mentioned in terms of the product its various dimensions, which are the core product, the extended product and augmented product. This is essential to fully understand the functioning of these criteria of marketing mix. As a definition „a product is a bundle of features, that targets the creation of customer value.“ (Homburg/Krohmer 2009, Page 160)

To create this overall product value we can systemize the lifecycle stage of the product in order to decide on the policy we apply to. There are the possibilities of innovation management, the management of products that already exist on the market and the management of brand names. As our product does not exist like this in the market and will implement customer perception of novelty, we will focus our product strategy on innovation management. The process of the innovation management starts with the firm establishment of your innovation. We did this in our chapter of state of the art, where we investigated on the functioning of the boat and also the technology we will apply. Ongoing we defined and selected the best concept for our boat with its design, measurement and engineering blueprint. Lastly the ultimate process stage will be the market implementation.

Our product strategy will be to offer high quality that we want to outline in our promotion and a extensive customer service that ensures a close and longterm relation with them. The product will have a long expected life time and throughout this we need to keep the customer linked to us in order to not only attain income by selling our product but also to offer maintenance services. Additionally there will be a warranty given on all components for their proper functioning. This will benefit our customer lifetime value, as already explained in the beginning of this chapter. In terms of our brand name, we created a unique and simple logo that is outlining the robust functioning of our product and the reliability. With this we want to create a certain emotion and recognition in the minds of the customer.
Figure 65 pictures our simple and unique logo.

Figure 65: Horizon Sail Logo

The main dimension when thinking of this brand management that we answered is: Figure 66

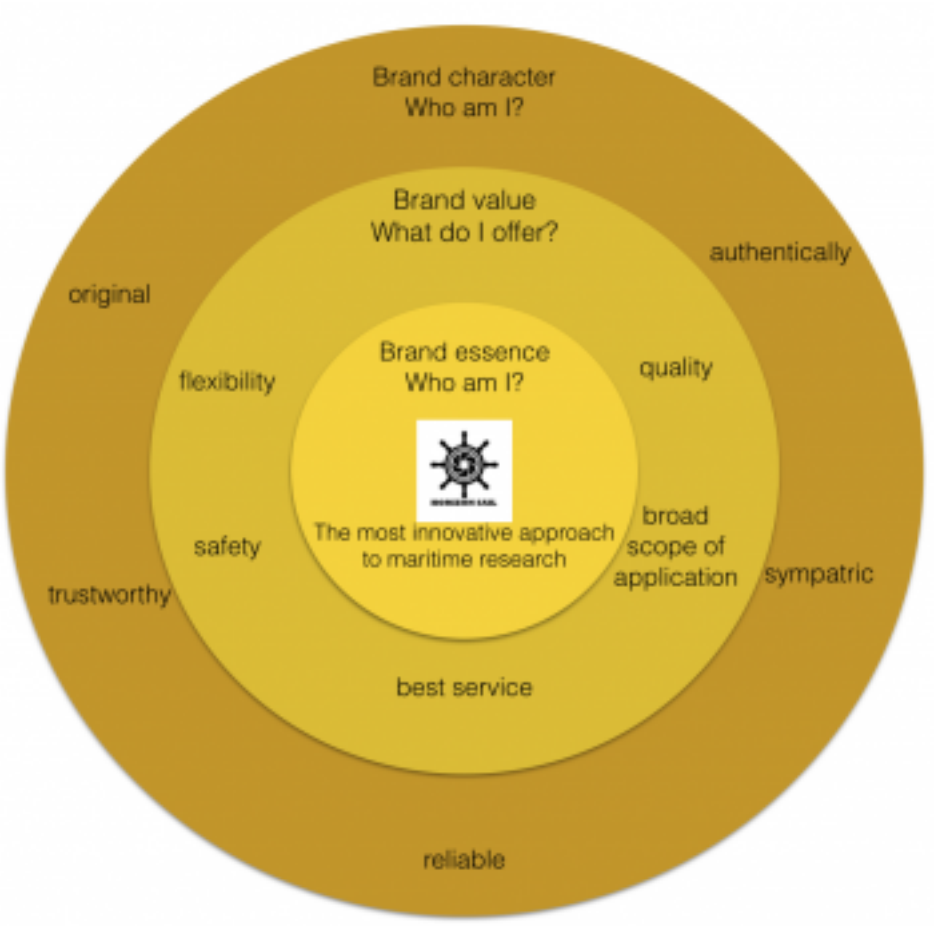


Figure 66: Brand Management

Our slogan will be: **Autonomous Sailing, Always one-step ahead!**

Now we want to describe the marketing mix in terms of the pricing of the product. The price of the product has some characteristics that are very important to mention. Firstly the price can be change very fast. However it is hard to return to former price levels in the same speed. One of the reasons is the high influence of the price towards the impression of the customer. Furthermore any change in the price can have a fast effect on sales and on the market situation.

Taking this into consideration, there are many factors that effect the price of the product and our strategy in the first place. Undoubtedly our product will be produced with the strategy of engineer to order. This means that as soon as a customer decides to buy our product we will start to build the boat with the necessary sensors or cameras that the customer needs. However the design of the boat will remain the same with will decrease the total engineering costs but as there are multifunctional applications for the boat our overall organizational costs will be higher than producing by a mass production. As a result our prices will be adequate to cover our production costs plus our profit margin. The price also depends on the marketing objectives that we set before entering the market. Due to a low competition and our offer of a new innovative product which has to manifest the quality we promised, our objective will be the product quality leadership. Higher prices have to cover the costs of our qualified employees and the costs for R&D. Nevertheless the still ongoing crisis in Europe and especially in Portugal are affecting our price concept as well. Although the outbreak of the financial crisis is already a couple of years ago, we are still facing the consequences, which are inherent for our price level. This might enable us to offer financing possibilities to our potential customers in order to skip the high purchase costs and split them over the years of usage. Besides this will enhance the bonding towards our company as well. To find the best price and still cover costs we will undertake a cost based analysis before entering the market. This will ensure that we can exactly define the overall production costs and then add a profit margin that is on the one hand acceptable for the customer and on the other hand will ensure a constant business growth. The overall strategy will be a so-called „skimming strategy“ where we implement the product in the market to a reasonable high price to exploit the willingness of the customers to pay for this innovative boat. At the end this will enable us to quickly equalize our costs for R&D, product development and starting up the business.

Table 22: Cost Allocation

Component	Cost
Sail	150€
Sensors & Camera	Depending on customer
Hull	150€
Keel	95€€
Rudder	75€

The next part of the marketing mix is the promotion strategy. Basically the promotion is about transferring a statement towards the customer to create certain knowledge, expectancy and desire to buy our product. The most common methodology to define this process is „AIDA“. This approach is about four main steps: attention, interest, desire and action. These are the four phases that a customer has to go through to finally purchase the product. To enhance this, there are different ways for marketing communication explained in Figure 63.

