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Diseño del interior del coche solar para el World Solar Challenge

Autor/es

Germán Bielsa Pérez

Director/es

Magnus Andersson

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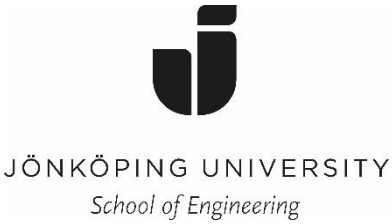

Design of the interior of the solar car for the World Solar Challenge

PAPER WITHIN *Industrial Design*
AUTHOR: *Germán Bielsa*
TUTOR: *Magnus Andersson*
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This exam work has been carried out at the School of Engineering in Jönköping in the subject area Industrial Design of the three-year Bachelor of Science in Engineering program. The authors take full responsibility for opinions, conclusions and findings presented.

Examiner: Olof Granath

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Abstract

This thesis analyzes the interior of the solar car, used by the JU Solar Team, to improve the user experience in terms of user interaction and ergonomics.

Following the Design Thinking methodology, it starts with a research phase to understand how the user interacts with the car and the elements required for this interaction during the race. It also studies the dimension of the actual interior and the anthropometric factors, some changes are proposed for a more efficient use of the space.

The next phase explores new buttons and configurations for the steering wheel. The use of prototypes and sketches leads the development of the ideas, which are further developed and defined, including the graphical design and the dimensions of the interior. In the findings, the redesign of the steering wheel and interior is shown in several renders with an explanation of the final design decisions, which can be summarized in:

A new shape for the steering wheel where most of the buttons have been added with new shapes and colors. The emergency buttons and light indicators have been allocated on a central control panel. The user has access to the buttons without releasing the steering wheel and the dimension of the canapé has been reduced thanks to a more efficient use of the space.

As a part of the thesis a full scale model of the steering wheels and a 1:10 scale model of the interior is provided.

This thesis solves some of the problems in the actual design of the solar car and explore some of the important factors in user interaction. A human-centered design approach to a project usually driven by the performance of the car and not the user experience.

Sammanfattning

Denna avhandling omfattar utveckling av interiör för solbilar med inriktning mot att förbättra för användaren. Arbetet avser att appliceras på Ju Solar teams solbil som ska delta för Högskolan i Jönköping i World Solar Challenge 2017.

Forskningen i projektet fokuserar på att förstå hur användaren interagerar och samspelar med bilen och de faktiska problem som föraren har att hantera under tävlingen.

Studien omfattar också antropometriska mått där förslag på ändringar gjorts för att optimera utrymmet.

Utvärdering av idéer har gjorts med hjälp av skisser och prototyper, som inkluderar den grafiska designen

Designbesluten kan sammanfattas med följande:

- De viktiga knapparna är alla samlade i ratten.
- Användning av form och färg samt position för att enkelt kunna skilja mellan knappar och dess funktioner.
- Ny form för ratten med en extra grepp-zon i den övre delen. Ny utformning av knappar, former och konfiguration för ratten.
- En central manöverpanel med ljusindikatorer för föraren.
- Nya dimensioner av interiören för att minska förarhuvens storlek och därmed minska luftmotståndet.

Som en del av avhandlingen finns en fullskalemodell av ratten och en modell i skala 1:10 av interiören tillhandahålls.

Solbilar utvecklas vanligen med prestanda som prioritet men denna avhandling utforskar de problemområden som finns i anslutning till solbilens förarmiljö med människan i centrum.

Keywords

Design, User interaction, Ergonomic, Solar car, Steering wheel

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1 Introduction

This report describes a Bachelor Thesis undertaken as the last part of the Bachelor program in Industrial design and product development at the University of Zaragoza during an exchange year at Jönköping University. It has been conducted in collaboration with the JU Solar Team. The following section covers the background and aims of the project

1.1 Background

Jönköping University Solar Team is a group of students and teacher that compete in the World Solar Challenge a solar-powered car race, which covers 3,022 km across the dessert of Australia. [1][2]

To win this race there are two factors. The first one is the racing strategy, which consists on an efficient use of the energy resources like charging the batteries as much as possible during daylight and the optimal racing speed, depending on the weather forecast and battery. The second one is the car design related to aerodynamics, weight distribution and maneuverability. [1][3]

The focus on these areas to achieve the victory or finish between the first ones could make us forget that is the driver the one controlling the car, his driving conditions are important for the accomplishment of the goals and the car design should be user-centered.

Analyze the interaction of the user with the car, the ergonomics of the car and how improve the general user experience of the solar car should be as important as the efficiency of the car.

1.2 Purpose and research questions

The main goal of this project is to propose a design for the interior of the solar car. To achieve this goal, it is necessary to analyze the interior of the car and the interaction of the user with it, provide solutions that solve encountered problems or improve the user experience without affecting the car's performance.

The research question that would be answered would be "How does the user interact with the car and how to improve it without affecting the car's performance?"

It will focus, from the interior of the car, mainly on the buttons, the steering wheel and the seat.

1.3 Delimitations

This report will not cover the exterior design of the car (except for the canapé that delimits the dimensions of the interior), the materials, manufacturing process or any mechanical or electrical issues.

1.4 Outline

The report is organized as follows, first the theoretical background, to describe the framework of the project, and the methods used in the process; then, how these methods have been applied, their results and the decisions taken to get to a result.

Finally, the result will be discussed and a conclusion will be state for further develop of the design.

2 Theoretical background

Having made a survey of current literature in the area of your exam work you will recount relevant parts in this section. It is crucial that you refer to all the sources you use in this chapter in accordance with the rules for referencing mentioned above. Note that the text must not be transcribed from a paper or a book but must be a summary. Transcription may only be done when "quoting" and should be used sparingly.

If you work with the design of products/systems this section may include various theoretical concepts and design theories, design philosophies, etc., that have inspired you in developing the design you are creating.

2.1 Design Thinking

Every design activity must follow a methodology adequate to the purpose of the project. The reason behind the use of a methodology is to stablish a series of actions, process or tools empirically tested [4]

One of this methodologies that has been widely use is Design Thinking, based in understand and find solutions to the real problems of the user. Or what is known as a user-centered design. It was developed as a theory in the 70s at Stanford University (EEUU)

This methodology comes from the way the product designer works, and has been develop to be use in other fields like business planning. [5]

Tim Brown, SEO of IDEO, describes Design thinking implemented in the business world as:

"It is a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity."

"Design thinking is a formal method for practical, creative resolution of problems and creation of solutions."

The design process is seen as different spaces rather than a series of steps. The first one is call "inspiration", related to find a problem, an opportunity, or both to solve, the second one is "ideation" for the process of generating, developing, and testing ideas that will solve the problem, and the last one is "implementation" for putting the product into the market.

"Projects will loop back through these spaces—particularly the first two— more than once as ideas are refined and new directions taken."

He also describes the Design Thinker's personality and how to use it for generate innovation.

He lists the following characteristics that people should develop to apply Design Thinking: Empathy, integrative thinking, optimism, experimentalism and collaboration. [6]

The Design thinking methodology that is used in design project have five steps or phases that follows the ones describe by Tim Brown. This are the five phases:

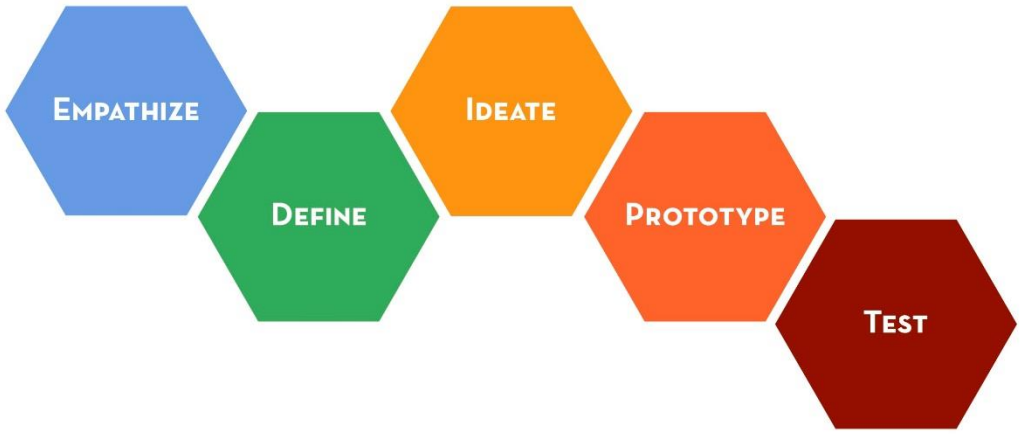

Figure 1: Design Thinking Framework [7]

Empathize: This is the base for a human-centered design methodology, to understand the user and being immerse in their experiences.

Define: Express the problem or synthesize the findings to stablish a point of view or goals to the project. Identify the problem

Ideate: Idea generation and exploration of the solutions. Expansion phase

Prototype: Project your ideas into the physical world to finds improvements and take decisions.

Test: Test the prototypes or solutions with the real user to evaluate the idea.

[5][7]

2.2 Ergonomics

Ergonomics is a multidisciplinary science that involves the study of humans and its relations with machines and the environment around them, to optimize human well-being and the task performance.

It is a multidisciplinary science because it studies the humans, physically and cognitively, the products, and the environment. [8] [9]

2.2.1 Anthropometry

Anthropometry is the science of studying the measures of the human body, one of the goals of this science is the design of systems that implies human interaction.

The anthropometrics dimension of people depends on sex, age, ethnical and socioeconomically factors. This means they change over times for a same population.

The anthropometrical data can be used in different ways to design a product:

Personalized design: The dimensions of the product are based on the dimension of a single individual. For example, a F1 race car seat

Extremes design: The dimensions of the product are based on the dimension of the extremes individuals. It allows maximizing the number of people that will be comfortable using the product. It often used in product that can adjust their dimensions, as office chairs.

Average design: The dimensions of the product are based on the average dimension of the population.

[9]

2.2.2 User experience

“Person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service. User experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors and accomplishments that occur before, during and after use.” [10] ISO 9241-210:2010 Human-centered design for interactive systems

2.2.3 Interface design

“For the user, the product does not exit. Only the interface exists” [9]

The user interface is defined as:

“All components of an interactive system (software or hardware) that provide information and controls for the user to accomplish specific tasks with the interactive system” [10]

The interface is a point where two systems meet, in this case the user and the product that generate a communication process between them to conduct an objective. There can be 5 ways of communication: Tactile, audible, visual, smell and taste.

There are three steps in the interaction design:

- Conceptual design or mental model**:** How the user think thing works. It can be different for the user and for the designer.

- Logic design: How interface interact with itself. The functions, information given and its relation.
- Physical design: The physical design of the interface.

Guidelines to have in mind for the interface design:

Hierarchy: allows the user understands the importance, function or frequency of use.

Clarity and simplicity

Affordances: the possibility of an action on an object or environment. It should be clear which movement or action the user should do.

Scope and visibility

Feedback: the user should know what is happening.

Prevent errors: the system should prevent user errors.

Gestalt laws: the whole is other than the sum of the parts. It is related to the cognitive ergonomics and how our mind creates patterns or complex shape from simpler ones.

Pareto principle: 20% of the buttons take 80% of the actions.

Hick law: the time to take a decision increased with the number of alternatives. More options, more probability of not choosing one.

[9]

3 Methods

3.1 Mind map

“A mind map is a graphical representation of ideas and aspects around a central theme, and how these aspects are related to each other. With a mind map one can map all the relevant aspects and ideas around a theme, bringing overview and clarity to a problem. […] A mind map is like a tree, with branches leading to the thoughts and aspect of the theme.” [11]

3.2 Literature review

“A literature review is performed by searching and examining literature such as conceptual literature, articles, conference papers, books, theses, completed research reports and other media and materials which contains information about the relevant research topic.” [12]

3.3 Brief

A design brief is a document or report created at the begging of a new project. It contains the guideline for the project, where the company, the designer or both define the objectives. The main points they discuss and develop are the problem, the goals, the expected result and delimitation. They can include as many sections as needed. [13]

3.4 Ergonomic analysis

Also referred as space design or task-centered design. Starting with the user posture, given by the task he has to do, the zones of vision and reach are stablished. Then the dimension of the space is built around the user. [9]

3.5 Functional analysis

It is method of analyzing and developing an abstract model of a new or existing product. It is a way to organize the functions and features that you want a product or service to have. Functions are abstractions of what a product should do without material features as shape, dimensions, etc. [14]

3.6 Storyboard

A storyboard is a series of images displayed in sequence for the purpose of visualizing a sequence. [15]

Used as a design method:

“A storyboard is a valuable aid to the designer, because it provides a visual description of the use of a product. […] A storyboard not only helps the product designer to get a grip on user groups, context, product use and timing, but also to communicate about these aspects with all the people involved. With a storyboard the powerful aspects of visualization are exploited.” [16]

3.7 Gantt chart

"A Gantt chart, commonly used in project management, is one of the most popular and useful ways of showing activities (tasks or events) displayed against time. On the left of the chart is a list of the activities and along the top is a suitable time scale. Each activity is represented by a bar; the position and length of the bar reflects the start date, duration and end date of the activity." [17]

3.8 Internet research

It uses the internet as a way of obtain free information from the web. It is focused and purposeful, not recreational. The information can be found in form of text, video or images. [18]

3.9 Interview

"A meeting at which information is obtained (as by a reporter, television commentator, or pollster) from a person" [19]

3.10 Collage

"A collage is a visual representation made from an assembly of different forms, materials and sources creating a new whole. [...] Making collages is an important visualization technique in the design process, next to sketching and three dimensional modelling. With collages, visual representations of the context, user group or product category is made with the objective of deriving (visual) criteria."

They can serve different purpose, they help determine design criteria for example for the color palette, the design language, the materials, the feelings that the user will feel.

Mood boards are types of collage used in consumer research that help to empathize with the user or his lifestyle. [20]

3.11 Sketching

Sketching as different roles in the design process. It can be used as a visual exploration to visualizes our thought or ideas. It allows to communicate the ideas with the client, company or co-workers so everyone has the same idea in mind. And it is a quickly way to explore concepts due its flexibility and spontaneity. This makes the sketching process an unbeaten tool for idea and concept generation [21]

3.12 3D modelling

"It is the process of developing a mathematically representation of any three-dimensional surface of an object via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation. The model can also be physically created using 3D printing devices." [22]

3.13 Prototyping

“A prototype is an initial model of an object built to test a design. Prototypes are widely used in design and engineering to perfect items and processes before implementing them on a large scale. A prototype is a vital part of the design process because it allows designers to see the product in action, so they can see what works and what does not. It is also useful for showing designs to corporate executives or investors to persuade them to support a project.

Often the only way to see if a design actually works is to build it and try it out. If the prototype reveals problems, the designers can modify the design and build another prototype. New products often go through several rounds of prototypes before the design is finalized.

Prototypes are not meant to be perfect versions of the designed products. It is often impossible to use the same materials that will be put in the actual product, and there may be no factory process to build it yet. Prototypes must be built by hand, using materials that are similar to, but not identical to, the intended ones. This results in a prototype that is not exactly what the final design will contain, but that is close enough to let the designers see if it will work or not.

A prototype may replicate just one portion of a design. It may create the look of the object without its functionality, or the functionality without the look.” [23]

3.14 Rendering

“3D Rendering is the process of producing an image based on three-dimensional data stored within a computer. 3D rendering is a creative process that is similar to photography or cinematography, because you are lighting and staging scenes and producing images. Unlike regular photography, however, the scenes being photographed are imaginary, and everything appearing in a 3D rendering needs to be created (or re-created) in the computer before it can be rendered.” [24]

4 Implementation

4.1 Planning

First thing to do at the beginning any project is to establish a realistic time distribution. A bachelor thesis is worth 15 ECTS and each credit is equivalent to 25 hours of study, then the bachelor thesis should take 375 hours. [25]

For a 40 hours of work per week a 10 weeks' project should be planned. The schedule can be seen in the Gant diagram below.

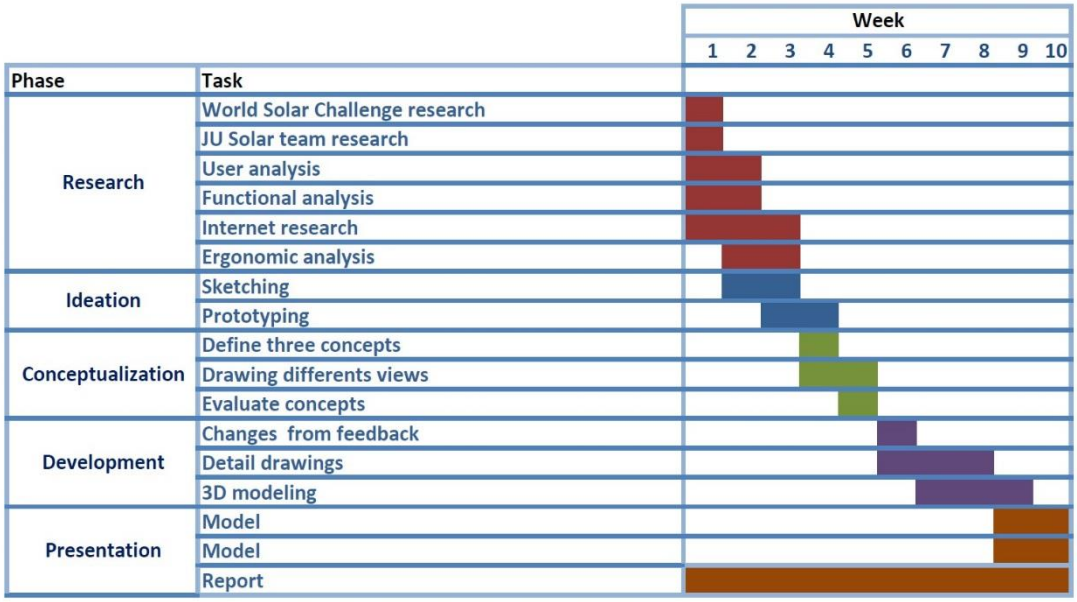

Figure 2: Gant diagram

The design process is based on the Design thinking methodology, but with some changes to adapt it to this project. In this own version there is five phases.

Empathize and define are combine in research, ideation is divided in ideation, conceptualization and development, and the last one is presentation. Prototyping and test are considered as a tool to using during other phases.