Figure 67

Figure 67: Marketing Communication

As our product is innovative, has a certain complexity and needs to be sold B2B, we will focus on a direct contact towards our customers. For us it will be important to design our way of advertising informative and comparative. As our product is not a totally new technology, we will try to convince our potential customers to compare current products that might serve the same function with our product. A good example could be a data buoy, which is only a stationary

data collector. A good tool that we will use in terms of public relations will be a website that we design to informed potential customers about the product, company at its benefits. This is an easy and cheap way that is nearly for everybody accessible. Nowadays the medium of the World Wide Web becomes more important in terms of advertisement. We also want to place our own business pages in social medias. The costs for a website to maintain are very low. There are many tools that will support us by designing the website on our own and maintain them. The biggest advantage of this is for us that we can more or less control our advertisement success with the supervision of the number of visitors on the website. Also we can use multimedia like videos or clips to demonstrate our product in action.

Although personal selling is one of the most expensive ways for promotion, we will use this as a core approach to reach for customer interest. On the one hand we want to participate on different events like shows and expositions. This will help to be able to catch the customer's interest by showing videos, demonstrations or convince them face-to-face. Although there might be the risk that not everyone on this expositions will be interested in this but this also highly depends on the topic of the expositions. There is also the possibility for the direct contact to use specialized leaflets like the one we already designed to send it to potential customers. It is possible to individualize these to give the impression of being something special for our company. Additionally we can send qualified and trained sellers to the companies as well.

We also want to use print media, which has the big advantages of the exact timing and you can do it in a short period of time. Although you might have the problem of a high percentage of dispersion you actually need to get a first idea of the product in the market. You could place advertisements in journals for robotics, engineering or researches like „Geo Magazine“ where you have at

least a reader that is interested in technologies.

Lastly we come to the place in the methodology of the „4P´s“. First there are three central decisions to do respective the market orientated activities.

Figure 68

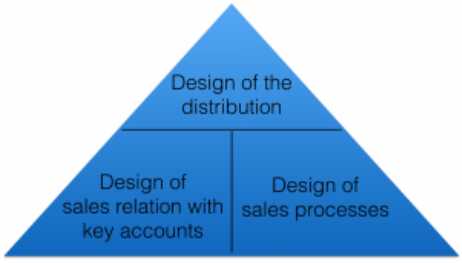


Figure 68: Market Orientated Activities

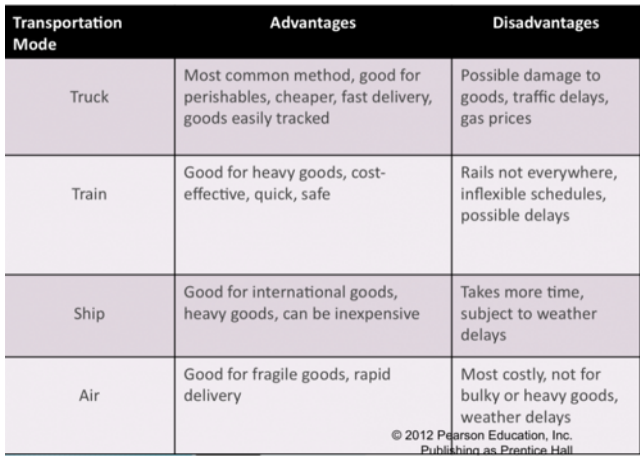
The design of the distribution refers to our sales organization and also to the ways of distribution we choose. For the sales department we want to install a key account manager who will be responsible for maintaining a close contact with our customers and ensure a high level of satisfaction with our product and services. Furthermore we will offer trainings to ensure that our sales employees are well prepared to convince potential customers about our product. For us it is more useful to have less qualified employees than a high amount of employees without the right skills to persuade customers. Personal selling demands a high level of qualification to understand how to approach customers and how to guide them on the right way to finally purchase. Also they have to understand the product, which is more complex than others. In terms of the different distribution channels we choose to do indirect distribution through external delivery services. The main considerations that we took into account are to think about efficiency and effectiveness. Due to the fact that our company will be small and has a low limited budget we can not afford to have an own delivery service and also we do not have any experiences. By negotiating a contract with an external delivery service we can first ensure high level of know how to handle the boat and also we will have a guarantee for safe delivery. The big disadvantage is that we will rely on the high standard of service by the external but to minimize this we can compare them and define common goals.

Nevertheless we will have a direct contact to the customer.

In terms of the sales relation with the key accounts, we will have a personal and direct selling. This means we will use fairs or directly contact our potential customers. Although this is an expensive way we will be able to build up an intensive relation with them and also adjust the functionality of the boat for customers individually. Sales professionals at the customers ground or telephone, sending flyer and information material can do the direct contact. Lastly we have the design of our sales processes that includes the logistics. Our business will not have an extra storage for finished goods, as we will engineer to order.

This will decrease our costs. Furthermore we will offer the possibility to transport our product via container vessels internationally. For this we will design a transport box to ensure safety and a fully functioning product. Another possibility is to use trucks from our external delivery service. For this our transport box will be also very handy. Here is a list of possible transport modes and their pros and cons. [29]

Figure 69



Transportation Mode	Advantages	Disadvantages
Truck	Most common method, good for perishables, cheaper, fast delivery, goods easily tracked	Possible damage to goods, traffic delays, gas prices
Train	Good for heavy goods, cost-effective, quick, safe	Rails not everywhere, inflexible schedules, possible delays
Ship	Good for international goods, heavy goods, can be inexpensive	Takes more time, subject to weather delays
Air	Good for fragile goods, rapid delivery	Most costly, not for bulky or heavy goods, weather delays

Figure 69: Transport Possibilities

4.8 Budget

The purpose of this section is to quantify and choose how to spend an initial budget of 5000 Euro for the first year. At the moment we are not going to have any cost for employers and staff. The most important aim in the first year is to advertise and make known the product, for this reason lot of money will be spent in travels, to take our product in any of most important naval and robotic Fairs.

Figure 70 displays how we are going to spend the marketing budget.

Figure 70: Budget distribution

This is a list of Fairs in which we want to participate.