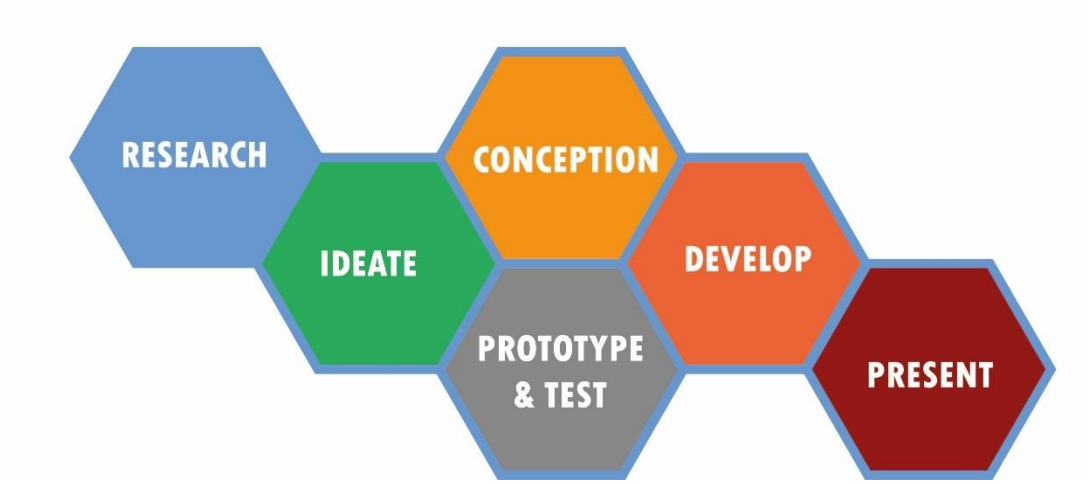

Figure 3: Design Thinking Variation

Research: this one, following the design thinking methodology, is about empathize with the user, looking for trends, explore the competence, analysis the exiting product and define and extract some conclusion from all this research that can be used for the design. The conclusion from this phase should guide us through the whole process and it should be the place to come in case of doubt or lack of ideas.

Ideation: the same that in the design thinking process, in this phase all the knowledge gained in the previous one is use to generate ideas. It is the most creative phase where there are no wrong ideas and it is the perfect time to explore the boundaries of the project. The aim is quantity not quality.

Conception: the goal is to create between 2 or 3 concept with enough detail to difference between each other and to evaluate and select one for further develop. It is the conclusion of the ideation phase, where the best ideas are putting together to create a product.

Development: Once the final concept is selected, in this stage it will be develop to define all the details of the product and solve the problems that can be encountered. The result of this phase should be a 3D model, which implies that all the dimensions are defined.

Presentation: to finish with the project is necessary to make some presentation images with a rendering of the model, with the user or in a realistic environment.

The design thinking methodology also includes prototyping and testing, but in this variation, it is not considered this as a separate stage, prototyping and testing allow you to validate your result in different parts of the projects. The design process is a circular process where feedback and going back the verify results is common, even some phases can merge at some point.

Another part of the planning is the design brief, to stablish a framework, so what to expect from this work it is known. It is divided in five sections: who are the people

behind this project, the goals and the reason behind them, the project scope, results and delimitations of the project:

Who are they and what do they do?

"JU Solar Team is a group of twelve students and two teachers with different background, education and experiences. The unique mix of competence within the team, combined with a large amount of will and ambition will lead us across the desert of Australia and past the finish line in Adelaide!

With a common goal, and individual responsibilities the team will design the optimal solar car, which will represent Jönköping University, Sweden and the Nordic countries in the World Solar Challenge." [2]

What are the goals? Why?

- The main goal is to improve the user experience, i.e., the driving experience.
- The lack of design in the interior made it a quite difficult user-friendly environment. That has two disadvantages. The first one is the user interaction problems and the second the psychological effect of a rough interior.
- Driving already need the full attention from the driver to watch the road, any extra cognitive effort, to control the car, could put the user in danger.
- The comfort of the driver is related on his performance.
- The performance of the car is related to the skill of the driver and the speed of the car, also related to the energy available.

Project scope

- Redesign the buttons to make the learning curve easy and fast for new users.
- Redistribute the buttons to make them more accessible to the user, reduce the time and physical requirements to use it.
- Redesign the seat to make it comfortable and adaptable to different users.
- Created a friendly-user environment that fits the design of the car and creates a pleasant feeling to the user.
- Try to minimize the weight of any structure created and the energy consumed.
- Change the dimension of the cockpit to improve the aerodynamic of the cars while fitting the user needs.
- Make sure all the changes fit the regulations of the World Solar Challenge.

Results expected

- Reports with the findings from the research phase with the actual problems or improvement suggestions for the user.
- Ideas to solve the problems and complete the goals proposed.
- One detailed design solution with a representative prototype.

Delimitations

- Mechanical or electrical problems or solutions that require deep knowledge of the subject. This is a design project.

- The budget of the solar car is limited, and mostly focus on the efficiency of the solar cells, motor and electrical system. The interior is not the main focus for winning the race. It has a secondary importance.
- The ergonomic analysis would be enough to allow a comfortable seat and driving experience but without any deep ergonomic analysis, as a user test. Using only theoretical knowledge and public information and resources.

4.2 Research

As explained in the design methodology the first part is to research to emphasize with the user and product. In this phase, information is collected from different sources and with different purposes.

4.2.1 World Solar Challenge

First step is to learn about the Solar Car Challenge reading all the info in their webpage that it has been included as theoretical background. Then to read the regulation of the race, with no real use in this stage, but that would condition the design in later phases. A summary is included in APPENDIX 1.

The information obtain from here was not really useful to empathize with the user, just to have a general picture of the competition, so looking on YouTube for videos about the race was necessary. There are two documentaries about universities participating in it. They film their entire journey in Australia, explaining the problems, strategies and how they feel. [26] [27] [28]

This kind of videos really allows to understand a lot better the race and to try to collect the feeling that the videos left, a storyboard was created where the different stage during the use of the car are showed. From entering the car, driving and finally gather with the team, from each image there are two words that describe the feelings of the picture in that moment. The purpose of the words is to allow creating a mood board that reflects the feelings during the race. Full storyboard in APPENDIX 2

Figure 4: Story board

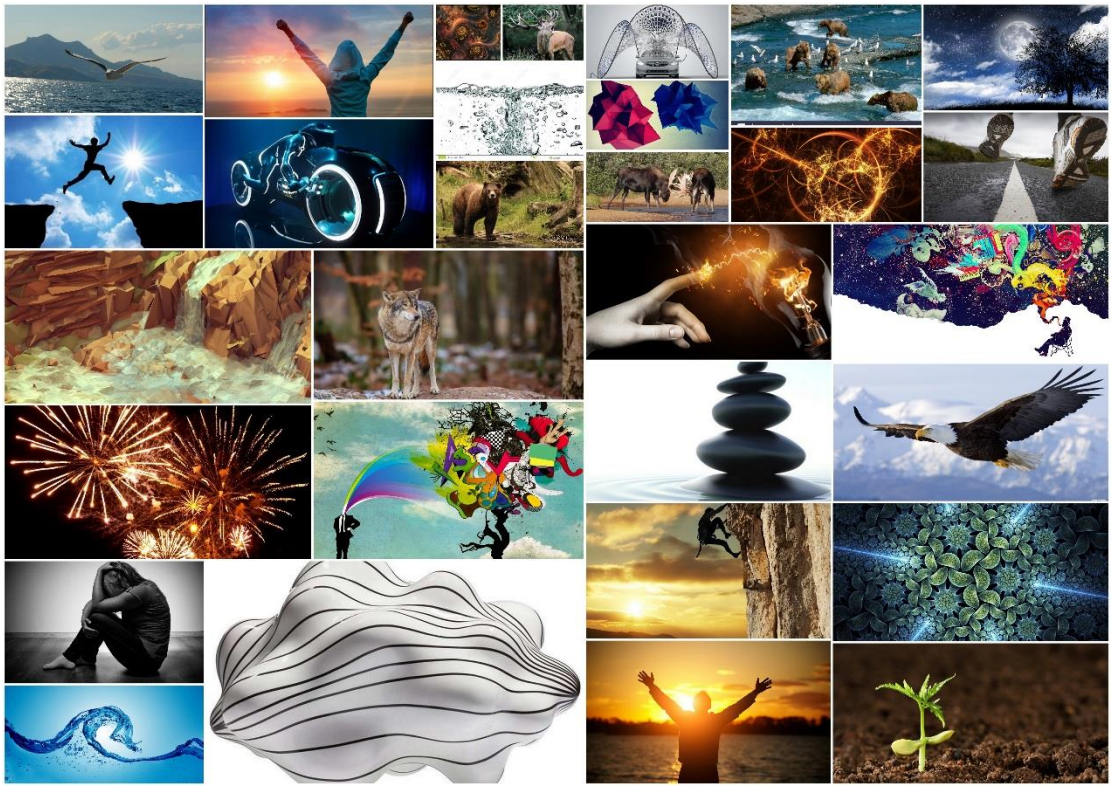

Figure 5: Mood board

This was a first approach to the general picture of World Solar challenge, now the actual racing car should be analyzed.

4.2.2 JU Solar Team Car

With the guidance of the course coordinator in two different days, he shows both cars, the one use in 2015 and the rests of the one from 2013. Here are the observations from those days, which will be used to generate ideas. The pictures from the car can be found in APPENDIX 3:

- Change in the crash bar in carbon fiber from been in the chassis to be in the seat. Steel.
- Heat inside the cockpit hours driving the car.
- Opening mechanism of the cockpit not change necessary.
- Claustrophobic interior.
- Change in the dimension of the cockpit to make it slimmer.
- Speed is a rotatory button, so speed does not change and you waste less energy.
- A brake pedal.
- Two rudimentary holes to put bottles of water.
- All the buttons in a steel bar. Two different shapes. Round and leaver (too close all together).
- Two screens.
- The windshield is not perfect, not 100% transparent.
- The seat is just textile between the steel bar/crash bar.
- The interior is the space between the wheels, no physical separation, but they have it in the previous version.
- There is not a Cad version of the interior, just the general shape of the car.

- The roof of the cockpit can be separate in different parts (three previous years).
- The button of regeneration, it regulated manually by the driver depending of the brake force, and the speed is setting also manually.
- The button in the bottom has to be pressed all time to make the car run, while the pedal is for stop.
- There is a hole in the front of the cabin for the entrance of air, but it is done in an aerodynamic way.
- There is a camera behind the seat for the screen in the front.
- There is the tracker box in the back part of the canapé.
- The interior is supposed to be noisy.

This data was about how the car worked, why some decisions were taken, the change from one year to another, the main problems of the car, etc. A user analysis is done to get an inside point of view.

4.2.3 User Analysis

A small questionnaire was sent to the driver by email. The questionnaire was about his personal opinion about the car, his experience and the changes he would like to see in the car. To see which kind of questions should have been asked, and the problems that could be faced during the design mind map was made to explore the information needed. The questionnaire was based on this mind map.

After he sent the answers, a second email was sent to ask some more new questions.

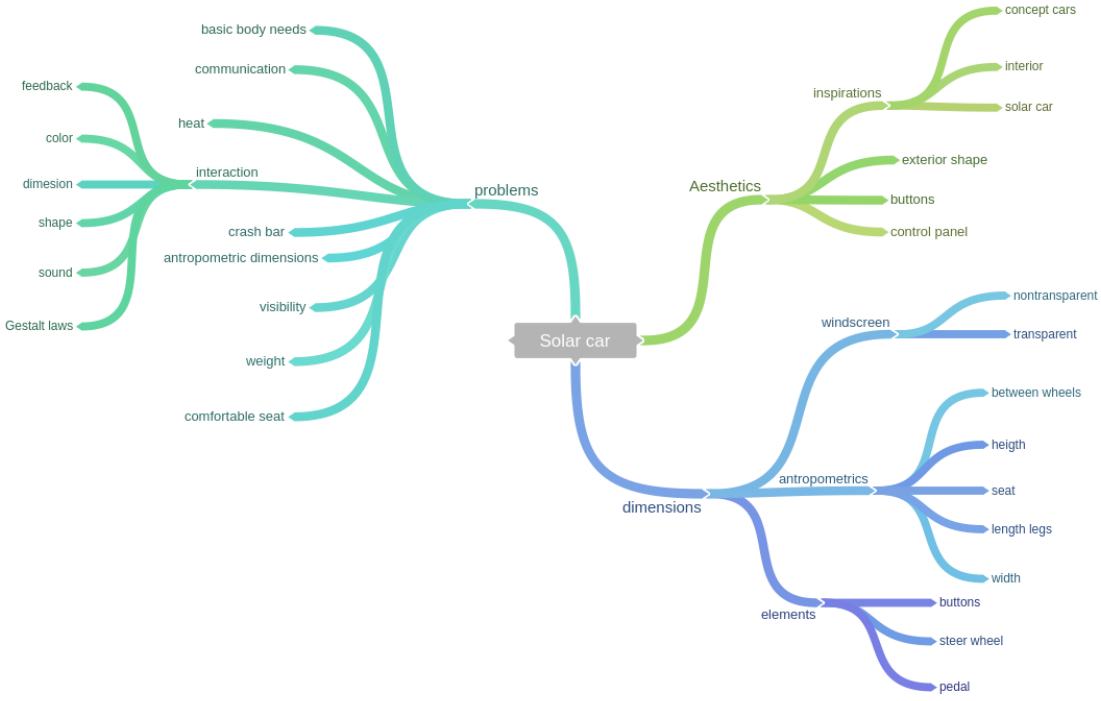

Figure 6: Mind Map

The conclusion from this user analysis was:

- Good explanation of the function of all the buttons (*see functional analysis*).
- Put most of the buttons on the steering wheel.
- The speed and regeneration button are the most important, right now you have to remove one hand from the steering wheel to adjust them.
- Prioritize the location of the buttons.
- Change grip on the steering wheel, Thumb support.
- Plenty of space inside, but uncomfortable seat, lack of lumbar support and arm resting.
- Quite noisy inside the cockpit.

Most of the information from the user analysis allows understanding the function of the buttons, so it was useful for the next step. The complete answers can be found in in APPENDIX 4

4.2.4 Functional Analysis

Here it is listed the interaction elements from the interior to have in mind all the factors for the design:

- **PANIC button:** Switch off battery an all the electrical systems
- **D1 button:** Individual power point tracker on and off switch
- **A2 button:** Individual power point tracker on and off switch
- **B3 button:** Individual power point tracker on and off switch
- **C4 button:** Individual power point tracker on and off switch
- **MPPT button:** power point tracker system on and off switch. Multi power point tracker converts the electricity from the solar cell to the right voltage. It checks the voltage of the battery and the energy from the cell and then it adjusts it so they match. It increases the current to reduce the voltage.
- **Reverse button:** Reverse the rotation of the wheels
- **ECO button:** Determines of much current should be put to the electrical motor, saves energy when selected by limiting the current.
- **Solar button:** Solar cell electrical system on and off switch
- **BATTERY button:** Reset the battery
- **REG button:** Adjust the energy recovery from the brakes
- **SPEED button:** Adjust the speed of the car
- **BRAKE pedal:** Stop the back wheels
- **Power button:** Makes the car run when push
- **Steer wheel:** rotate the front wheels
- **Open the canapé inside:** Allow the user open the canapé from the inside
- **Open the canapé outside:** Allow to open the canapé from the outside
- **Right indicator:** Right light on and off switch
- **Left indicator:** Left light on and off switch
- ***Hazard warning:** Right and left light on and off switch
- **Horn:** Sound warning
- **Water holder:** Holds two bottles of water
- **Seatbelt:** Secure the occupant of the vehicle
- **Roll bar:** When you have a driver in a seat, you need a hood that goes around the driver to avoid the user to hit the ground if the car rolls over.
- **Roll cage:** The structural components around the driver

- **Crush zone:** Outside the roll cage, the space between the inner cage and the other structure. You have some to get the impact before it hit the roll cage
- **Speed screen:** Visualize the speed of the car
- **Back camera screen:** Visualize the back of the road

Even if it looks there is a lot, the main focus are the buttons that control the car that you can see in the picture below:

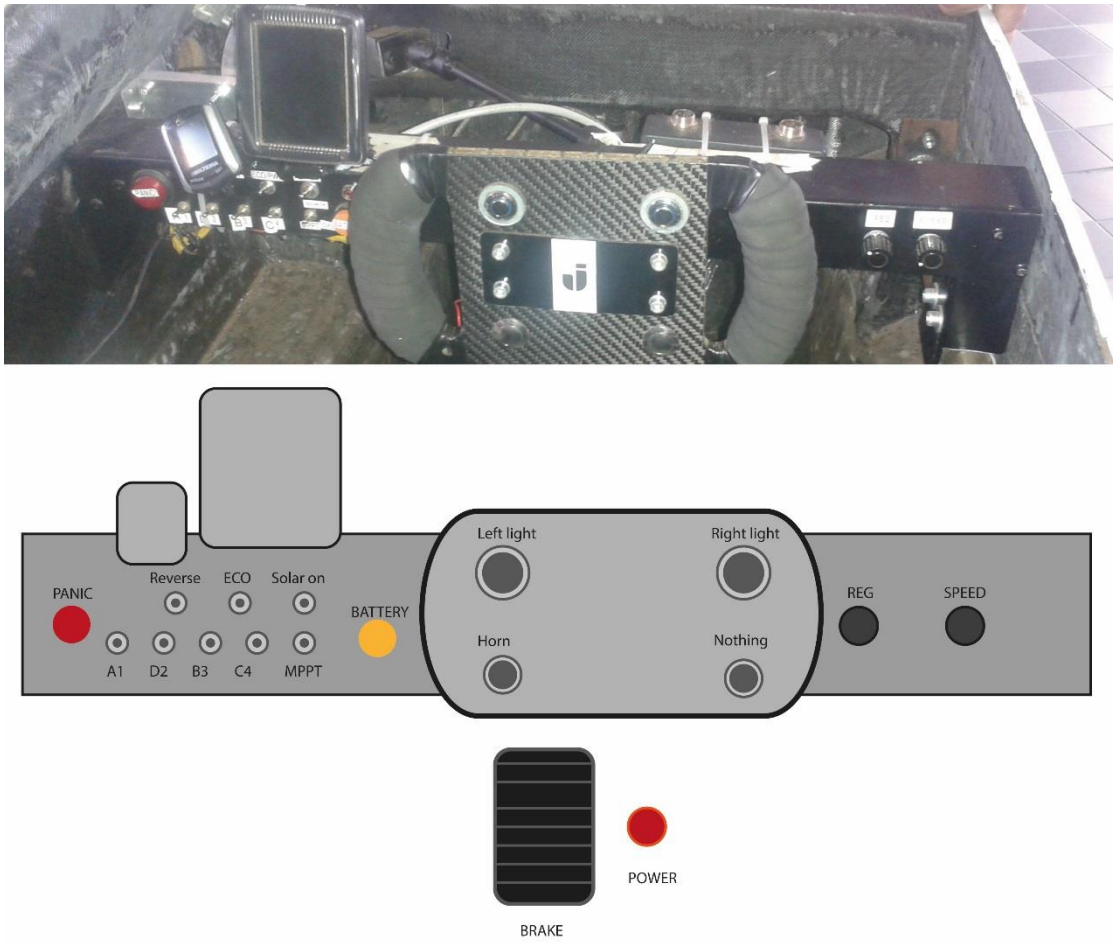

Figure 7: Functional analysis scheme

The conclusions from this analysis to take into account later for the design of the buttons are:

- Most of the function can be grouped.
- Buttons should be prioritized because the space is limited.
- Buttons should have a shape depending on their function and position, base how they are operated.
- Code color and hierarchy can help to organize it.
- It should be easy for the user to reach and operate the controls.
- Text or icons to describe the function of the buttons.

4.2.5 Internet research

At this point, there was enough information about the solar car, but it has to be taken into account what other people know. It was necessary an internet research that includes the competence, previous works and cars.

For the competence, there were plenty of photos in the gallery in the World Solar Challenge webpage and in the videos from YouTube. [3] [26] [27] [28]

Some of them have some features already seen in the user analysis; some of them have interesting and alternative designs.

Figure 8: Solar cars board

As a part of this research a search was made for cars, concept cars, futuristic cars or just any car that could be interesting, and were put it together with some other products, also considered as a good design or interesting shapes. This board will be used as an inspiration during the ideation phase, as an example of products considered aesthetically pleasant.

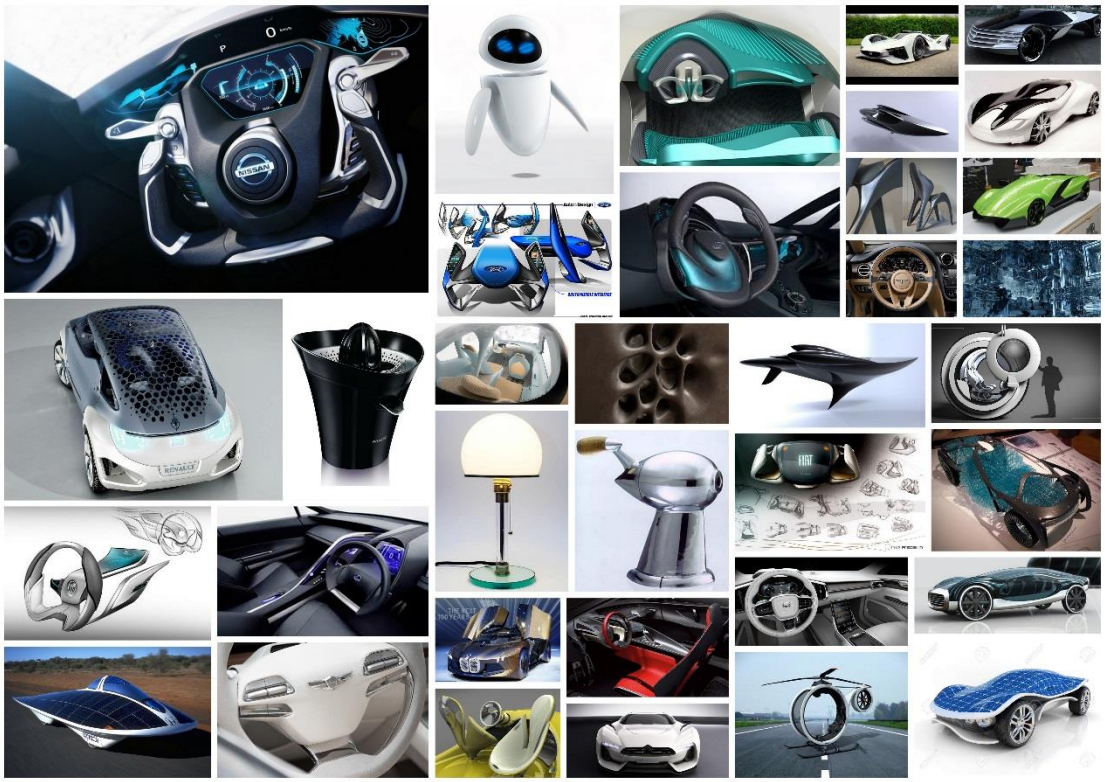

Figure 9: Cars board

The last part of the internet research was to look for papers with information or results about cockpit and steering wheel design. [30] [31] [32] [33] [34]

The conclusion from all this information is:

- Most of steering wheels use round buttons whit different colors and white labels
- Some of them have screens in the steering wheel.
- Not all of them are rectangles, F1 style; some of them are also circular.
- Light indicators in the buttons
- Most drivers (81%) prefer circular steering wheels.
- Non-circular steering wheels are considered for luxury or race cars.
- 60% of drivers prefer three stroke in the steering wheels, nexus between the center hub and the grip.
- In-car display should be positioned high and as far as possible from the driver to reduce glance time
- Information display should be displayed in red or orange, as these colors appear at a greater distance to all other colors.
- Bespoke bucket seat gives better support from dynamic vehicles forces and is safer than a passenger car seat, but cannot be adapted to different users.
- 80% of drivers put hand on the upper half of the steering wheel and in a symmetrical position.

4.2.6 Ergonomic Analysis

In this part the posture of the driver, the dimensions of the car and where to place the different components are going to be analyze. With pictures of the solar car and measures of the interior, a schematic drawing of the vehicle was built.

Since the dimensions of the driver are unknown, in this analysis the dimension of percentile 50 of Sweden male should be taken, because is better to do it too big rather than too small, and using a 3d mannequin from the front and side view.

Table 3
Anthropometric descriptive statistics: mean values with standard deviation for male and female participants scanned in Studies A and B. *p*-Values indicate significance of difference between studies.

		Female					Male				
		Study A ($n=201$)		Study B ($n=61$)		*p*-value	Study A ($n=67$)		Study B ($n=38$)		*p*-value
		M	SD	*M*	SD		*M*	SD	*M*	SD	
1	Stature	1677	68	1663	66	0.18	1789	62	1796	83	0.67
2	Eye height	1555	67	1546	64	0.35	1661	61	1671	80	0.54
3	Shoulder height	1360	65	1355	57	0.54	1446	58	1469	76	0.10
4	Elbow height	1053	51	1009	41	<0.005	1115	48	1084	63	0.01
5	Iliac spine height	937	52	923	49	0.06	1008	48	992	60	0.17
8	Sitting height (erect)	897	33	877	36	<0.005	946	32	940	44	0.44
9	Eye height, sitting	767	33	763	33	0.384	814	37	815	42	0.93
10	Shoulder height, sitting	575	30	574	25	0.92	604	29	614	37	0.13
12	Elbow height, sitting	238	27	236	25	0.54	240	26	240	31	0.92
13	Thigh clearance	149	14	141	15	<0.005	160	15	151	17	0.01
14	Buttock–knee length	595	34	591	27	0.33	613	28	614	38	0.91
15	Buttock–popliteal length (seat depth)	477	29	481	34	0.38	492	27	502	31	0.11
16	Knee height	525	30	511	32	<0.005	562	25	540	35	<0.005
18	Shoulder (biacromial) breadth	355	18	362	19	0.02	388	19	411	20	<0.005
19	Shoulder (bideltoid) breadth	424	23	426	22	0.73	472	25	484	28	0.05
25	Thorax depth at the nipple	253	28	191	17	<0.005	252	30	242	32	0.13
28	Abdominal depth, sitting	232	37	244	39	0.03	238	31	272	58	<0.005
29	Shoulder–elbow length	341	19	339	22	0.39	368	17	374	24	0.16
32	Head length	191	8	185	9	<0.005	201	6	197	10	0.02
33	Head breadth	147	5	148	5	0.48	153	5	155	8	0.12
34	Head circumference	555	14	557	11	0.34	580	14	583	21	0.56
35	Hand length, right	181	9	174	8	<0.005	194	9	192	10	0.22
36	Hand breadth, right	78	4	80	5	<0.005	88	5	87	6	0.63
37	Hand length, left	180	9	176	9	<0.005	194	9	194	10	0.87
38	Hand breadth, left	77	4	83	5	<0.005	86	5	87	6	0.91
39	Foot length. right	242	13	242	11	0.83	263	15	268	15	0.12
40	Foot breadth, right	92	5	92	5	0.42	101	5	102	7	0.24
41	Foot length, left	243	13	245	11	0.23	265	12	268	14	0.30
42	Foot breadth, left	91	5	92	5	0.26	99	5	102	6	0.02
43	Weight (kg)	65	11	65	9	0.80	76	11	80	17	0.16

Figure 10: Anthropometric statistics [29]

The first step is to build the actual structure and put the dummy. Here it can be seen if there is some dimension that it should be change or if there is anything wrong in the actual car.

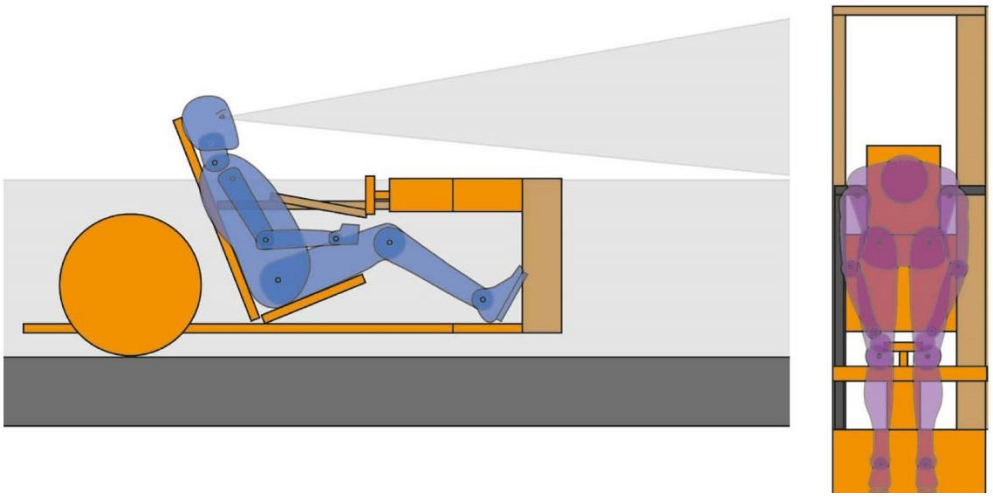

Figure 11: 2D scheme. Original car dimensions

Then the regulations from the previous analysis have been applied to see the limitations on the modification that can be applied. This rules define, the minimum height for the eyes, the field of vision and the most important, the minimum space requirements.

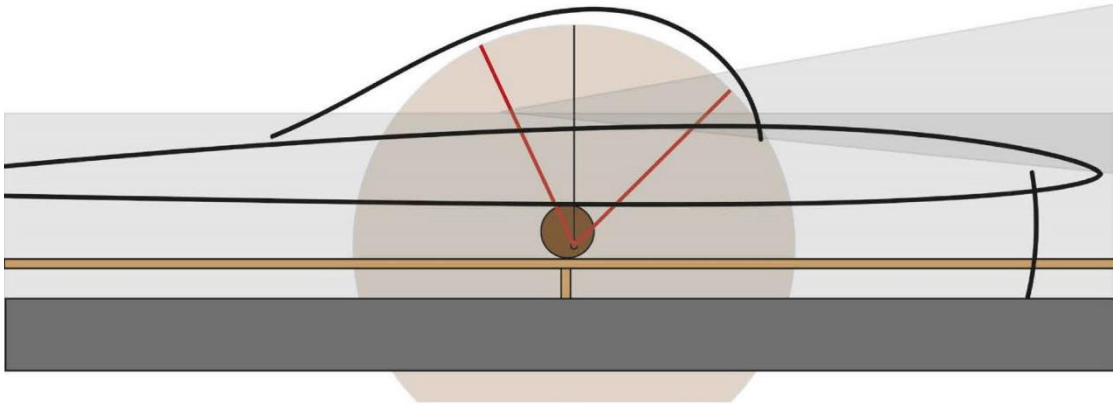

Figure 12: 2D scheme. Visual and dimensional limitations

From this point, different positions for the driver were tried, with the aim to improve the aerodynamics without compromise the ergonomics. Some measures from manuals on the internet were followed to be sure that the seat was been comfortable, due this was not a real user test. [35]

At the end, there are three options to follow:

Raise the height of the car body so the shoulder fit inside and the canapé can be smaller.

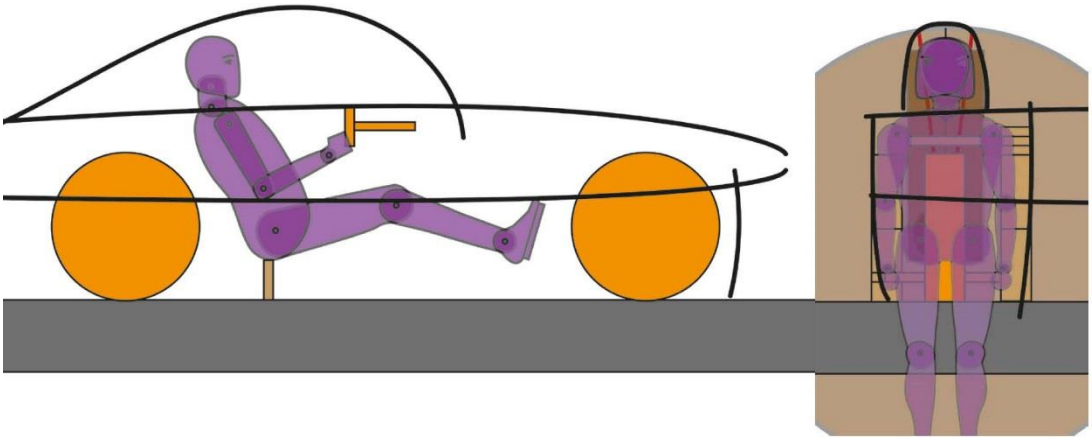

Figure 13: 2D scheme. Option 1

Keep the car as it is, where the shoulders prevent to reduce the width of the canapé, but it could be shape to reduce it in the top part.

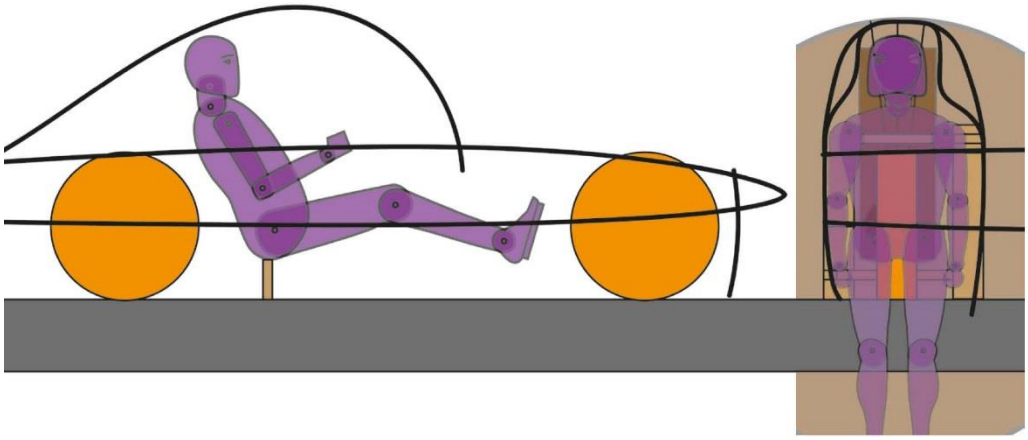

Figure 14: 2D scheme. Option 2

Keep the height of the car body, but tilt the seat so the shoulders fit in it. Then the canapé can be slimmer but due to other restrictions, it has to keep the height.

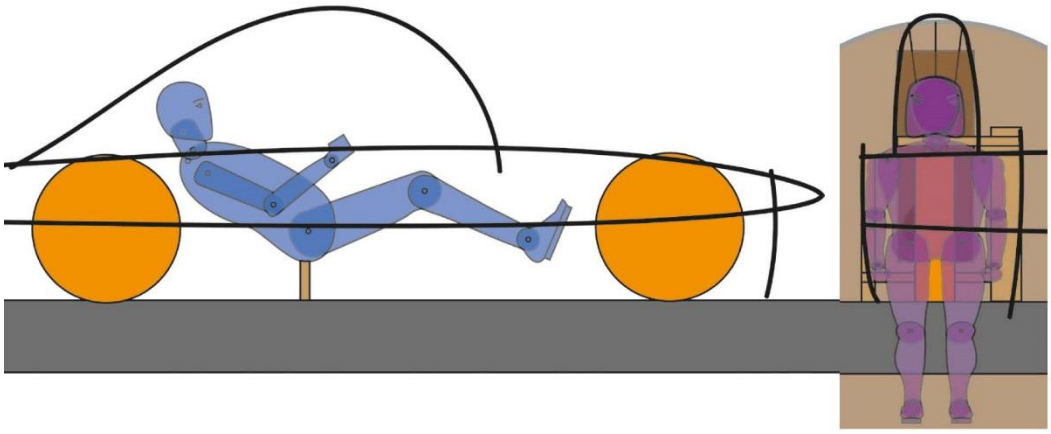

Figure 15: 2D scheme. Option 3

An also some conclusions to have in mind:

- The limitations of the regulation make quite difficult to implement any improvement to reduce the dimensions of the canapé.
- The improvement of the comfort for the user will came from the seat, based on the materials and shape and not from the shape of the driver space.
- The width for the seat seem correct, but the seat is located asymmetrically in the cockpit
- Below the seat, there is space to put the water.
- Since the last regulation, now a parking brake must be added. The driver should operate it from the driving position.

- The steering wheel should be tilted depending in the position of the arm so it allows the wrist to be straight.
- The steering wheel is around 350 mm in a horizontal line from the body, the recommended distant is around 200 mm. It can be closer to the driver.
- The space between the steering wheel and the seat should be enough for the driver to enter and exit the car in the 15 seconds allowed but the rules.
- The holes for the wheels are not separate from the cockpit; it causes sand or other particles to enter the car, as well as air.

4.3 Ideation

From all the conclusions of the analysis, it was decided that the main focus in the project should be the steering wheel. This decision is driven by the feedback from the driver which really wanted to put the buttons on it, as well in the analysis from the competence, must of the steering wheels have the buttons embedded.

The first step was to sketch different kind of buttons and considering the implications of their use. At the beginning, some approach to the shape of the buttons to recognize them without looking was made. It was also important to know if there are activated or not, depending on their shape or with visuals signs.