Table 23: Interesting fairs for our product

Name	Position	Period
European Unmanned Maritime Systems	Portugal	May
SMM	Hamburg	September
Salone Nautico	Genova	October
Hannover Messe	Hannover	April
Autonomous Unmanned Systems & Robotics Expo	Israel	September

4.9 Strategy Control

The strategy control is a tool for us to make sure that we are on the previously defined track and still attaining our marketing goals. To ensure this we will monitor, compare and correct our work performance. We need to ensure that our activities are done in a way to enhance the accomplishment of our organizational or marketing goals. As we set our objectives and analyzed our market opportunities we have to monitor our achievement. Doing so we need to get data from our performance, which can be customer feedback or quantifiable data like our return on investment, liquidity development or market share. All of these data has to be collected regularly and analyzed by our employees. If there are some asymmetries occurring we need to take action and get back on track. A well implemented controlling will build a basis to let us know if we attain our goals or not, it will be empowering for our employees as a platform for a feedback on their performance and also will protect the workplace. Our basic control process will be divided in three steps. First after defining our goals and standards we will measure our actual performance, then we will compare our performance with our goals and then you can take managerial action. The goals set by us now can be either to easy to attain, which is not challenging and therefore should be increased or they are too high so we need to adjust them or find new strategies to attain these goals.

Figure 71 displays our process of controlling the marketing and organizational activities.

Figure 71: Control process

To measure our performance there are different possibilities. First there is the personal observation. This has the advantages that you get firsthand knowledge and also the information retained is not filtered. On the other hand it is very time consuming and may be more costly than other possibilities. Next there is the statistical report. This is an easy way to visualize you performance and also effective in showing the relationships involved. Oral reports are one of the fastest ways to get information and also allow verbal and nonverbal feedback. We want to use this as we are going to ask our customers if the product matches their expectations and if they are satisfied with our customer service. Lastly there is the possibility of written reports. This will enable us to store and retrieve the knowledge gathered.

Our whole process of control in respect to our managerial decisions will look like the following: Figure 72

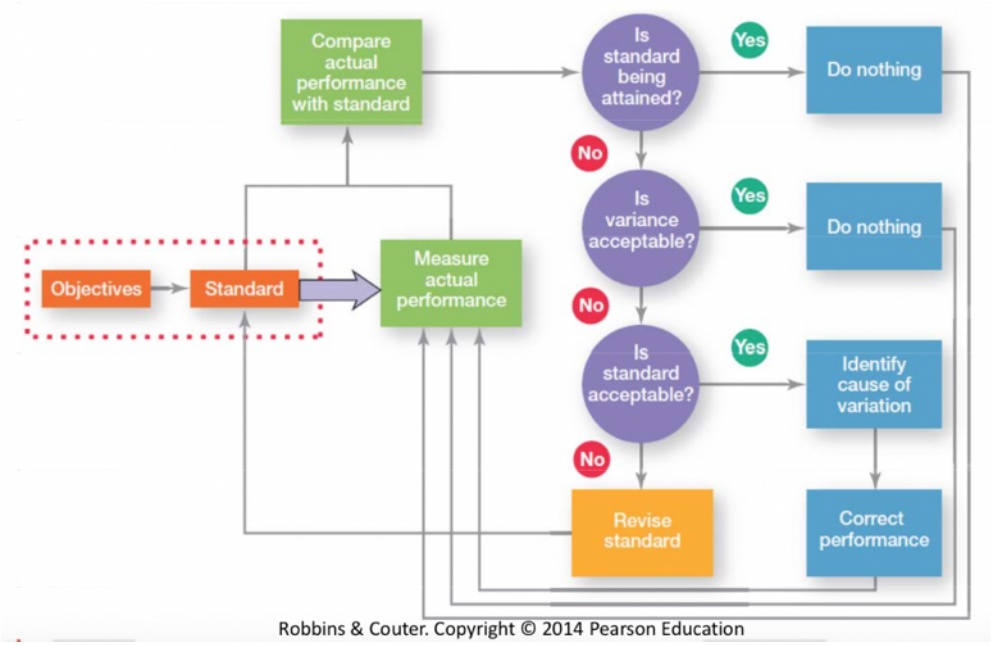


Figure 72: Control process in detail

This principle of measuring our marketing efficiency will be a process that can be also applicable for other areas such as our financial area, human resources and production area to monitor our productivity and efficiency.
To support this process we will implement a management information system (MIS), which will provide our management with needed information on a regular basis.

4.10 Conclusion

Summing up the previous chapter, we can state that our innovative product will attain a unique selling position. We do not have direct competitors that offer similar range of functioning. To attain a high level of customer satisfaction we want to sell highest quality and retain a close relation towards them. For a long-term profitability we want to offer a broad range of customer service and implement the feeling of uniqueness for each customer. We will focus on the B2B market by mainly approaching them in direct contact. Although personal

selling is one of the most expensive and timely options, we consider it as the most efficient for our innovative product. For our first step in the market we will use leaflets and articles as promotion and also focus on fairs to get a wide basis of potential customers to know about our product.

By end 2016 we want to explore the European market and increase our profitability by improving our production processes and marketing strategy. Our extended level of experience will do this from our primary market Portugal. Our core standards of our company will be high quality, fair customer and employee treatment and offering best service at the market.

5 Eco-efficiency Measures for Sustainability

5.1 Introduction

Sustainability is currently playing a major role in all our lives and the issue is causing much debate over the planet to save our civilization and environment. It has been on the forefront of the international agenda for more than a quarter of a century, yet we continue as a species to build economies at considerable costs to the environment. It is evident that social and economic sustainability are only solution although to do so we must have a healthy plan.

“These are the living forms that constitute the fabric of the ecosystems which sustain life on Earth – and the barometer of what we are doing to our own planet, our only home. We ignore their decline at our peril.” Marco Lambertini Director General WWF International [30]

The world ecosystem is being undermined by the human race, as we have become the dominant force that shapes these systems for our own gain. It appears that the solution is a healthier balance to preserve our plant, from

supporting the quality of life for animals and humans of communities around the globe. The diagram below illustrates the three most in important domains that affect our way of living.