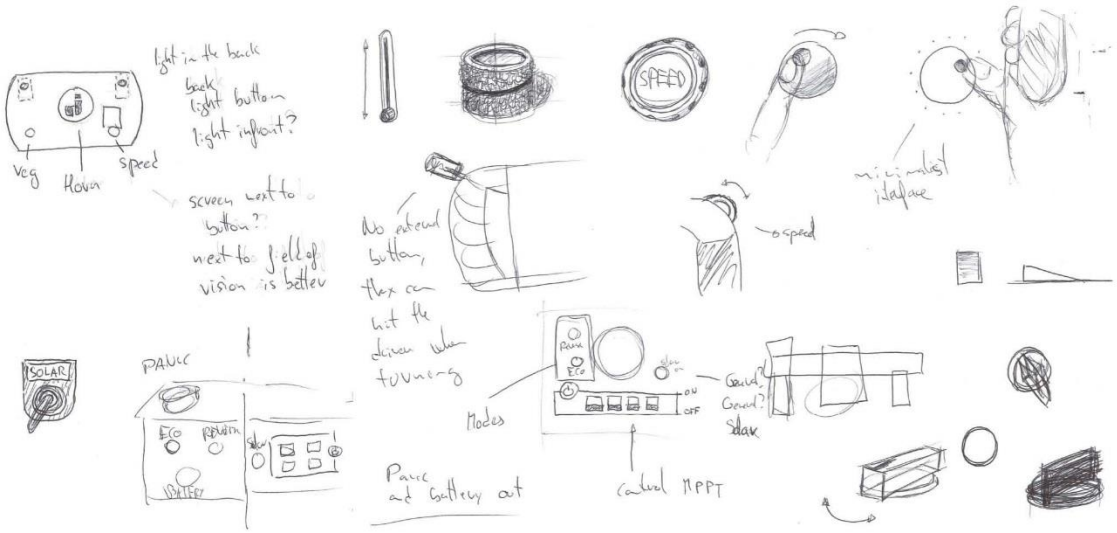

Figure 16: Sketches 1

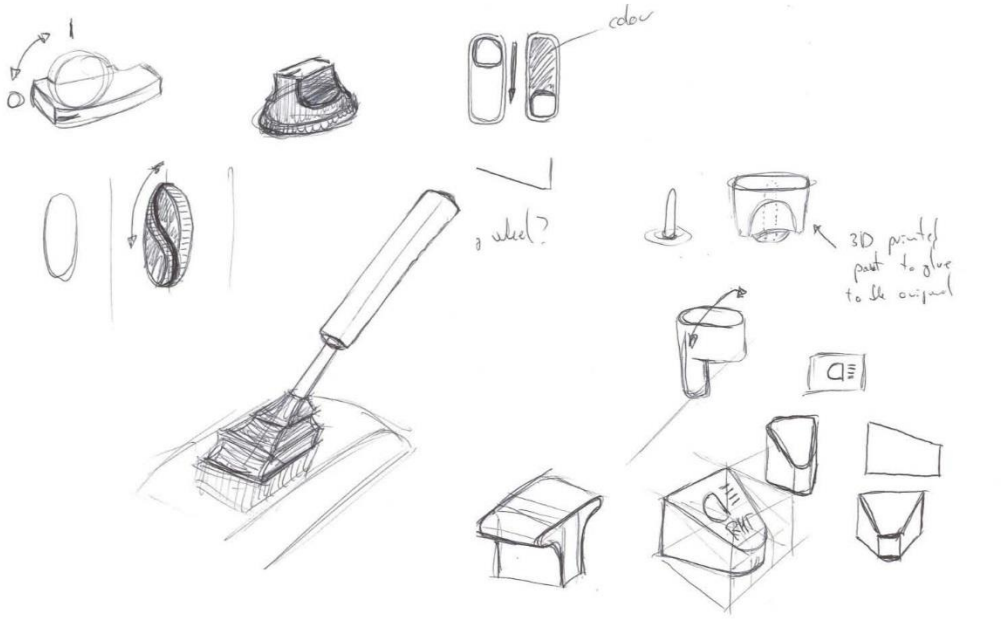

Figure 17: Sketches 2

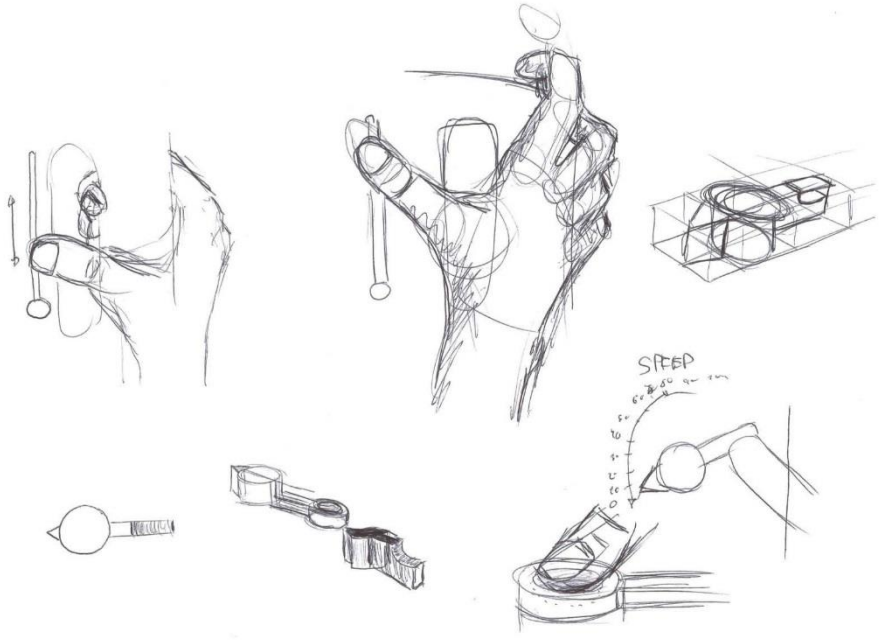

Figure 18: Sketches 3

Then the focus changed to the spatial position, because they should be easy to reach even when you are holding the steering wheel. They should not hit the driver when he turns it. And if some buttons have similar or complementary functionalities, they should be grouped.

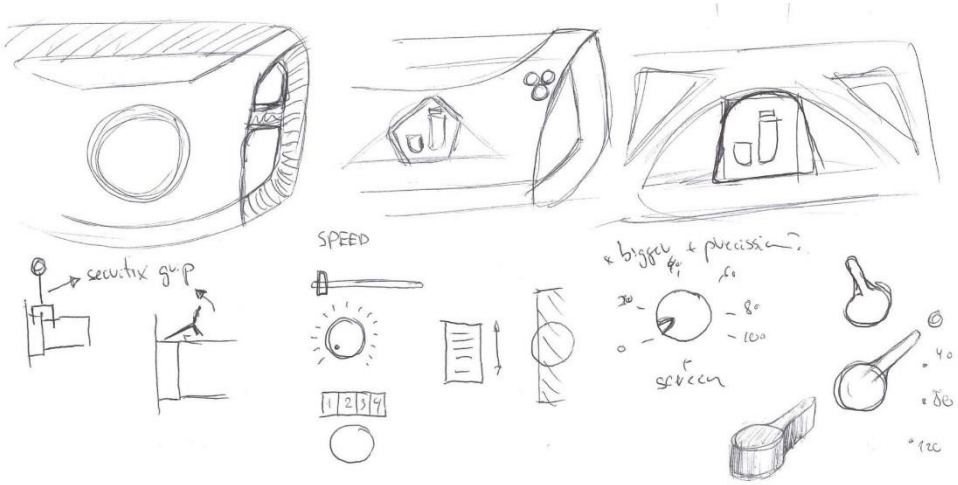

Figure 19: Sketches 4

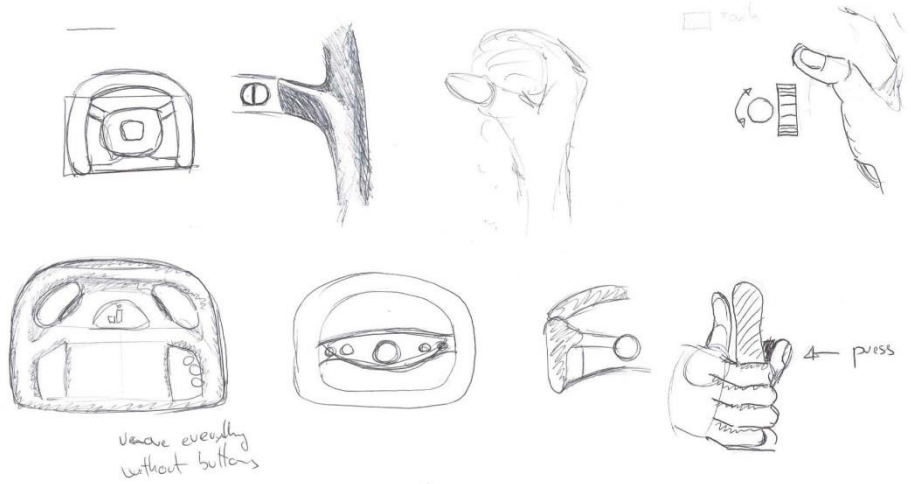

Figure 20: Sketches 5

The other factor to design the steering wheel is ergonomics, to have a conformable grip. Some shapes were sketched for it, but it was decided that it would be easy to make some prototypes with cardboard to actually check the ergonomics.

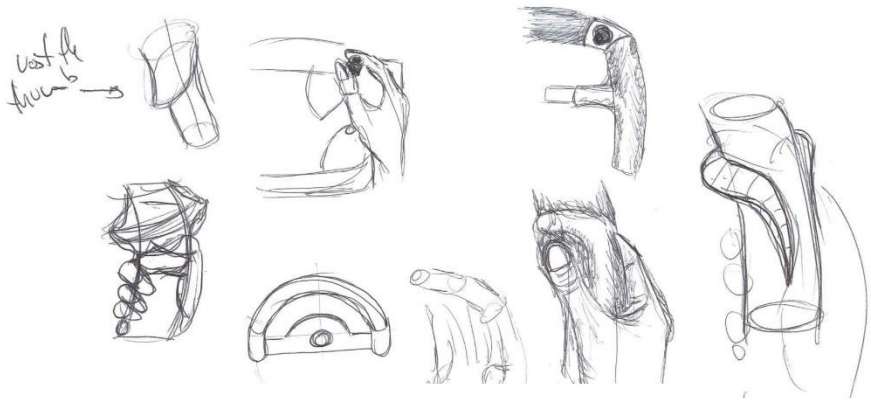

Figure 21: Sketches 6

Figure 22: Prototypes. Original on top

The same dimension as the original one was used and only some parameters were changed. One of the goals was to increase the gripping zones (plastic bags in the prototypes). Most of the steering wheels seen in other cars look from a F1; you hold it from the sides. This give you better control in the turns and you use less space, but from the user analysis he wanted the opportunity to change hands position and in addition a more relax sensation, like if you were driving your normal car.

Figure 23: Prototype with extra gripping zone

It was possible to check the best zones to put the most used buttons, or where would be difficult for the user manipulate a switch.

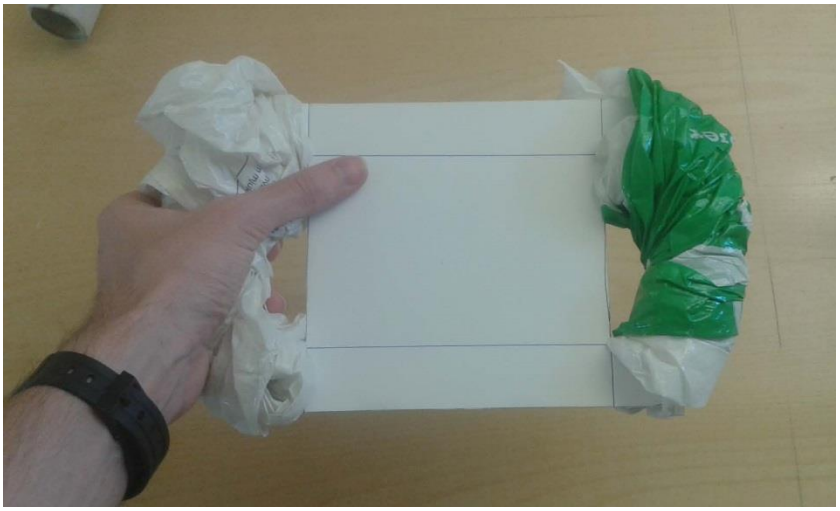

Figure 24: Prototype of the original one

Once there were some ideas about the shape of the wheel and buttons, it was time to start to work with some shapes, try to explore more complicated design for it.

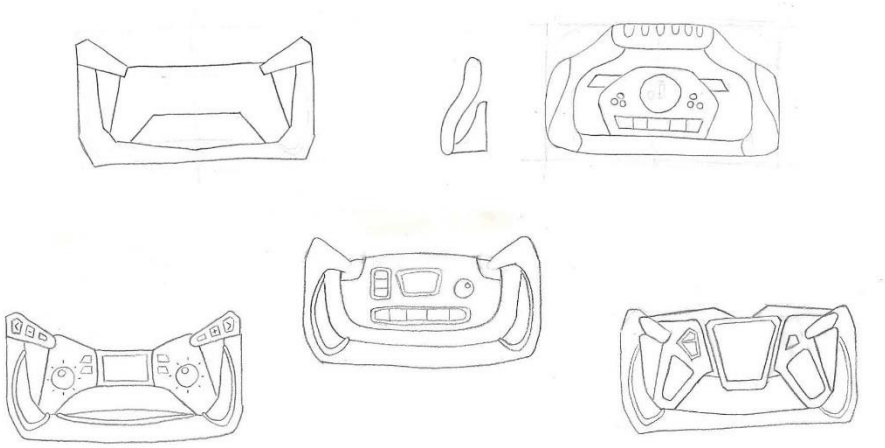

Figure 25: Sketches 7

And some more developed buttons

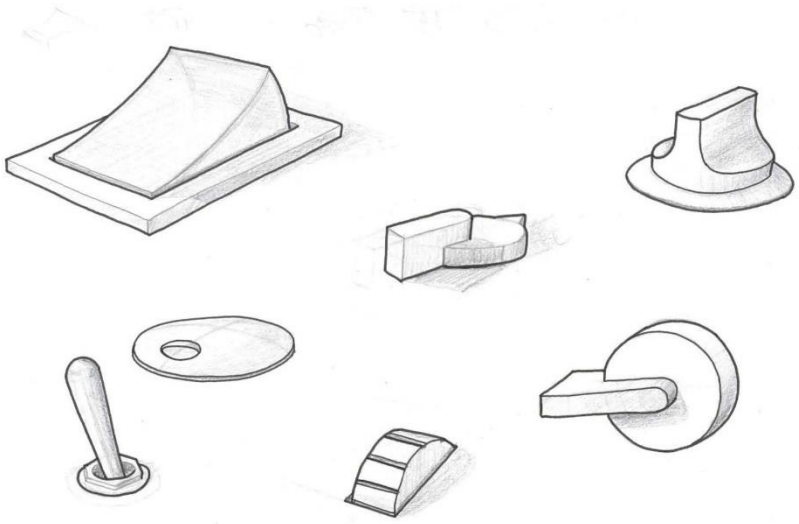

Figure 26: Sketches 8

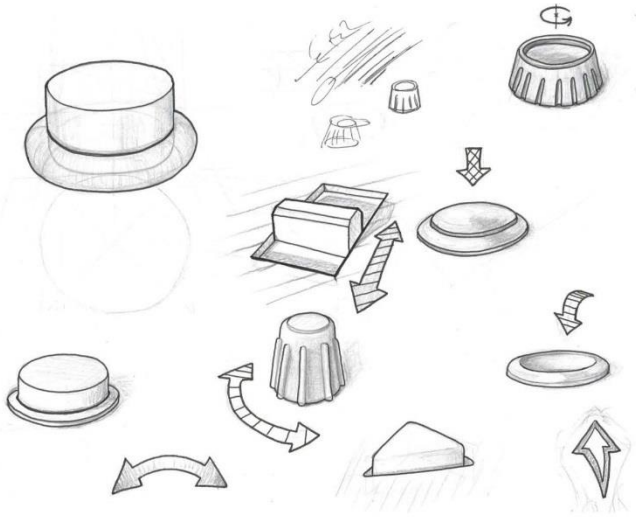

Figure 27: Sketches 9

Now it is a good point to start putting ideas together to develop three concepts.

4.4 Conceptualization

Here it will be presented three different concepts for the interior of the solar car based on the ideas from the previous phase. Each concept is explained, and each one has different design specifications. To present them it has been use the old picture of the solar car and combined with the new concept to see how it would look.

Every concept has two pictures, one is a detail view of the steering wheel and buttons, and the other one is a general view of the interior of the car.

The graphical design and the dimensions of the interior are let for latest phases, once the final design is done.

4.4.1 Concept “Traditional”

Figure 28: Concept traditional. Steering wheel

This firs concept keeps the style of the actual solar car. The changes made are mostly concerning the main problems detected by the user.

Almost all the buttons have been added to the steering wheel. Each button has different shapes and colors so they are easily identified. There are three types of buttons all the same that in the actual car

The speed and regeneration are in the middle with visual indicators to give some feedback to the user, previously missing. The logo is also the horn, as in many cars.

The “emergency buttons”, to stop the car and resetting the battery is still in the horizontal bar, away from the functional buttons.

The screens have been relocated one at each side of the steering wheels, the right side, where the speed button is with the speed monitor and the back camera screen is in the left side, where the reverse buttons is placed. This also allows the user to just focus in one screen each time.

The bottle holders have been replaced with the parking break, now the user can store the water under the seat.

The shape of the steering wheels has been modified so now it has support for the thumbs and the upper part is fitted to control the car, so the user can change hand position and rest.

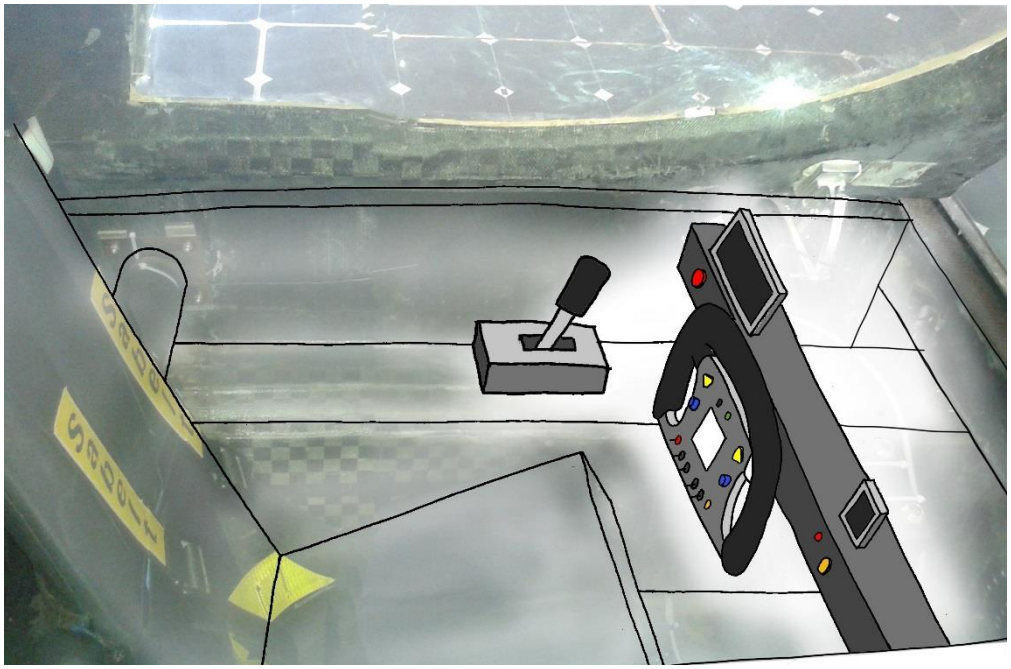

Figure 29: Concept traditional. Interior

The breaking pedal is still the same, but now the start buttons next to it is also a pedal since it is more comfortable pressing it with the feet.

The seat is quite similar, but now it needs to have foam in the backrest as it is in the seat due to regulation. In addition, it has been reinforced to give a bit more lumbar supports.

The dimensions are the same, except that the width has been reduced and the steering wheels has been centered.

4.4.2 Concept “Sky”

Figure 30: Concept sky. Steering wheel

The second concept aim for a more organic shape and a friendlier interior.

Only the buttons affecting directly the drive are in the steering wheels. Each button has different shapes and colors so they are easily identified.

The light indicators are two levers that are triggered from behind towards the user. The speed and regeneration buttons are the main buttons, and there are supposed to be controlled with the tip of a finger. The logo is also the horn, as in many cars.

The screens, “emergency buttons” and the MPPT are in the front panel, keeping it clean and organized. This front panel allows the user to have the screen in front of him so he just needs to look down to get the feedback from the car.

The bottle holders have been replaced with the parking break, now the user can store the water under the seat.

The shape of the steering wheels has been modifying so the user can grab it from many positions.

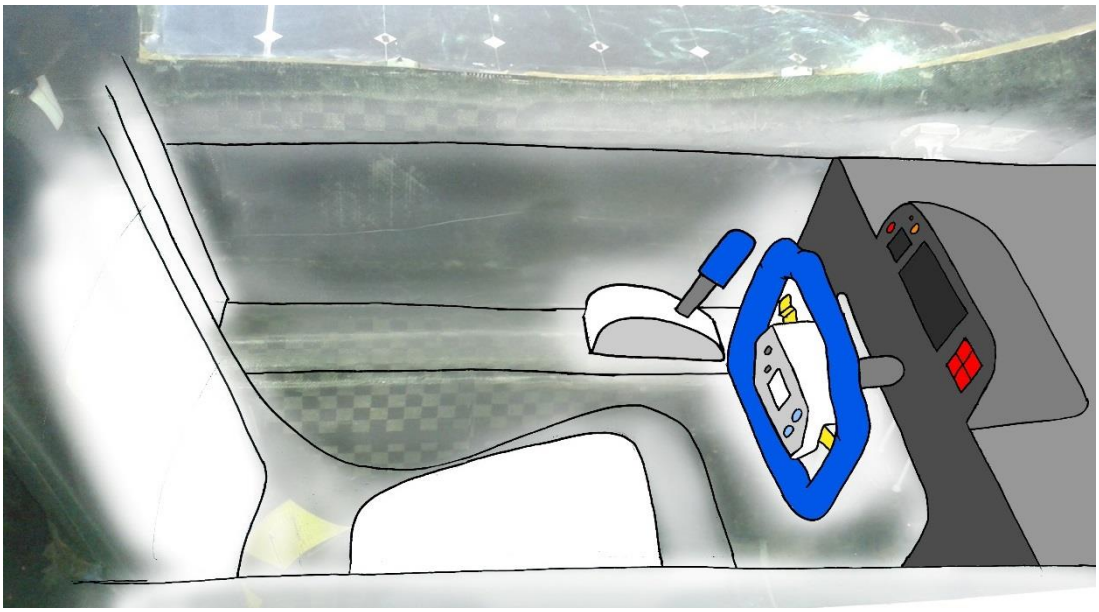

Figure 31: Concept sky. Interior

The breaking pedal is still the same, but now the start buttons next to it is also a pedal since it is more comfortable pressing it with the feet.

The seat is a sheet of hard molded plastic supported by some tubes. It has attached some foam cushions.

The dimensions are the same, except that the width has been reduced and the steering wheel has been centered and put it a bit closer.

4.4.3 Concept “Racing”

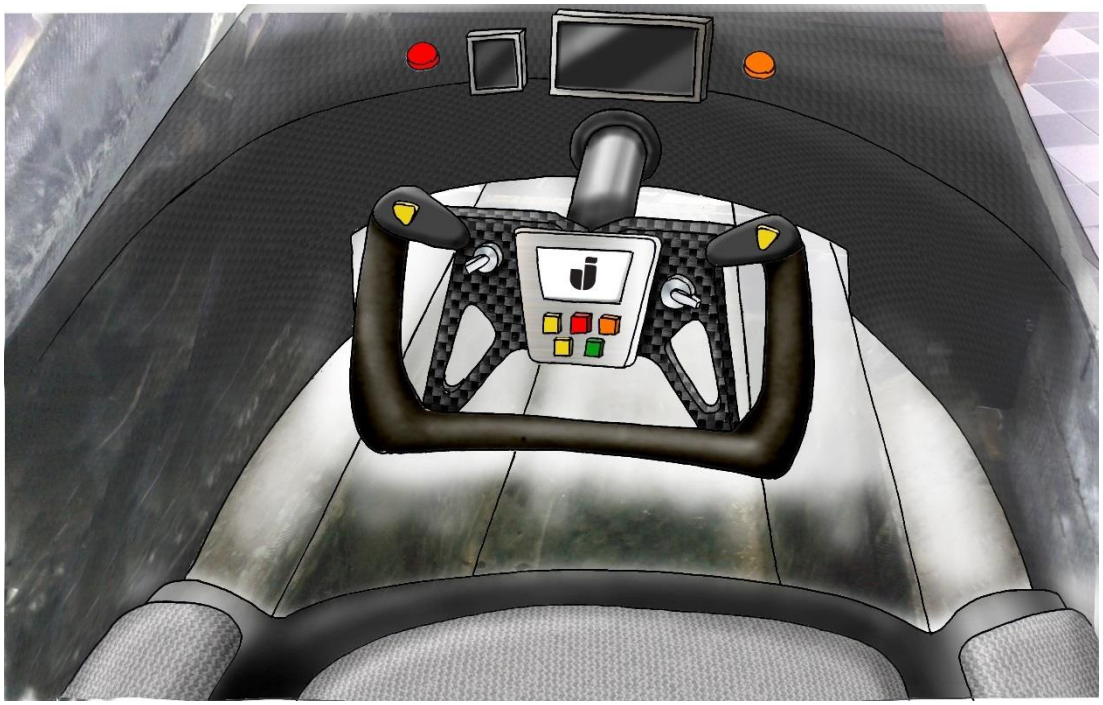

Figure 32: Concept race. Steering wheel

The last concept looks for a more professional look.

Almost all the buttons have been added to the steering wheel. Each button has different shapes and colors so they are easily identified. The major change in shape is the speed and regeneration button that can be controlled with a finger up and down. The logo is also the horn, as in many cars.

The “emergency buttons”, to stop the car and resetting the battery is in the horizontal surface, away from the functional buttons.

The screens have been relocated; they are now in the middle and away from the steering wheel but still in the user line of sight.

The breaking pedal is still the same, but now the start buttons next to it is also a pedal since it is more comfortable pressing it with the feet.

The shape of the steering wheels has been modified so now it has support for the thumbs, next to the light indicators and the bottom part is fitted to control the car, so the user can change hand position and rest.

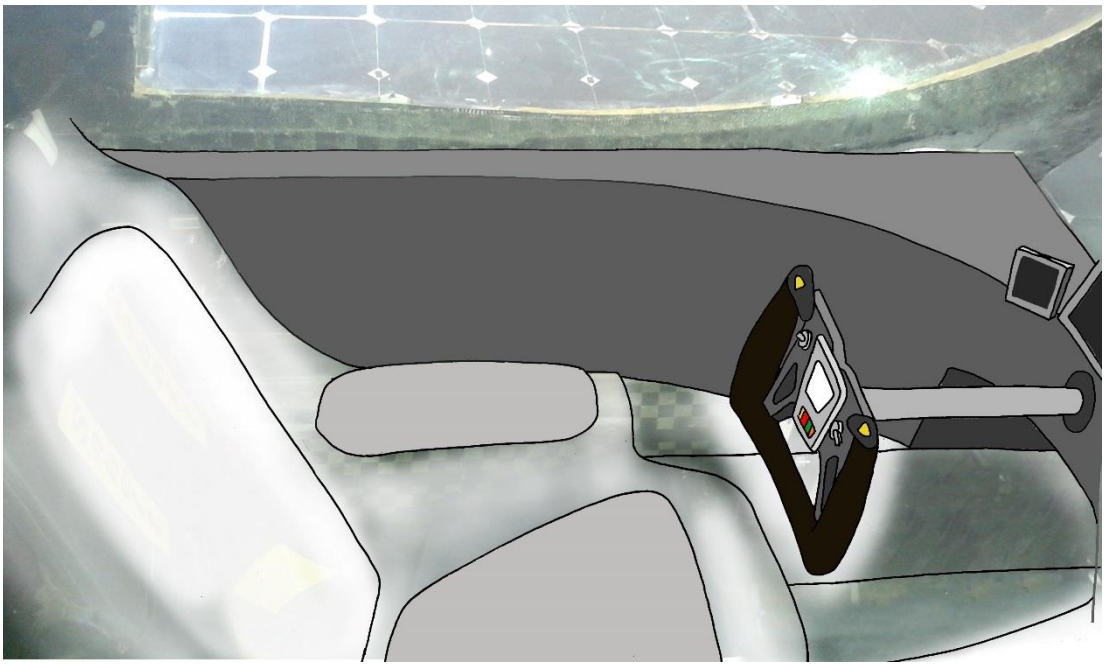

Figure 33: Concept race. Interior

In this concept, the seat is more tilted and closed to the steering wheel, so when the driver sits the knees are behind it. The steering wheel can be removed to facilitate the entry or exit from the car, but it is not necessary.

The seat is more like a bucket seat, adapted to the size of the driver that can keep the water under it.

4.4.4 Selection

The three concepts were sent to the course coordinator to receive some feedback.

The first concept was considerers to similar to the actual deign and he was looking for something more innovative to get away from the old design.

Therefore, the solution was to try to combine some ideas from each concept.

4.5 Development

I wanted to keep the basic structure of the first concept, having three main points to grab it, the side and the upper half. But more hollow, like the third concept. Therefore, it will keep an organic shape in the exterior but a stronger shape in the middle.

The goal was to make the upper part similar to the radius of a real steering wheel so the user can comfortable hold it, whit his hands in almost a horizontal position. The sides go down straight so the external shape can fit in the dimension stablished.

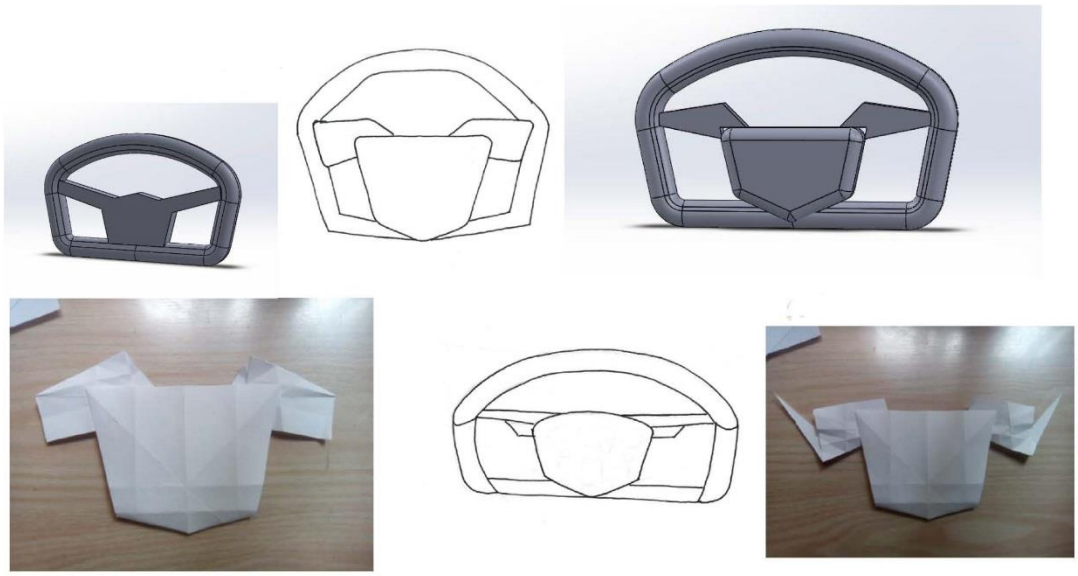

Figure 34: Sketches, prototypes and 3d models. Development

The basic shape of the interior is a pentagon because it represents stability and toughness, but it also looks dynamic with the diagonal sides.

Other import part of the development was how to join the central part with the external one. Joining both in the bottom part and in two more joints, to give them some stability and thumb support.

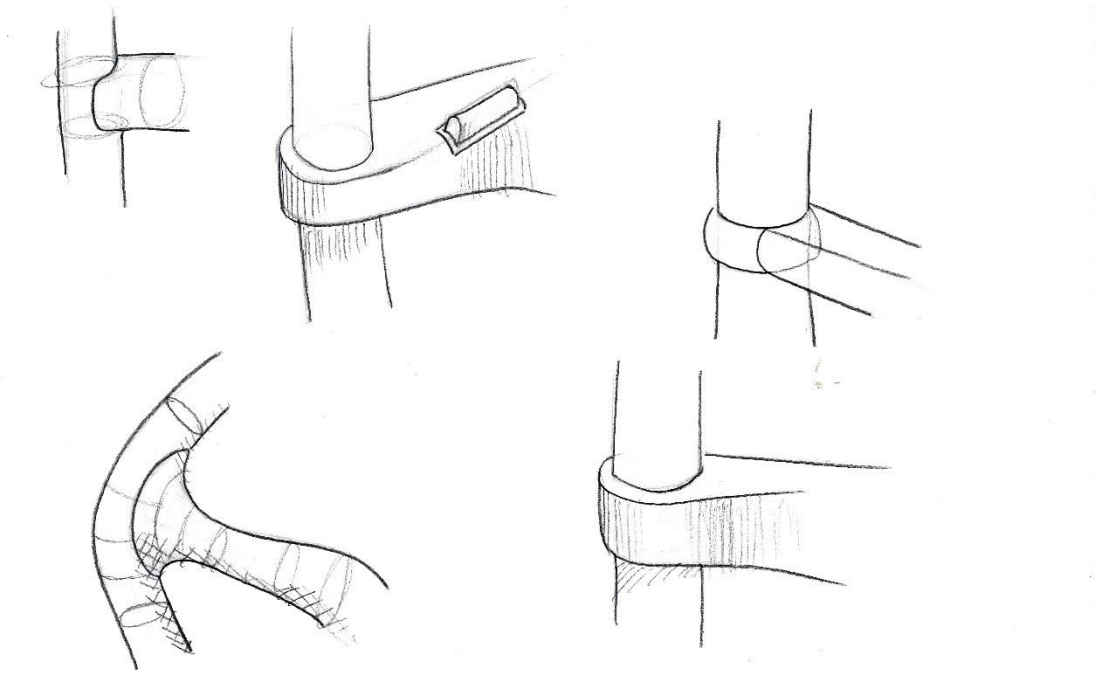

Figure 35: Sketches 10

Once the general shape of the steering wheel it has been generated, some different buttons configurations will be tested, so a small prototype was built with cardboard with the real dimensions and try different buttons, made with cardboard and clay.

Figure 36: Prototype in cardboard

This allows us to decide the position of the buttons and the dimensions, so they could fit inside it. One important factor to have in mind is that the easiest way to access the buttons is with the thumb, so the user can keep most of the hand controlling the wheel.

Some of the decisions were made, like which buttons were going to be in the steering wheels. It was decided to leave behind as few as possible. So only the panic buttons will be away from the driver's hand. That means that the buttons to reset the battery and the one to stop all the electrical system should be put in the control panel with the screens.

To get more space for the buttons, the direction light will be behind the steering wheel, as in most of the actual cars

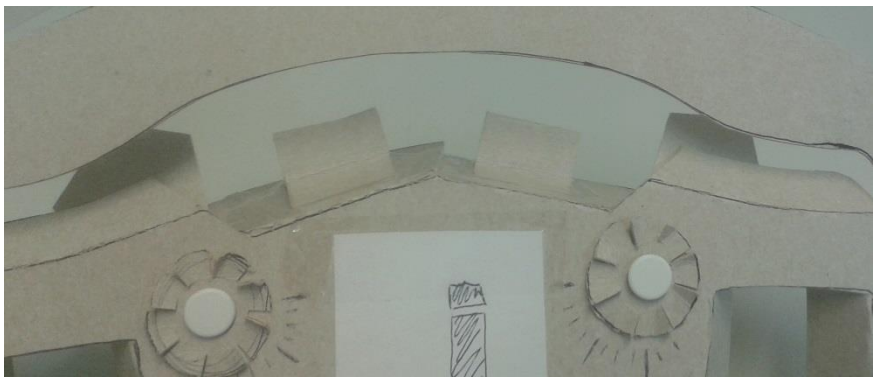

Figure 37: Prototype in cardboard 2

The first buttons to work with, are the speed and regeneration button, these are, based on the research, the ones that the user will be using more. The best spot it is near the thumbs, so the user can rotate them with one finger. The buttons need some recess to generate grip. The rotation will be counterclockwise for the regeneration, in the left, and clockwise for the speed, in the right. So the movement of the thumb goes up-down in both sides.

Figure 38: Prototype in clay

The only button related to this two will be the reverse button, so it will be located below the speed button.

The fives buttons in charge of the MPPT should be together, so they will be in the bottom part.

The two buttons left, one to turn one the eco mode and the other to turn on the solar cells, where put in the top part of the central body, so you don't have all the buttons in the same surface

For the rest of the interior it was decided to use the second concept, where there was a small control panel in front of the user.

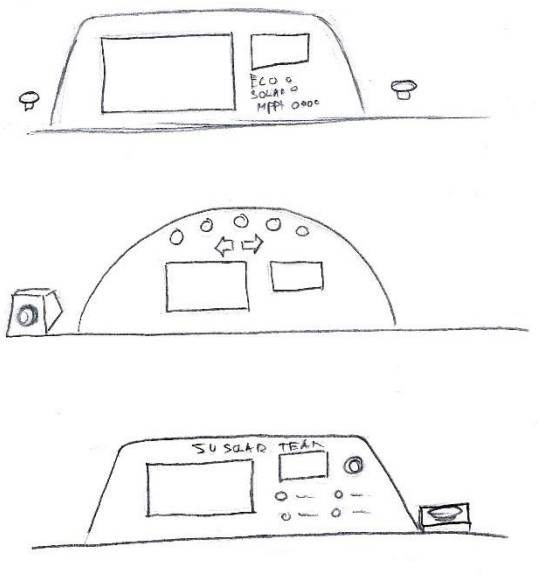

Figure 39: Sketches 11

The control panel includes the back rear camera in the left and the speed in the right. It was decided to add light indicator so the user know which buttons are activated.

Once the buttons were defined was necessary to design the graphics to indicate how to use the buttons and its functions.

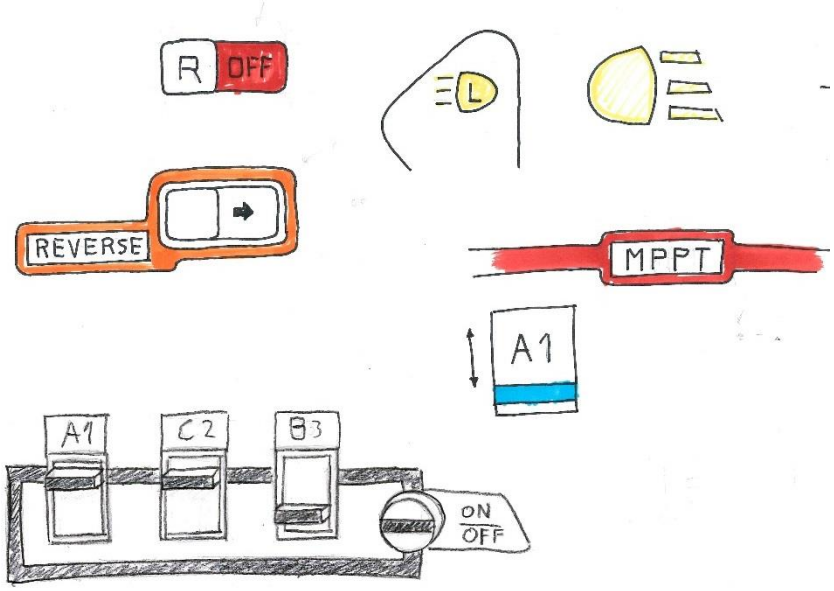

Figure 40: Sketches 12

For the MPPT group a visual graphic was used, that indicates when they are connected or not, they have their names in the button.