Figure 73

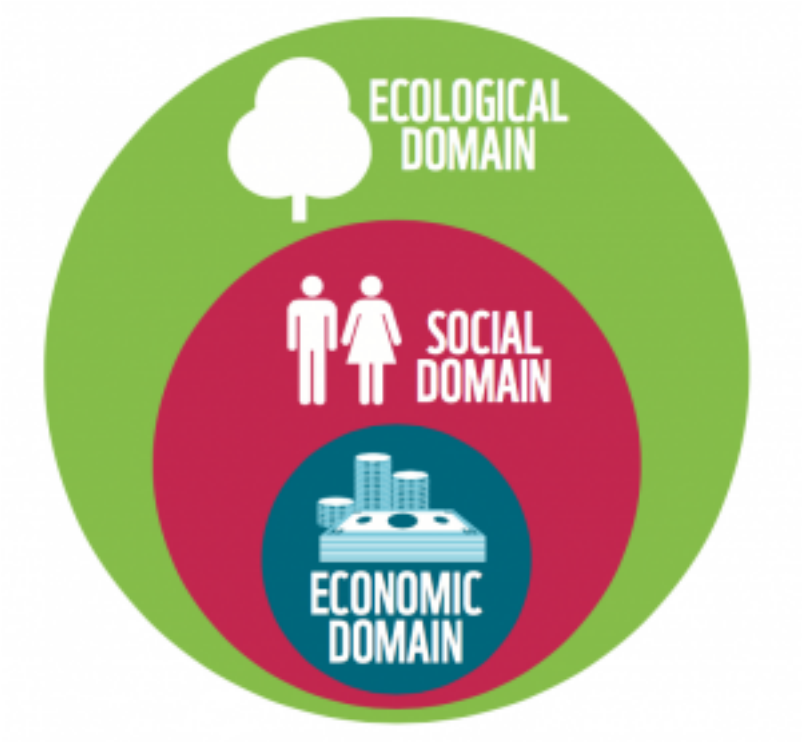


Figure 73: Sustainable dimensions

1. Environmental
2. Social
3. Economic

These interconnected variables are linked indefinitely to achieve eco-efficiency, and each variable has an array of sections that must be achieved to conquer the sustainability of our planet.

Our company, “Horizon Sails” thrives to become sustainable by seizing all opportunities to do so at minimal risk to the business, people and the planet. The environmentally friendly approach to material selection and sourcing combined

with our aware manufacturing process and efficient distribution is a priority.

As an accomplished manufacturer and distributor of autonomous sail boats for a variety of environmental aids (sea exploration data etc.) based in Porto, Portugal. The focus to target Europe and Asia was made because of there green policy advancements in recent years has shown a large gap in the market for data collectors at sea. In 2015 we opened our first manufacturing site and distribution warehouse. Our products are custom made for the clients and from an array of easily resourced materials that are supplied from companies in Portugal.

Table 24: Company network

Connection	Goal
Customers	World Wide Environmental Aid Workers/ Researchers/ Security etc.
Suppliers	Local suppliers to develop safe relationships to ensure quality in deliveries and materials for client deadlines
Stakeholders	The stakeholders need accurate, relevant and reliable information regarding investments and targets for our market
Employees	Major asset, dedication and skill is required for a sustainable vision of the company
Communities	Major asset, dedication and skill is required for a sustainable vision of the company

5.2 Environmental

We follow Environmentally Conscious Design and Manufacturing. Our key to the solution of environmental problems lies in our policy of adopting environmentally friendly products and production operations – the concept of a eco-factory. We adopt the following guidelines for environmentally conscious product design towards design for environment so as to make the daily operations of a treatment plant environmentally friendly:

5.2.1 Process

(1) Save energy and the use of renewable energy - Using Energy Star approved equipment is a great way to reduce your total power consumption. The Energy Star sticker is present on energy-efficient office equipment and home appliances.

(2) Minimizing the number of components and ensuring minimal handling of components by Design for assembly (DFA). DFA is a process by which products are designed with ease of assembly in mind. If a product contains fewer parts it will take less time to assemble, thereby reducing assembly costs. Design for disassembly (DFD) methodology must be implemented to speed the disposal process. Deciding this method of disassembly during the early design phase and promoting it will allow for parts to be recycled easier at the end of the products life.

(3) Become a paperless business - Memos, manuals, and other documents don't need to be printed out. By taking your workplace communications to the email inbox, you can reduce your environmental impact while simultaneously saving electricity.

(4) Embrace natural lighting - Artificial light is expensive, unhealthy, and environmentally unfriendly. Installing a day lighting system in your building doesn't need to be expensive – in fact, when you look at the long-term savings, it's actually a very cost-effective choice.

5.2.2 Pollution Control

5.2.2.1 Plant Emission

(1) Following environmentally conscious manufacturing by adopting environmentally responsible activities like "Zero avoidable pollution" and

“green manufacturing”. Viewing and analyze waste, to transform it from an unavoidable result of our processes, in a measure of our efficiency. The waster a process generates, the less efficient it is. **(2)** Selecting materials for product design for recycling. Our idea is to select those materials that have the right properties for our design and also that can be reused and recycled with the lowest costs. Efficiency rise in energy uses and reduce the proportion of VOC (Volatile Organic Compounds) emission. Our purpose is to reach the Gold standard.

- The Gold Standard, supported by WWF, is the most rigorous certification standard globally for carbon offset projects. It ensures that energy efficiency and renewable energy projects actually reduce carbon dioxide (CO2) emissions, and provide benefits to the local population.

(3) Our plant can use a Cogeneration system to heat and power the factory. The heat can be used to raise steam for industrial processes or hot water for local heating, depending on the temperature. This simultaneous production of heat and power is known as Combined Heat and Power (CHP).

(4) Reducing use of water. We want to use tools developed by the World Business Council for Sustainable Development and World Resources Institute to identify levels of water stress at each of our manufacturing sites. We want to use Cooling towers with an efficient closed regeneration loop.

(5) Carbon Capture and Storage. One of our first aim is reducing emissions of CO2. The best technology to do it is the so-called CCS. It is divided in three stages: Capture, transport and the storage. Post-process capture. CO2 is separated from a mixture of gases at the end of the production process, for instance from combustion flue gases. Transport of CO2 in pipelines is a known and mature technology, with significant experience from more than 6 000 km of CO2 pipes in the United States. Geological storage of CO2 involves the

injection of CO2 into appropriate geologic formations that are typically located between one and three kilometers under the ground. By now there are risks related to the possibility offered by the technology of CO2 confinement that are mainly of two types : the unexpected release of massive amounts of CO2 as a result of geological events or other modifications of the containment structures and a gradual and silent leaking into the atmosphere prolonged in time. By now only five companies use CCS all around the world, because we are now in a development phase. If this phase will success, probably CCS will be very common in the next 20 years. In this case we will use it if our production will be big enough to produce a consistent quantity of CO2. [37]

5.2.2.2 Sea Emissions

For our product we have to take in considerations some of the environmental problems of the oceans and understand how our product could be ocean-friendly.

Sea Surface Temperature

Ocean surface temperatures increased over the 20th century. Even with some year-to-year change, the overall increase is evident, and sea surface temperatures have been higher during the last thirty years than at any other time since faithful observations began in the late 1800s. Global warming caused by emissions of heat-trapping carbon dioxide has increased the average ocean global temperature by about 0.18°F (0.1°C). This warming has occurred from the surface to a depth of about 2,300 feet (700 meters), where most marine life thrives. [35] The only way to reduce ocean temperatures is to dramatically reduce emissions of carbon dioxide. However, even if we immediately dropped carbon dioxide emissions to zero, the gases we've already released would take decades or longer to dissipate.

In relation to our product we will reduce our own carbon dioxide emission when producing the boat and also by the boat operating without relying on fuel. Another aspect is that our boat will be useful to monitor these environmental developments of the sea to get a better understanding and improve our precautions.

Sea Level

Sea level has increased at a rate of roughly six-tenths of an inch per decade since 1880. The rate of increase has accelerated in recent years to more than an inch per decade. Changes in sea level are relative and vary by region. Along the U.S. coastline, sea level has raised the most along the Mid-Atlantic coast and parts of the Gulf coast, where some stations registered increases of more than 8 inches between 1960 and 2013. Sea level has decreased relative to the land in parts of Alaska and the Northwest. Our boat can help to control these increase in the sea level.

Ocean Acidity

The ocean has become more acidic over the past few centuries because of increased levels of atmospheric carbon dioxide, which dissolves in the water. Higher acidity affects the balance of minerals in the water, which can make it more difficult for certain marine animals to build their skeletons and shells.

Over Fishing

The practice of commercial and non-commercial fishing which consumes fisheries by catching so many adult fish that not enough survive to replenish the population is abounding all around the world. Overfishing exceeds the carrying capacity of a fishery. On a global scale we have enough fishing capacity to cover at least four Earth like planets. [36]

The first consideration about our product is that the environmental impact is really different from motorboats and reconnaissance drones that could be used for similar purpose. Using just renewable energy our boat doesn't produce CO2.

These are some tips for our boat end consumers:

- WAX Boat - A good coat of wax on a fiberglass hull prevents surface dirt from becoming engrained. This will reduce the need for detergents when you wash your boat. Pollen, dust, spores, or salt occur naturally and will do no harm when they are washed into the water.
  wash topsides only- Limit dock side hull cleaning to the above water surface area only – from the boot stripe up. Use a sponge to effectively remove light growth without creating the clouds of heavy metals usually caused by scrubbing. Rinse your boat with fresh water.
  use non-toxic cleaners- many cleaning products contain phosphates and other chemicals that are toxic to aquatic ecosystems. Before using products with hazardous warning labels, such as skull and crossbones, try a natural cleaner like vinegar.
- Don't use toxic Antifouling paint: Most antifouling bottom paints are destructive to marine life. The newest coatings are formulated to have a less toxic and less long-lasting effect. Silicon, Teflon, and other “nonfouling” paints rely on a slick surface to inhibit growth rather than on toxic ingredients to kill growth.
- Dispose properly old paint. Paints, solvents and thinners have to be disposed at an appropriate household waste facility. Do not dispose of paint or chemical containers in regular dumpsters.

5.3 Economical

“Maintaining high and stable levels of economic growth is one of the key objectives of sustainable development. Abandoning economic growth is not an

option. But sustainable development is more than just economic growth. The quality of growth matter as well as the quantity“. UK Government Annual Report 2000, January 2001.

In terms of economical sustainability in total, we can say that it is more than just an increasing GDP in the economy. It includes a wide range of indicators such as investment, interest rates, productivity, and labor market and employment statistics. These indicators are supposed to tell us about the happiness and sustainable growth of the society. As the economic sustainability in terms of our company can be a measurement of our financial performance, management of intangible assets, influence on the economy and how our organization manages social and environmental impacts. [31]

Our product will be build with components from Portugal and also 100% manufactured here. This will reduce the cost of transportation and also increase the employment rate as we are focused to employ Portuguese people. In our production we will try to reduce the usage of electricity and water involved to improve our “ecological footprint”. Most of our transportation for exporting will be done by truck or ship in transport boxes to minimize the space needed. Additionally all our components will be chosen by high quality and long life time expectancy. For this we will compare all possibilities that we can think off and evaluate them upon the criteria of lifetime, recyclability, costs, maintenance effort and also upon the way of the component itself is produced in terms of its ecological effects.

Our aim is to improve our sustainable manufacturing practice, viewed as production methods and technologies that focus on economic development and environmental protection simultaneously. The development of Sustainable Manufacturing practice is seen in three different stages: product, process and

system. At the product level, the aim is to use the 6r approach (reduce, reuse, recycle, recover, redesign, remanufacture). At the process level is to optimize technological improvements, and at a system level to evolve from a organizational-based orientation to a entire supply chain orientation. A number of studies, performed in different countries with using various statistical methods and techniques, found that integration of social and environmental aspects into technical and organizational activities undertaken by firms would increase economic performance. For example focusing on energy efficiency, water conservation, waste reduction, and other resource efficient practices for improving the ecosystem life and reduce ecological impacts, we are able to increase operational efficiency in the way of cost savings, reduce production lead times, and improve quality and productivity as well as improve revenues or profitability. [34]

5.4 Social

Social Sustainability is defined as “the ability of a community to develop processes and structures which not only meet the needs of its current members but also support the ability of future generations to maintain a healthy community.” Read more: http://www.businessdictionary.com/definition/social-sustainability.html#ixzz3VEXNEbNJ

In this context we will try to operate in a way to satisfy the needs of our costumers while manufacturing the product respectively concerned about the nature and its reproductive capabilities. We need to ensure that the nature is preserved over a long period of time and the normative claims of social justice, human dignity and participation are fulfilled.

From Beate Littig, Erich Grießler 2005 Social sustainability: a catchword between political pragmatism and social theory, International Journal of Sustainable Development 8(1-2):65-79, p 72.

5.4.1 Work Schemes

5.4.1.1 Evaluation

Social sustainability and its management have achieved a greater impact for maintaining good relations towards employees, customers and the society. For maintaining a fair and good relation towards our employees we want to implement an evaluation system. This will help us to quantify the amount of work an employee has done and fairly install a bonus and recognition evaluation. Promotion has to be made upon the contribution made towards achieving company goals. Many times it is rather a subjective decision not based on qualifications. The evaluation will be held once a month and consists of quickly answerable questions that can be marked by a scale from 1-10. Line managers with a lower span of control than 15 people should always make the evaluation. This will ensure a close contact towards the colleagues. The next higher management level etc. will evaluate the line managers.

Also in relation to the evaluation system and the fact to ensure fair promotion on basis of commitment we want to install incentives. These incentives can be variable, from extra days off, up to money bonuses. On the other hand it is possible to reward with trainings and seminars to improve the qualifications and reduce at the same time the accidents due to higher qualified worker.

5.4.1.2 Health

We want to install a health care system in the company. Once or twice a week we want a doctor to come to our company and do health checks for our employees. This will be on an optional basis for them as a service by the company.

The work environment is a vital ethos for our company, as we want our employees to feel adequately safe in there position. Implementing continuous

training seasons and refresher courses will see the accident rate in work lower to zero. In addition external auditors will evaluate our safety scheme to ensure all areas are covered and employee satisfaction is exceptionally high.