The speed and regeneration have an indicator that shows to which direction they rotate.

The power button will be a pedal button as the breaks, because it was the easiest solution, and the parking break will be in at the level of the arm at the right side, as it is in a car.

The two holders for the water will be move under the seat, to keep the weight as low as possible and eliminate things from the driver space.

The dimension of the interior is the most important part, so following the findings from the ergonomics analysis the measures were chosen. From the three options founded in that analysis the most appropriate was to tilt the seat and raise a bit the main car body, so the shoulders are below the canapé. This way the canapé can be smaller. In addition, some measures are being adjusted like the asymmetrical design, some extra space on the sides and the control panel and steering wheel are closer to the user, so it is comfortable to hold it

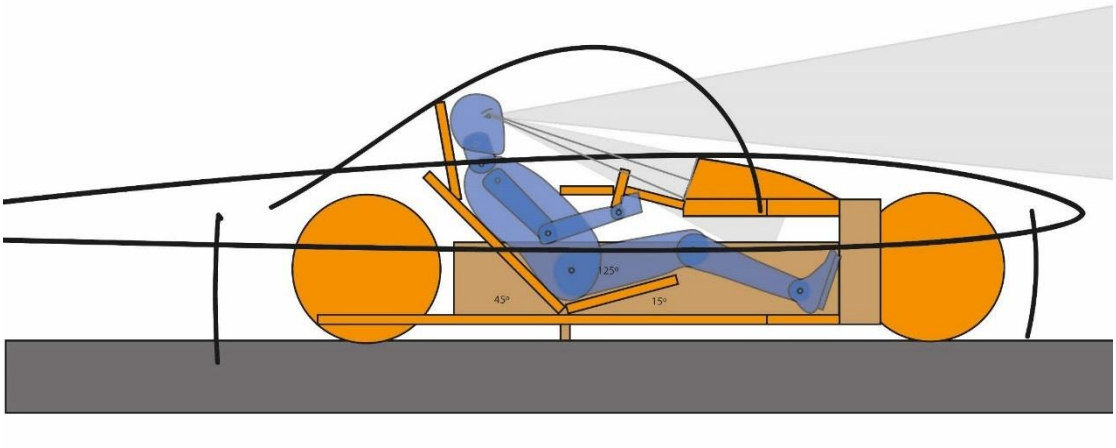

Figure 41: 2D scheme. Final option

The seat follows the human body, in a way that the user can be tilted but with the head in a vertical position to watch the road. The angles chosen are based on the recommendations from the National Institute for Occupational Safety and Health (NIOSH) from EEUU.

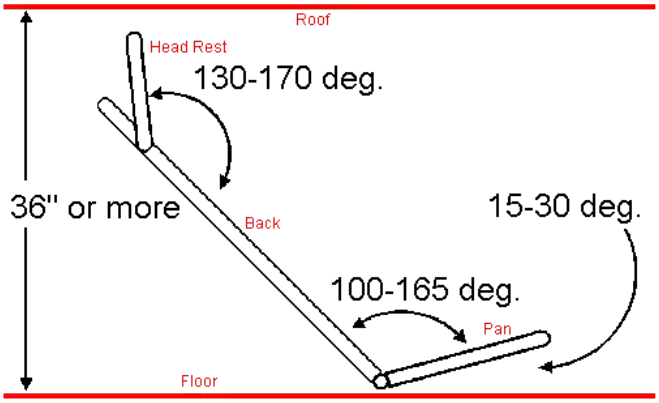

Figure 42: Ergonomic design recommendations [35]

The dimension can be found in the APPENDIX 5. In the blueprints there is not all the measures of the models, since not all of them are necessary, only the ones that affect the user and the anthropometrics factors of driving.

In the APPENDIX 6 it can be found the pictures of the final model. One model of the steering wheel in real size and a dimensional model of the interior in scale 1:10.

5 Findings and analysis

In this section the final result will be presented, and all the changes in the solar car.

5.1 Shape

Figure 43: Render 1

The steering wheel is divided in two main parts, the grip and the central body, both symmetrical. The external part can be hold from the laterals and from the upper half, it has four union points with the central body, two of them in the bottom, and two of them at the sides where the path change from straight to curve.

The upper part allows the user a comfortable grip and enough space to put both hands, it gives the same driving sensation as in a normal car and you can change the position.

The central part, coming originally from a pentagon is separate enough to allow the user hands to go through the holes. The joints with the gripping zone, in the corners of the pentagon, had an extra polygonal shape, to give more complexity to the design and to let the joints in a flat surface and not directly in the corners.

The part where the buttons are located is a recess, to gain more space and have all of them in the same zone. All of the corners are rounded for safe reason and to give a smooth look, but keeping a strong look thanks to the polygonal shapes.

5.2 Buttons and graphics

The speed and regen buttons are the main buttons in importance and size, close to your thumbs they can be operated by turning them. They do not have any graphical scale since you can check the speed in the control panel, but it includes an icon to indicate the direction of the rotation to increase or reduce the value. The speed is at the right side, considering that the user is right handed. It has grooves in the surface to make it easier to turn it and have a chrome finished

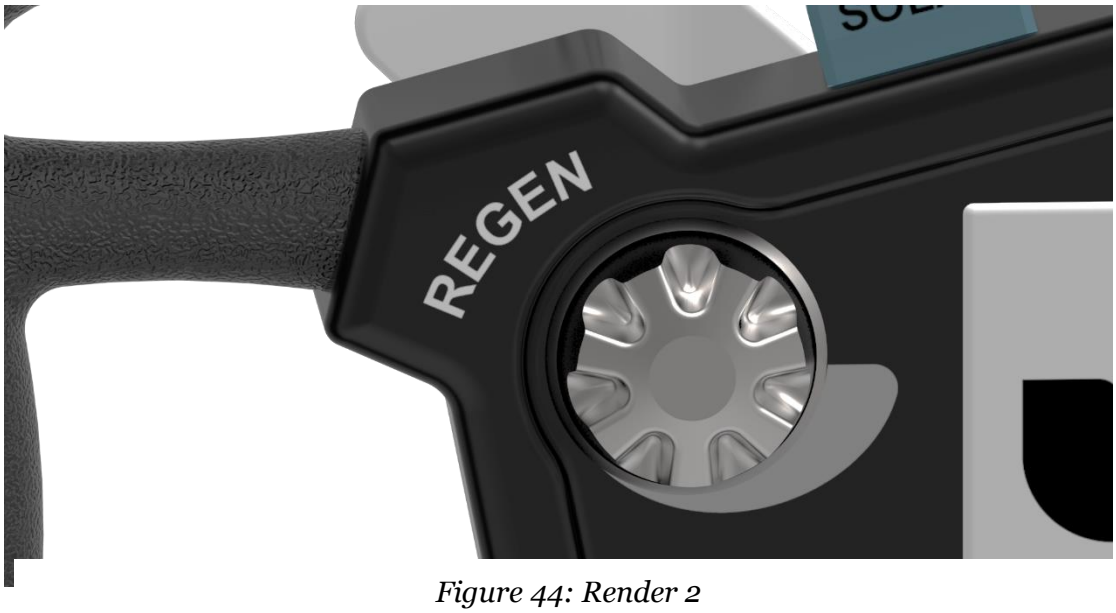

Figure 44: Render 2

Under the speed button, there is the reverse button, with an R on it, to change the direction of rotation of the motor. To switch it on the user has to move it to the right. It shows if it is on or off in every moment. It uses the orange color to take the user visual attention, orange was chosen instead of red, since red it is associate with danger.

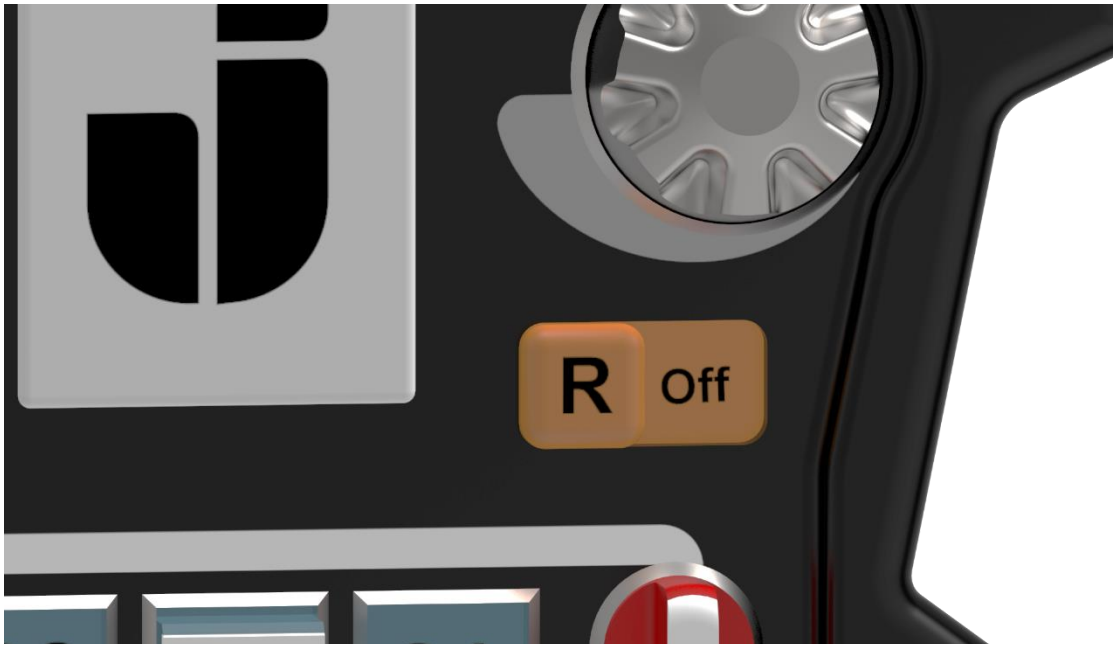

Figure 45: Render 3

In the bottom part, you find the buttons to control the MPPT, consisting in the on/off switch and four controllers. The switch is a rotatory button with two position and the other ones you can move it up and down and they have its name on themselves. The graphics show when they are operatives since there is a white line passing through them, when they are in white line they are working. They are in the bottom part because the user does not need them that often and its movement is quite limited. The switch is in red to show the importance that it can turn on/off all the buttons at once, and the MPPTs are in blue, that it is a neutral color and it is use in the exterior design of the car.

Figure 46: Render4

On the top part, there is the buttons for the eco mode and the one to turn on the solar cell. They are there to not overload the front part with switches and because the user does not have to activate or deactivate them during the race so often. They are easy to reach and the move forward to activate them, so if they are far from the user they are off. They have their names on the front side and they are also blue.

Figure 47: Render 5

The horn is on the university logo in the middle, it is the only button that is activated by pushing it. Therefore, if you hit the steering wheel the horn will sound, without affect the other buttons. This decision is based on security reasons, if the user has to hit the horn, this action should not interfere with the maneuverability of the car.

The last buttons in the steering wheel are the turn light indicators. They are behind as you could find in a car, but really close to the steering wheel so is easy to active them. As the other buttons, if the user pushes them towards him they will activate the lights. They have a small light graphic to indicate their function. They are white so it easy to see them, since the steering wheel is black and the interior will be probably also black.

Figure 48: Render 6

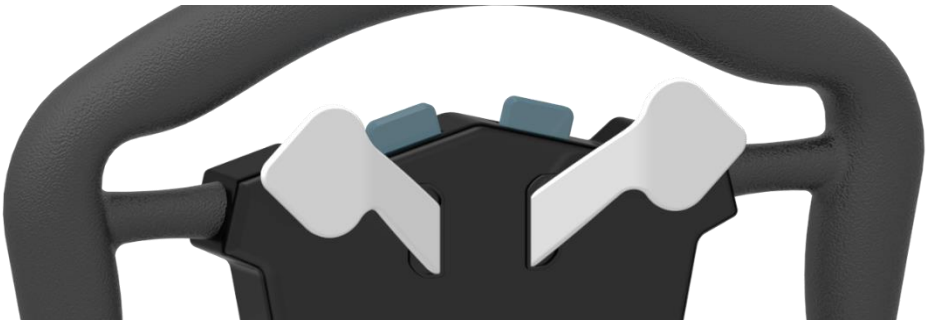

Figure 49: Render 7

The goal of the buttons is that everyone should understand its function, to make the driving experience intuitive, and to make the user remember the position and function of each one, feeling them without apart the view from the road.

5.3 Interior

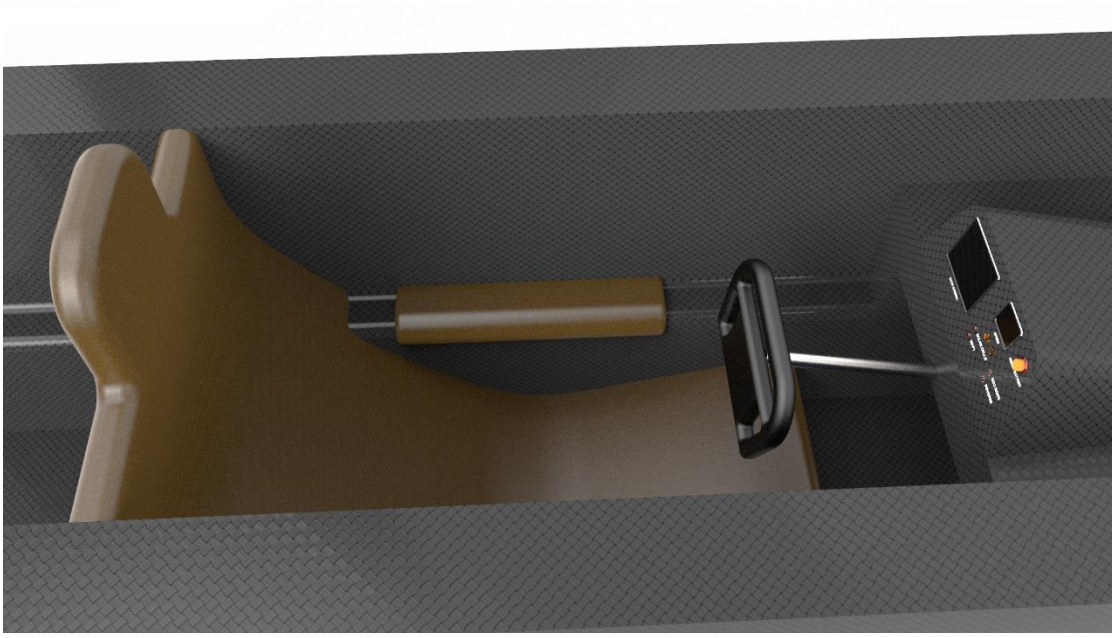

Figure 50: Render 8

Two pedals control the power button and the break as it was said during the development, since the power button has to be pressed all time it will give a better surface for the feet. They do not have any graphic because the user cannot see them.

The parking break has a simple design, similar to a normal car, since it is a new addition for the car due to the new regulations. The JU Solar Team should decide how it would work before apply any design. It also does not have any graphic because people identify the shape and position to a parking break.

Figure 51: Render 9

There are only two left buttons, the panic button to shut down all the electrical system and stop the car and the battery button, to reset the battery if it is necessary. This last one is on the control panel surrounded with a light ring that will light up when there is any electrical problem in the car. The panic button is on the right side of the control panel but outside it, in the horizontal surface of the car. It is in a small platform slightly tilted for a better vision. It is away from the user normal space, but still in range for him in case it will need it. The battery button is in orange to be easily spotted, and the panic buttons is in red, to be easily spotted and express danger.

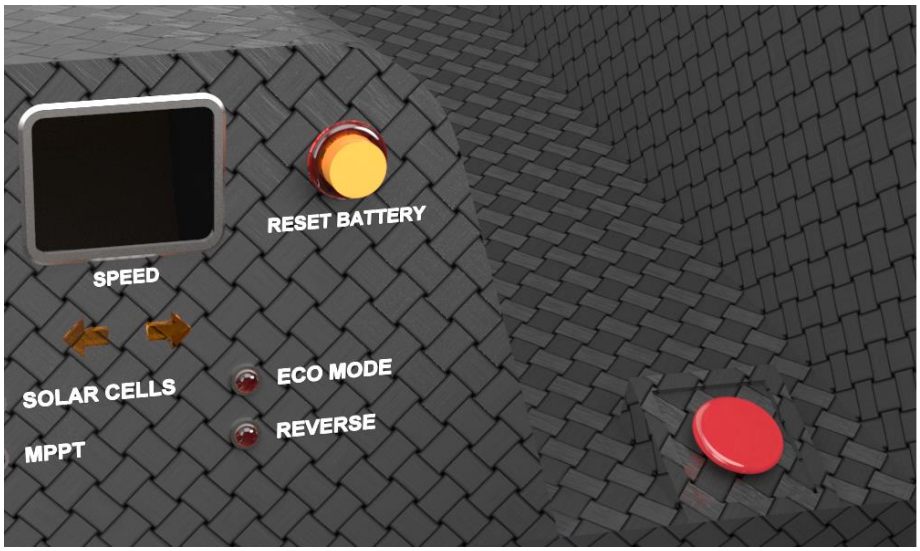

Figure 52: Render 10

The control panel is mainly to give feedback to the driver, no to control anything. It has the two screens, the one for the back camera, that it is in the left and the speed screen that it is in the same side as the speed button, the right. Both of them are as high as possible, so the driver ‘s eyes movement form the road to the panel is reduce. It is also to avoid the steering wheel blocking the line of vision.

Figure 53: Render 11

The rest of elements in the control panel are light indicators. Therefore, in case the user needs to know the situation of a switch he can check it from here, closer to the field of vision from the road. This buttons are to indicate if the MPPT are active and which ones, if the eco mode is active, if the car is going backwards (reverse mode) and if the solar cells are active.

The two recipients two hold two bottles of water will be located under the seat, to keep a cleaner space in the cockpit, and putting this weight at a lower point.

5.4 Comparison, mayor changes

Figure 54: Before and after of the steering wheel

Figure 55: Before and after of the interior

Location of the buttons: The buttons have been included in the steering wheels given the user more control and security to use them while he is driving.

Hierarchy of buttons: Now you can see the differences between the buttons, they have different shapes, locations. They are in different spaces following a more logical order.

Personality: The shape of the steering wheel gives its own personality.

Grip: Now the user has different positions to grab the steering wheel, with thumb support.

Ergonomic improvements: The small changes in the dimension of the interior design will give the user a better driving experience. A closer steering wheel, cleaner control panel and feedback lights. Comfortable seat with lumbar support (require by the regulations) and a reduction in the dimension of the canapé.