5.4.1.2 Family

Another approach will be to become a family friendly company. In terms of being family friendly we want to build up for example cooperation with kinder gardens and install flexible working shifts. If we can offer good kinder gardens for our employees, they will feel confident that their kids are well and in good surrounding. This will improve the identification with our company and increase the willingness to commit towards their work. Additionally it is today quiet often possible to pay a certain percentage of your monthly wage into a fund held by the company. When working for a long time at this company you get a pension payment back, which will increase the income when the employee retires. This is a great chance for employees to finance themselves for the time after working respectively if the governmental security system is not able to finance the retirement of people anymore.

5.4.1.3 Additional

Next if our company will start to grow and strengthen its position in the market we want to try to support our employees in finding accommodations and subsidize local transport tickets. On the one hand it will be easier for our employees to life close to the company or use an environmentally friendlier way to get to work.

5.4.1.4 Auditing

Another approach of ensuring social sustainability in terms of the society aspect will be to participate in a European Auditing Scheme. It is called “Eco Management and Audit Scheme” (EMAS) and consists of the idea to voluntarily audit your own company by externals in terms of eco efficient management. After the audit we will be a certified company that fulfills more than the

obligations made by the government. By publishing our report about the organizational effects on the environment we will be transparent for the stakeholders and also be held officially responsible for the goals we prescribe upon. To guarantee that we will achieve these goals we will install an environmental officer that will supervise and correct the production when getting “off the track”. However, our company will strive to accomplish the ISO 14001 as well. The EMAS is more or less an additional commitment based on ISO 14001.

5.4.1.5 Education

On going to our social commitment we want to source our products locally and strengthen the local economy. Also there is the possibility to support the community by holding seminars and presentations at local universities. We can teach student about work experiences and send engineers to the universities to speak about naval engineering and design. This will also increase our reputation at the young professionals and improve the accessibility to get highly qualified students in our company, maybe also by internships.

5.4 Life Cycle Analysis

5.4.1 Extraction of Raw Materials

Analysis and quantification of the main components for the boat will be reviewed thoroughly. Highlighting which raw materials, energy and resources are used throughout the production and transportation processes. In our case we can mend the use of wood for the main structure of the boat, which is a renewable source of material. Any other material considerations will be under a great amount of scrutiny to verify the best possible selection for our project.

5.4.2 Design Process

Initially the unique design of a model boat is required which will be manufactured and it will have low environmental loaded activity, the design phase is not usually considered into the system. However, the components that it contain can take part on the environmental affect in our case. Our idea has been to reduce the quantity of material furthermore to provide the boat with the proper form and with some energy sources that will not affect the environment.

5.4.3 Manufacturing and Production

The production includes all stages from materials to the final product. It contains materials, input processes (energy, water etc.), output processes (waste, emissions etc.) The idea is to reduce the manufacturing and production consumption, like minimizing the use of energy on building, and try to cause less impact as possible, taking the maximum profit to all materials used to reduce the quantity of wastes.

5.4.4 Packaging and Distribution

The distribution plan for the product from our manufacturing warehouse to the final user is described below. The plan is to produce the boat in a place near the sea and in the principle country to use it, which in our case is Portugal, to avoid

the use of transport. However, if in a future we have some international customers, the idea is to design a special package for those boats, as these are not so big so we will fill a truck, train, boat or plane with the maximum capacity and find the best route for our distribution employees to successfully deliver the product on time and perfect condition.

5.4.5 Customer Use and Maintenance

The user lifetime with the boat proceeds here, during this phase users' profile and its behavior is highly determinant. It is dependent on the level of expertise from the user and the intensity of which they use it. There is a variety of activities the boat may for fill therefore must all be analyzed. The activities include, sailing, mooring, and maintenance.

First of all the boat has to be designed in a form that needs as minimal maintenance possible, which requires a big consumption of energy, both in the technicians contraction as in the storage safety costs. One of our points is to provide an easily understood manual to the consumers to let them take care and repair their own boat and reduce many costs. In addition, the way the users make the boat work can effect on the environmental impact so we also will provide a user guide to explain the best way to use the product.

5.4.6 End of life

The end of life includes disposal and recycling of waste materials. Once the user decides the end of life of the product there are several possibilities they can perform for the final treatment. Disposal documentation is required, as a company we have signed an agreement to accept boats at the disposal stage to recycle and use available components in newer products.

If the owner chooses to recycle them self then a controlling method for the end of our product has been implemented, a method called DFD, Design for Disassembly, which is used to design the product in order to make an easy and economic deconstruction of it once it life ends. This deconstruction lets us to get those pieces that can still be reused from the boat and reduce costs on the production. For this, we will provide some place or service where the consumers will be able to leave the product receiving remuneration or any benefit for their implication. The second phase is to recycle those pieces that could be damaged to produce it again with les costs obviously, like in the case of PVC pieces, which can be completely recyclable.

5.4 Conclusion

In conclusion to this chapter, Eco-efficiency Measures for Sustainability, our company will adopt an ethos to work towards targets and goals, which will see us, progress over time as a major sustainable players for our environment. Our products will be under constant scrutiny during the entire lifetime, conducting rigorous policies and commitments to the environments, consumers and shareholders.

We strive to:

- Advance our technologies & solutions
- Help customers effectively
- Limit the environmental impact
- Work together for mutual benefit

All these elements position us as a prominent player in the global environmental transition: a corporate culture enabling the company to generate competitive advantage. To follow this path and grow our business in the medium and long term means the involvement of every manager, employee and partner, individually and collectively in a work management strategy. In the next chapter the ethical and deontological concerns of a business culture will be highlighted and advanced, allowing us to deliver a broad understanding of what is right and wrong on several platforms of ethics.

6. Ethical and Deontological Concerns

6.1 Introduction

In this chapter, we are going to outline the importance of a strong ethical basis in our business. Our main object will be to explain our ethical concerns in terms of Engineering Ethics, Sales and Marketing Ethics, Academic Ethics, Environmental ethics and Liability of our sailing boat. Whenever setting up a new business idea and entering the market, you are in many ways confronted with ethical questions regarding the ways you operate. Ethical questions arise already in the ideation phase of a new product where you deal with core questions regarding your materials and the functioning itself. All ongoing steps will have an impact on the environment and also on humans that are in direct contact with the production process or by using it. These various situation are characterized by multifaceted decisions which will lead in a wrong direction when not, in terms of ethics, are thought through. Furthermore they are hardly reversible and shape an image in the customer minds. As our ethical action will enhance trust and good relation with customers, suppliers and other businesses it is a core process for our effective development and strong positioning in the market.

At the end we will have to follow some shorts of rules, like religious imperatives, ethical standards, the rules of courtesy and etiquette, and the legal norms to perform well.