5.5 Feedback from the actual JU Solar Team

Whit the model of the steering wheel it seemed appropriate to interview some of the actuals members of the JU Solar Team. To let them watch, touch and feel the new concept. The questions and answers can be found in APPENDIX 7.

The conclusions from this feedback:

- The general feeling about it was good; all of all consider it as an improvement from the previous model and a god job in general.
- Their perception about how to use the buttons was not perfect. The goal of making it more intuitive has not been fully achieved.
- The fact that it was a non-functional model affect the way they had to guess how the buttons were move.
- The horn is the only button without a label, so some people did not mention it as a buttons but some of them guess right that it was the horn.
- The rotation direction of the regeneration and speed button was confused. Most of them put that both follows the same directions to increase their power. The design choice for this counter-intuitive movement was checked during the prototyping phase since it was easier to rotate the buttons moving your thumbs from up to down, which creates this asynchronous movement.
- None of them mentioned the upper part of the steering wheel. All of them grab it by the sides. One reason behind this is because the steering wheel was not attach to anything so seems more natural to pick it from the sides due it horizontal proportions.
- The word that they identify with the steering wheel were similar to the ones were used for the design, obtained from the mood boards.

6 Discussion and conclusions

6.1 Discussion of method

Using design thinking as the main methodology and adapt it to the necessities of the project and my own workflow allows me more flexibility and work more comfortable knowing that it was based in one of the most used design methodologies.

About the methods used, all of them served their purpose but some of them could have been deeper or better prepared.

The user analysis phase should have included some methods like Fly in the Wall to watch how the driver interacts with the car, instead of just having the driver describing his experience. In addition, some user test in some parts of the project, with the prototypes will have given a more different feedback, since most of it came from me. That was one of the reason to made some interviews at the end of the project, to check and confirm some of the results and decisions.

The ergonomics analysis is quite useful and very methodological, and it really help to redesign the measure of the interior, the result would be more valid if you take the dimensions of the actual driver, but right now it a really good starting point.

The prototyping has been present during most of the phases, and I think it is really useful to advance and check your findings or improvements.

6.2 Discussion of findings

My research question was:

“How does the user interact with the car and how to improve it without affecting the car’s performance?”

This was a broad question since I did not know what I was going to find in the project, if I will have known all the research before to start maybe I will have just focus on the steering wheel, and I could have done a deeper research on it.

Some parts of what could be consider the interior of the card haven’t been touch, like the shape of the canapé (only the dimensions), the crash bar, the opening system.

However, I still have been able to answer the question and I think the results are significant if you compare them with the original product.

6.3 Conclusions

This project has achieved some changes in the solar car design that will help the user and the own car. The reduction on the canapé size makes the car less heavy and improves its aerodynamics. A more intuitive and easy to operate steering wheel increase the efficiency of the driver. The general look of the interior has been improved with a cleaner look.

Even some finding during the research phase can be helpful for posteriors improvements.

The solar car from the JU Solar team still has room for improvement, not only in the interior design.

To further develop of the interior, I will consider several points:

- Ergonomic analysis based on the real driver measures. This could improve his performance and reduce the dimensions of the car.
- Reduction of the buttons used to control de solar car. Simplifying the control of the car by automate some functions.
- Include some water feature in the cockpit. To reduce the heat in the car some spraying water system could help the driver. (Some competitors' solar cars have a button labeled "H2O", I suppose that is its function)
- Extractable steering wheel. Will help to driver to get out the car.

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8 Appendices

Appendix 1 Summary of the regulation

Appendix 2 Storyboard

Appendix 3 Car pictures

Appendix 4 User interview

Appendix 5 Blueprints

Appendix 6 Model pictures

Appendix 7 Feedback interview

8.1 Appendix 1: Summary of the regulation

Dimensions of the car:

- 5000 mm length, 2200 mm width and 1600 mm height

Wheels:

- Symmetrical across the longitudinal axis
- Separate for more than less the car length

Driver:

- Eyes at least 700 mm above the road
- Protected from a drop of 1 meter from every orientation
- Head space of 835 mm radius 45 forward, 25 backwards and 7 sideward
- Adequate ventilation and hydration (two liters at least)

Seat:

- The interior of the occupant cell adjacent to each occupant's pelvis, abdomen, thorax and shoulder should be covered with energy absorbing material at least 50 mm thick
- Forward facing or less than 10º
- Base and backrest
- Head restraint not less than 800 mm from the hip point to the top point
- Heels below the seat reference point
- More than 90 degrees between legs and body

Brake:

- Solar cars must be equipped with a parking brake that can be operated by the driver from the normal driving position.

Steering:

- It cannot catch clothes while driving
- Not spear the driver in an accident

Horn:

- Must have one

Instrumentation:

- Speed
- Direction indicators
- Hazard lights indicators
- Energy storage system warning
- Warning in case the battery exceeds its operating parameters

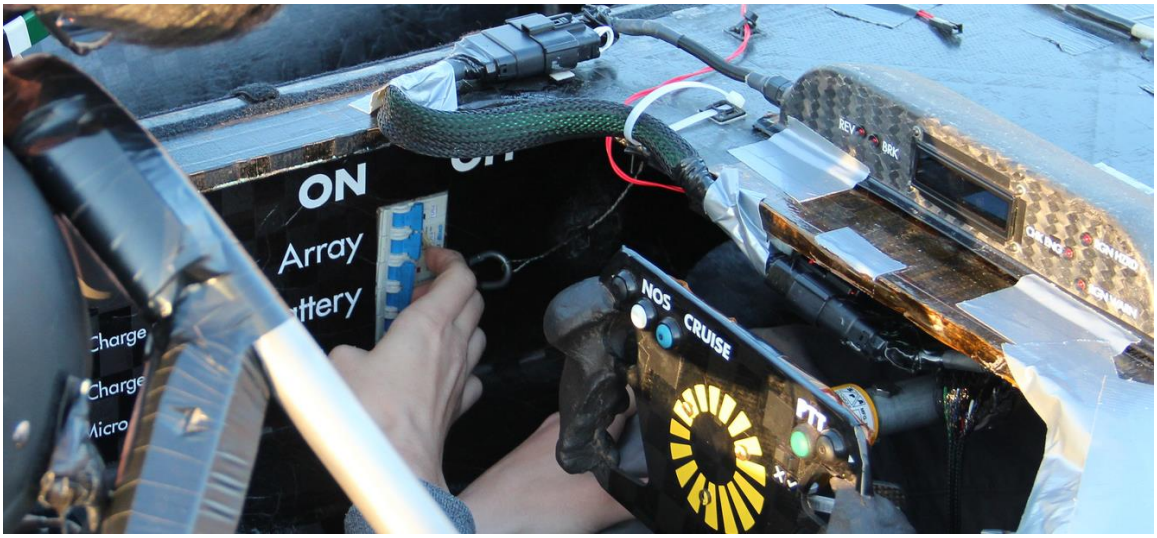
8.2 Appendix 2: Storyboard

The driver opens the door and enter the car, sits in there and put on the seatbelt. Someone pass the helmet and he put it, while also they handle her two bottles of fresh water to place it in the two holes.

Whit the voices of her team vanishing, they help her to close the canapé, she prepares himself for the mission ahead. The inside can easily reach the 45 degrees, during several hours. The excitement for the race overcome all the problems faced to be here.

A voice, the only companion inside the cockpit, star buzzing in to her ear. It's time to start the engine. The batteries are fully charged from yesterday.

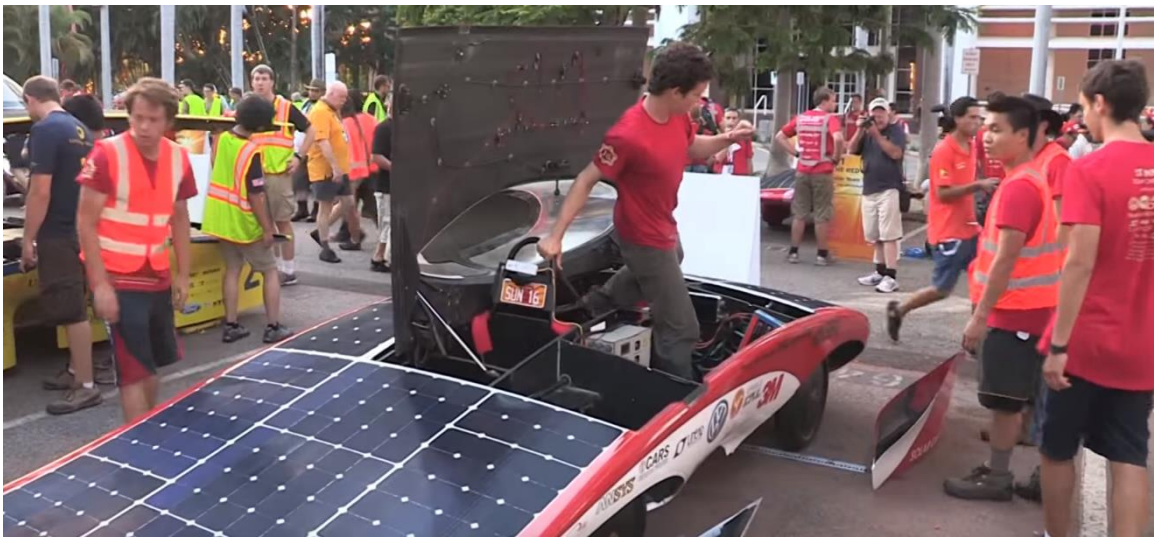
Turn on the solar cells, so they can start to harvest the energy from the sun, the MPPT has to be turned on too, so there is no problem with the voltage. The escort vehicle gets all the reading from the solar cells, and they know the speed you should be driving. When to stop or when to run.



She pushes the power buttons and begin to increase the speed to the value they told you, and the car start moving. The motor next to her is a sound she should get used to it. Looking for reducing the weight the car is not acoustic sealed, also is not complete seal, she has a little hole were her get some air, too cool down the temperature inside the vehicle.

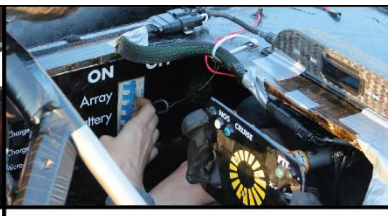
She looks to the road, her job, to keep the car between that two white lines, from time to time she look at the screen, to see the escort vehicle behind her, until they told her to stop.

Turn the right light on, and start to reduce speed, she uses the regeneration brakes to save all the energy she can, and finally she stops. She doesn't turn off the solar cells, so they can fully charge the battery, but she takes the seat belt and the helmet, and open the canapé so the little breeze of wind touches your face.



Compromise and Hope

Begining and Confidence



Excitement and Create

Control and Self-awareness

Freedoom and Wildness

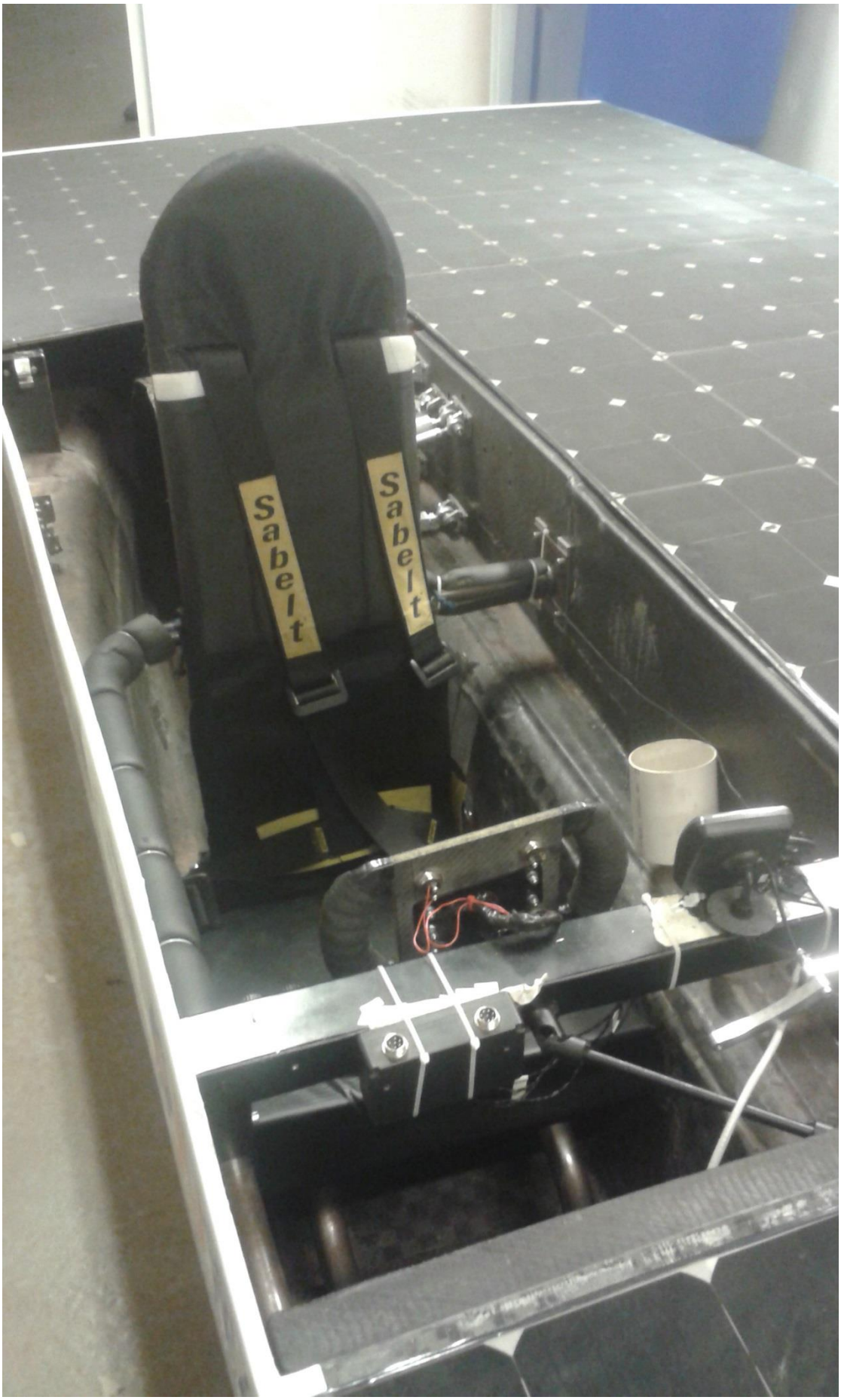
Isolation and Ambition

Adventure and Explore

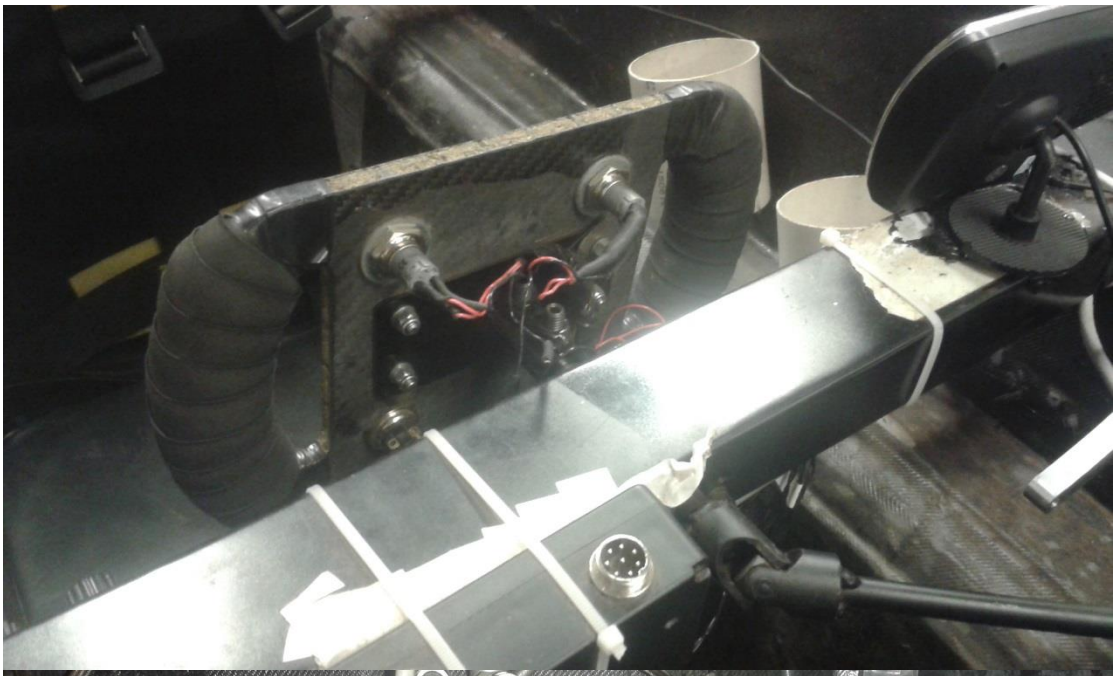
Control and Security

Accomplish and Teamwork

8.3 Appendix 3: Car pictures


Sabelt
Sabelt


PANIC!
ECO/PWR
A 1
B 3
C 4
MPPT
OFF
BAT ON



8.4 Appendix 4: User interview

Describe the function of the buttons, why do you use it, when do you use it, if there is any problem with them or anything you could consider interesting from your experience:

- **PANIC button:** “Used when there is panic situation and the battery and all electrical things need to be switched off immediately. Never used it during the solar car experience but I think it was placed in a good location and the closer and easy to reach the better"
- **D1 button:** "Individual Powerpoint tracker on and off switch, Location good, could be included in steering wheel "
- **A2 button:** "Individual Powerpoint tracker on and off switch Location good could be included in steering wheel "
- **B3 button:** "Individual Powerpoint tracker on and off switch Location good could be included in steering wheel "
- **C4 button:** "Individual Powerpoint tracker on and off switch Location good could be included in steering wheel "
- **MPPT button:** "Powerpoint tracker system on and off switch Location good could be included in steering wheel "
- **Reverse button:** "Makes car go backwards, would be nice to include in steering wheel"
- **ECO button:** "Determines of much current should be put to the electrical motor saves energy when selected. Good location could maybe be included in steering wheel"
- **Solar button:** "Don’t remember"
- **BATTERY button:** "Resets battery or turns it off don’t remember. Good location could be included in steering wheel"
- **REG button:** "This is and speed button are perhaps the most important that should be included in the steering wheel. Now you had remove one hand from the steering wheel every time you adjusted these. Makes steering unstable. If it were inserted in the steering wheel both hands can be kept on steering wheel at all the time which is good for safety and driving performance",
- SPEED button: "See above"
- **BRAKE pedal:** "Good location"
- **Power button:** "Good location could maybe be done a bit bigger"

OTHER COMMENTS: "The general feeling is that buttons that are used more often should be prioritized to be put on the steering wheel to keep driver with two hands on the wheel as much as possible.”

How comfortable did you find the seat? "Not comfortable at all, lack of lumbar support and support for arms when driving. Very loud something to remove that engine noise is preferable"

What is your opinion about the actual inside of the solar car? "Perhaps too much space it could be made less wide.”