"In law a man is guilty when he violates the rights of others. In ethics he is guilty if he only thinks of doing so." **- Immanuel Kant**

6.2 Engineering Ethics

Whenever you are designing a new product and thinking about the functioning as well as its components you are obliged to think also about the effect on the environment and user of the product. Our civilization is based on engineering and its progress. New technologies enable us to be more efficient, faster but also may involve negative side effects on the environment and human health. In consequence it needs some rules or guidelines that apply to engineering processes. There are standards of good practice set and formulated in a „Engineering Code of Ethics“. We will apply this to our product by naming them and referring to our engineering approach.

(1) Hold paramount the safety, health, and welfare of the public. In order to ensure safety, health and welfare of the public, we will design a boat that will be safe to use for any customer and also not be a threat when fulfilling its missions offshore. We will use highest standard of technology to minimize the threat of an nonviable boat. Furthermore we focused our material research on sustainable factors and also to care about the recycling at the end of its lifetime.

(2) Perform services only in areas of their competence. To due the fact that non of us has a profound background in naval engineering we try to keep in close contact with specialists from divers engineering fields. This will ensure a high level of competence and quality in performing the prototyping.

(3) Issue public statements only in an objective and truthful manner. This refers to our marketing strategy. We want to only present our company and product in a fair manner. We have to ensure that we only state proven facts about the product that we can be held responsible for.

(4) Act for each employer or client as faithful agents or trustees. It is important for us to remain our good teamwork on this project in the future. Only by a free flow of information regarding the product we will create a successful working atmosphere. However, this free information flow will be useful to enhance a feeling of participation for the employees and we might benefit by getting new ideas. The success of an innovative product lies in the commitment of every employee.

(5) Avoid deceptive acts. As our report is the basis for our business idea, we will be transparent in our mission for every stakeholder. These report is free accessible for everybody. Furthermore we created a website to enable everybody to get information about the product and us.
(6) Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession. This point is very important for us. Everybody in this team will do his best to fulfill these criteria. By doing so it will increase our reputation in the society and improve our brand name. [39]

6.3 Sales and Marketing Ethics

As the desire to make fast money is getting more and more important in our daily life, we see an alarming trend growing in business society. Many marketing and sales activities are based on these selfish and ruthless principles. Our company wants to instead be transparent and achieve a long-term relation with our clients. Therefore we will be consistent in our marketing strategy and honest about our product. Additionally we will not use any advertisement strategies that include talking other competitor products down. This approach will enhance a profound image of the company; enlarge our authenticity and also the customer confidence. Furthermore we strive to manufacture a high quality product offered to fair prices. When doing advertisements our potential customer will get the information needed on the technology, functionality and

the way of manufacturing it. This will provide him with a solid basis to decide himself if to purchase or not and if the product reaches his expectations. Instead of promising our customers some features and benefits of our product that cannot be delivered we want to try to get an understatement.

6.4 Academic Ethics

Due to our various study backgrounds at have only a little relation to the topic of naval engineering, we highly relied on gathering knowledge from different sources. These sources can be books, articles or websites regarding the topic of boat design and construction. In these terms we are stating the source of these knowledges in the bibliography to determine who's property it is. Our software used will be only based on free ware to avoid any licensing problems. Furthermore we are working in a group of people from different countries. This implies that we are used to different ways of working and have been raised surrounded by different cultures. Also we may have different aims and expectations of our goals regarding the project. Nevertheless we will try to work as a team by respecting the others and fulfilling each task at our best. Regarding the relation to our coordinators and teachers in class we will confront them with respect and work in class when asked to. Also we will prepare our meetings and homework for class.

6.5 Environmental Ethics

The point of environmental ethics concerns the fact of our ecological footprint. This means that every product has a certain impact on the environment and future generations living on this planet. Our mission is to minimize this ecological footprint in order to preserve the nature and manage to maintain a livable condition. The ethical approach should be to focus the design on reusable material and also think about the end of the lifecycle of the product. This means that our company wants to offer a recycling/ disassembly of the boat or components when not functioning anymore at our costs. To avoid that this is

happening early in the life cycle we will only use high quality material and ensure that our product is as less harmful to the environment as possible. As mentioned in the sustainability chapter we want to participate in the EMAS in order to operate environmentally friendly. This is an additional commitment apart from the regulations of the European Union and is based on the ISO 14000.

6.6 Liability

As a matter of fact the autonomous sailboat can also be a hazard for others when being out of control or capsizing. This may involve people or the ocean environment. Also we can be hold liable for the promised quality and warranty given. This is why we will exactly define the terms of our warranty and let it be checked by legislative authority. If there are any customer complaints occurring we need to find a reasonable way to satisfy both sides and remain our relationship in a respecting way. Furthermore we will enclose a user manual for our product to guide the customer along the functioning of the boat and also point out the hazards that are involved by using it. Next we have to maintain safety standards at our production, to protect our employees and also for ensuring safety when operating in sea.

Some directives regarding our product are:

- Machine Directive (2006/42/CE 2006-05-17);
- Electrical Safety: Low Level Voltage Directive (2006/95/CE 2006-12-12);
- Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive (2002/95/EC 2003-01-27);
- Mandatory adoption and use of the International System of Units (The NIST International Guide for the use of the International System of Units).

Additionally we need to be aware of copyrights, trademarks and patents and must not infringe these. Therefore we designed a logo ourselves and checked on the wipe, which is the abbreviation for World Intellectual Property Organization [16] if the name „Horizon Sail“ is already used. As our product will be implemented in the market, we need to register this as a trademark including our logo.

Last but not least we will follow the legal framework provided by the EU and the local governments.

6.7 Conclusion

Summing up this chapter we see that there are various ethical dimensions that we need to take into consideration. As the basis of our company we see the engineering ethics that we need to take as a guideline throughout our economic activity. Furthermore we will apply a code of conduct in our company that will ensure a fair treatment of employees and stakeholders. It will consist of setting guidance for the responsibilities and the right operational practices. The code of conduct will state principles, values and standards for the interaction in the organization itself and towards our environment.

Glossary

EPS	European Project Semester
ISEP	Instituto Superior de Engenharia do Porto
USB	Universal Serial Bus
ROHS	Restriction of Hazardous Substances
NIST	International System of Units
LOA	Length overall
LWL	Length of waterline
DWL	Designed waterline
LPP	Length between perpendiculars
FP	Forward perpendicular
AP	Aft perpendicular
B	Beam
BWL	Beam of waterline
T	Draft
CP	Prismatic coefficient
Cb	Block coefficient
SAN	Corecell styrene acrylonitrile
CNC	Computer Numerical Control
CG	Center of gravity
CB	Center of buoyancy
Sw	Wet Surface
NACA	National Advisory Committee of Aeronautics
Ah	Ampere hour
Wh	Watt hour
V	Volt
Kg	Kilogram
GPS	Global Positioning System
A	Ampere
M	Metric center
LSA	Autonomous System Laboratory
MW	Mega Watt
GWh	Giga Watt hour
TWh	Tera Watt hour
LODO	Land/Ocean Biogeochemical Observatory
B2B	Business to Business
B2G	Business to Government
NOC	National Oceanography Centre
NERC	National Environment Resource Council
R&D	Research and Development
US	United States
MIS	Management Information System
DFA	Design for Assembly

DFD	Design for Disassembly
VOL	Volatile Organic Compounds
CO_2	Carbon Dioxide
CCS	Carbon Capturing System
EMAS	European Mangement and Audit Scheme
ISO	International Organization of Standardization
WIPE	World Intellectual Property Organization

Bibliography

* [1] Ordered List ItemUnordered List Item Name, Title, Year. Available at URL [Accessed in February 2015].\\
* [2] Ordered List ItemMaritime Affairs, available at http://ec.europa.eu/maritimeaffairs/index_en.html
* [3] Larsson, Ralf and Eliasson, Principle of Yacht Design, 2000
* [4] Principle power, Wind float available at http://www.principlepowerinc.com/products/windfloat.html
* [5] Dean and company, the traingle online http://www.dean.com/delta-model/strategic-positioning
* [6] Technologies for Autonomous Sailing: Wings and Wind Sensors [[http://bit.ly/1BrsSAs]]
* [7] Fabrice Le Bars, Luc Jaulin: Robotic Sailing 2013
* [8] Solar Cell Comparison Chart – Mono-, Polycrystalline and Thin Film [[http://energyinformative.org/solar-cell-comparison-chart-mono-polycrystalline-thin-film/]]
* [9] Which Solar Panel Type is Best? Mono- vs. Polycrystalline vs. Thin Film [[http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/]]
* [10] Napelem típusok [[http://www.szabovillany.hu/index.php/napelemes-rendszerek/napelem-tipusok.html]]
* [11] The Real Lifespan of Solar Panels [[http://energyinformative.org/lifespan-solar-panels/]]
* [12] Batteries [[http://www.explainthatstuff.com/batteries.html]]
* [13] What's the Best Battery? [[http://batteryuniversity.com/learn/article/whats_the_best_battery]]
* [14] Joshua Earnest: Wind Power Technology
* [15] A fistful of Euros http://fistfulofeuros.net/afoe/portugal-please-switch-the-lights-off-when-you-leave
* [16] Green Report http://www.greenreport.it/_archivio2009/index.php?page=default&id=7141.
* [17] National Geographic Center http://noc.ac.uk/about-us/about-us
* [18] http://sailing.about.com/od/typesofsailboats/ss/Ruddertypes_5.htm#step-heading (3rd March 2015)
* [19] Bernd Kohler, K-designs,HOW BOARDS AND RUDDERS WORK, 2006
* [20] Aero-hydrodynamics and the Performance of Sailing Yachts:The Science Behind Sailing Yachts and their Design;Fabio Fossati;2009;Page 325
* [21] On the Stability of Sailboats; Anthony Craggs; Page 15-17
* [22]Aero-hydrodynamics and the Performance of Sailing Yachts:The Science Behind Sailing Yachts and their Design;Fabio Fossati;2009;Page 327-328

* [23] Float Your Boat!!:The Evolution and Science of Sailing;Mark Denny; Page153;2009
* [24,25] Practical Ship Production; A.W.Carmichael; Page 7;2011
* [26] Aero-hydrodynamics and the Performance of Sailing Yachts:The Science Behind Sailing Yachts and their Design;Fabio Fossati;2009;Page 2-4
* [27,28,29] Grundlagen des Marketing;Pearson Studium; Auflage: 5., aktualisierte Auflage (1. August 2010)
* [30] Living Planet Report 2014; Species and spaces, people and places;Living Planet Report;http://ba04e385e36eeed47f9c-abbcd57a2a90674a4bcb7fab6c6198d0.r88.cf1.rackcdn.com/Living_Planet_Report_2014.pdf
* [31] Economic Sustainability The business of staying in business; Deborah Doane & Alex MacGillivray New Economics Foundation;March 2001 ; http://projectsigma.co.uk/RnDStreams/RD_economic_sustain.pdf
* [32] http://uk.boats.com/boat-content/2013/12/boats-we-love-the-ac72-catamaran/ [Accesed 5th April 2015]
* [33]http://www.telegraph.co.uk/sport/othersports/sailing/10335496/Americas-Cup-how-the-yachts-go-faster-than-the-wind.html; [Accessed 5th April 2015]
* [34] "The Impact of Sustainable Manufacturing Practices and Innovation Performance on Economic Sustainability "; 2015; Norsiah Hami and Mohd Razali Muhamad and Zuhriah Ebrahim
* [35]Sea temperaure Rise;National geographic http://ocean.nationalgeographic.com/ocean/critical-issues-sea-temperature-rise/
* [36] Overfishing http://overfishing.org/pages/what_is_overfishing.php#note5
* [37] Technology Roadmap,Carbon Capture And Storage http://www.iea.org/publications/freepublications/publication/technologyroadmapcarboncaptureandstorage.pdf
* [38] What is GPS? http://www8.garmin.com/aboutGPS/
* [39] http://www.nspe.org/resources/ethics/code-ethics; [Accessed 5th April 2015]
* [40] http://www.gizmag.com/solar-power-linux-brain-autonomous-robot-sailboat-aims-to-conquer-the-atlantic/10517/; [Accessed 5th April 2015]
* [41] http://www.roboat.at/en/presse/; [Accessed 5th April 2015]
* [42] http://sailing.about.com/od/typesofsailboats/ss/Ruddertypes_5.htm#step-heading; [Accessed 3rd April 2015]
* [43] http://www.pdracer.com/rudder/;[Accessed 3rd April 2015]
* [44] http://ec.europa.eu/research/innovation-union/pdf/state-of-the-union/2012/countries/portugal_2013.pdf; [Accessed 3rd April 2015]
* [45] http://paginas.fe.up.pt/~jca/fast/;[Accessed 3rd April 2015]
* [46] http://www.gizmag.com/asv-roboat-fully-autonomous-sailboat-to-make-world-record-attempt/22559/; [Accessed 2nd April 2015]
* [47] http://www.saildrone.com/; [Accessed 2nd April 2015]

* [48] http://www.automarinesys.com/wp-content/uploads/2014/05/Datamaran_DataSheet.pdf; [Accessed 2nd April 2015]
* [49] http://www.poliziadistato.it/articolo/31029/; [Accessed 3rd April 2015]
* [50] http://www.superyachttimes.com/editorial/13/print/article/4189
* [51] http://www.tropicalboating.com/2012/10/saw-my-first-wingsail-in-person-today
* [52] http://www.sailboat-cruising.com/sailboat-keels.html