What do you think about the actually system for opening and close the cockpit? "The principle is good but the solution should be improved especially the hinges so they don’t harsh when opening"

What do you think about the space/dimensions for the driver? "Too much space really, so it is nice to sit in terms of space but for aerodynamics it could be improved."

Do you think the size of the screen and location is adequate? "Yes it is good,"

What do you think was a better option: have a crash bar in the seat, as it is now, or included in the shell as it was in the previous solar car design? "To have included as a shell, meaning that also a crash bar can be mounted to the shell and the seat is separate from the crash bar. As it is now the crash bar options is too heavy, including it in the shell and have a separate chair or a chair in another material would be nice to save weight"

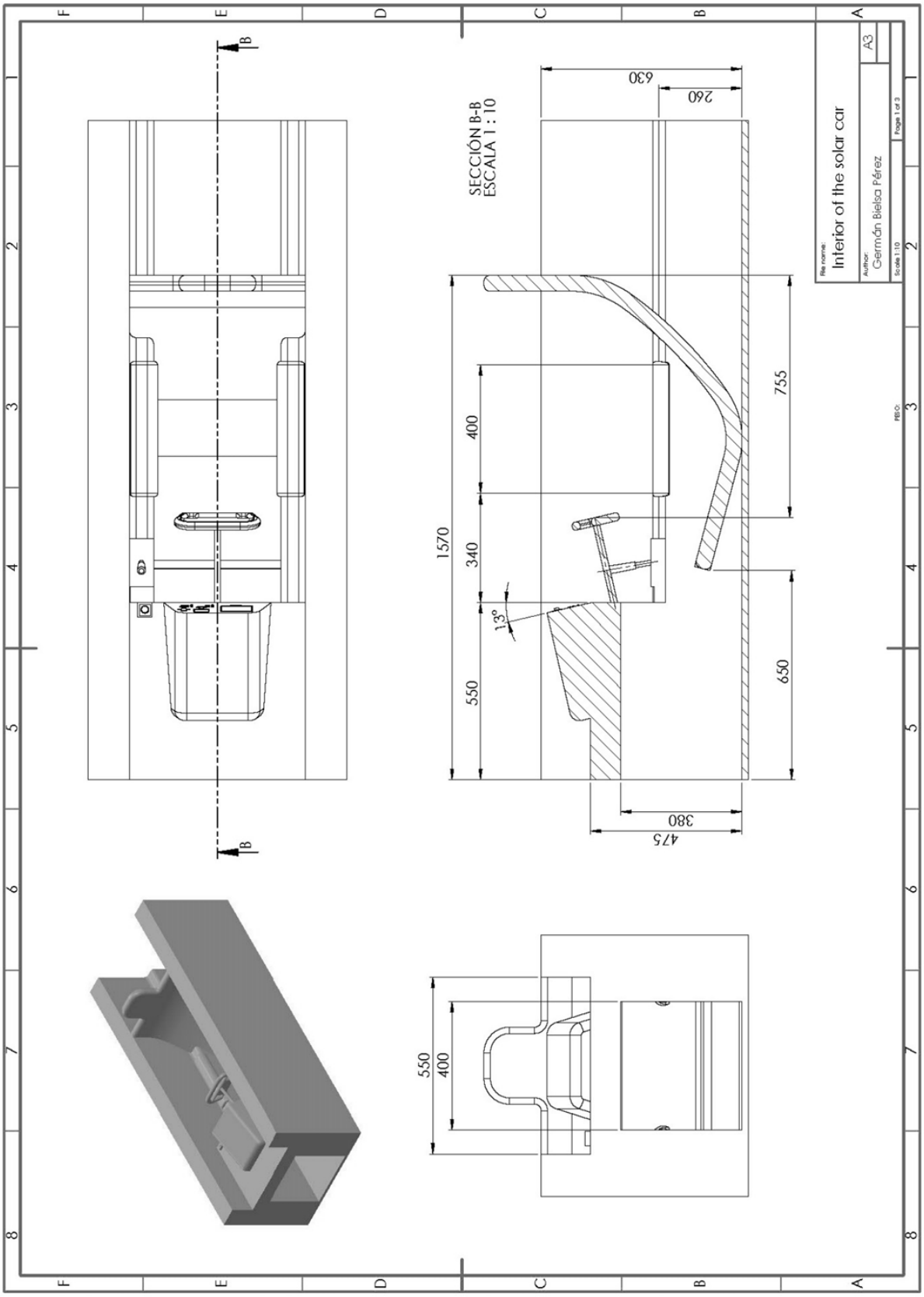
OTHER COMMENTS: "The steering wheel is in the way when getting in and out. Not that much in this solar car but some construction ideas had to be excluded because of the steering wheel. Having a solution where the steering wheel can be moved in some way when getting in and out is preferable."

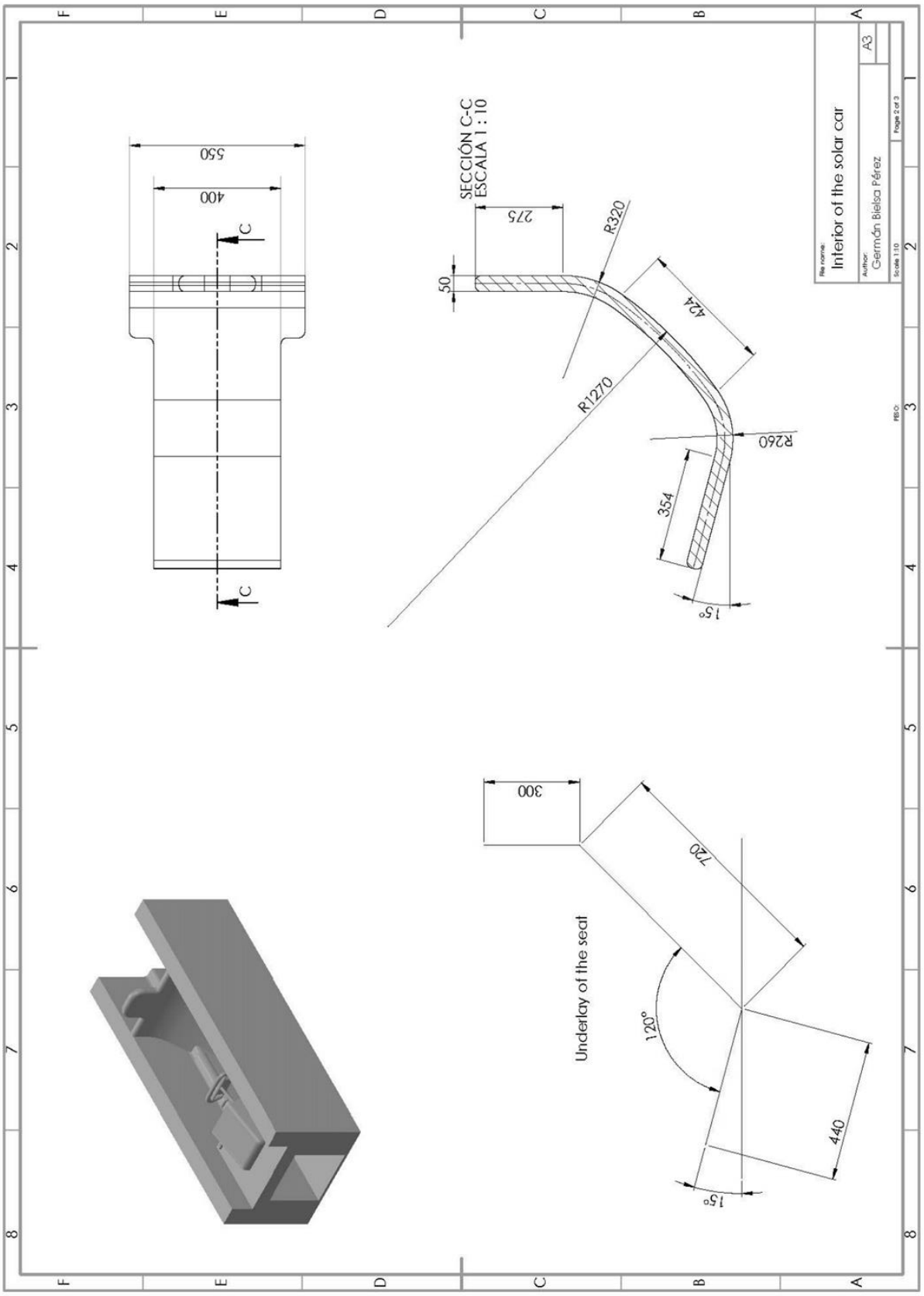
Do you have any complain/problem about the steer wheel? "Maybe more buttons and functions should be included inside it. The size and how you hold I think was nice but it in some way it is nice for the driver to be able to change grip. Some support for the thumb would also be nice"

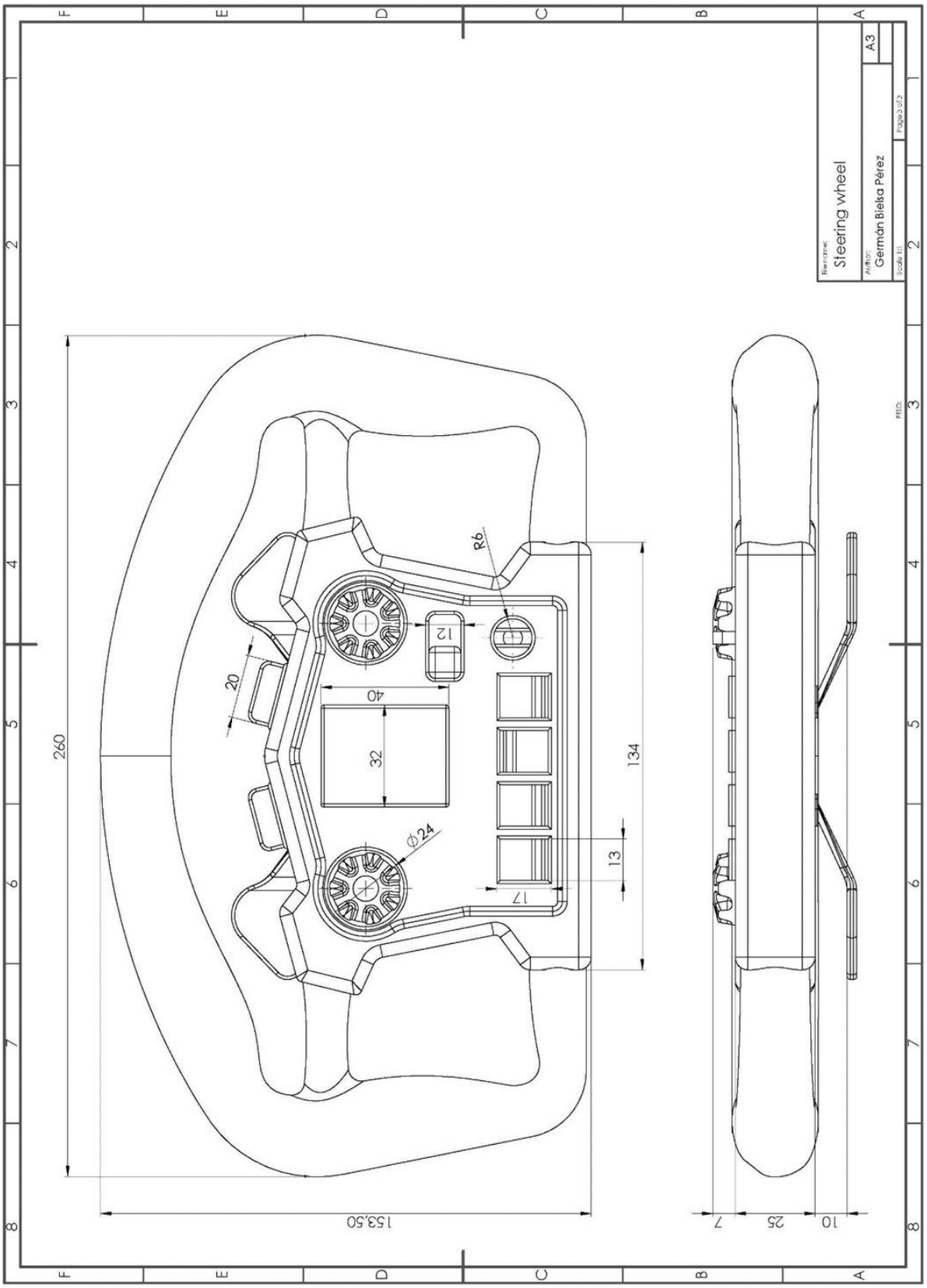
Do you have any complain/problem about the windshield? "No"

Any information that you want to add related to your experience as the driver of the solar car? What do you think can be improve, what problems should be solved? What was the most annoying thing while you were driving? "The most severe problem is the noise in the driver's area and the lack of supporting points for the body like lumbar support and arm resting support. "

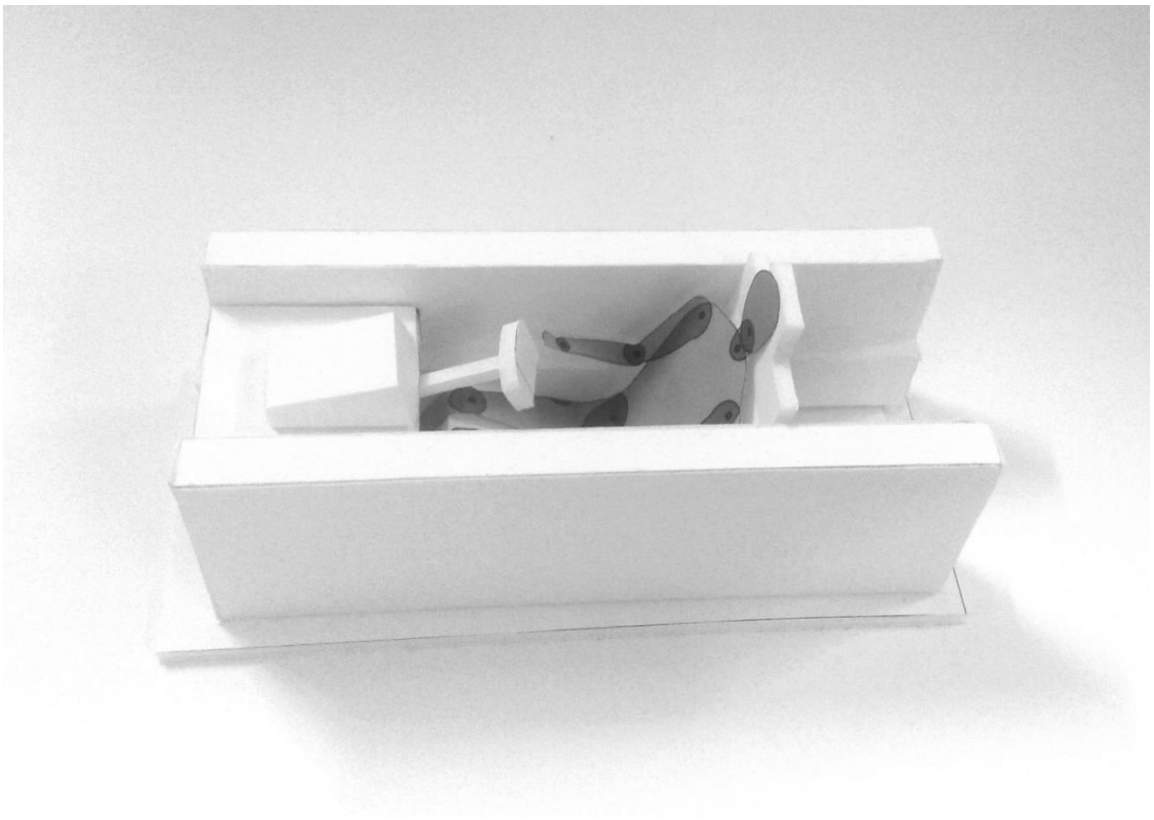
8.5 Appendix 5 Blueprints

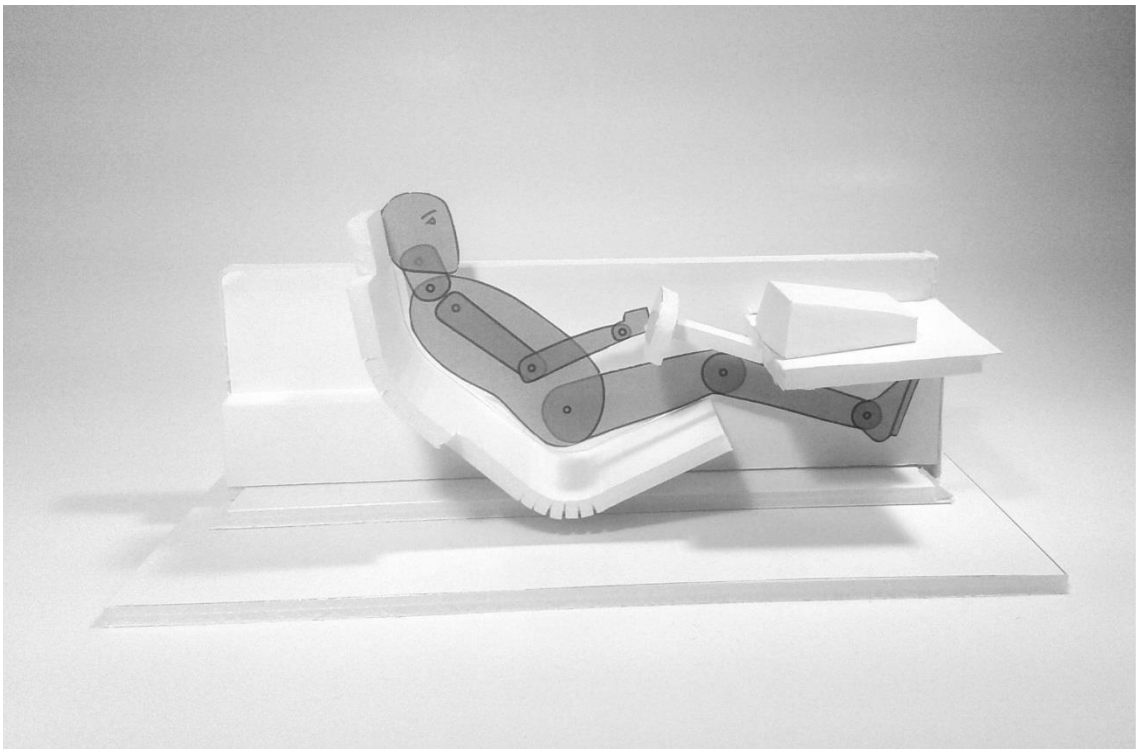



File name:
Inferior of the solar car
Author:
Germán Bielsa Pérez
A3
Scale 1:10
Page 2 of 3
SECCIÓN C-C
ESCALA 1 : 10
550
400
C
C
275
R320
50
424
R1270
R260
354
15°
300
720
Underlay of the seat
120°
440
15°


Steering wheel
Germán Bielsa Pérez
A3
260
153,50
134
R6
12
20
40
32
Φ24
13
17
7
25
10

8.6 Appendix 6 Model pictures





8.7 Appendix 7 Feedback interview

1. General impression of the steering wheel. What are your first thoughts about it? (Shape, colors, size, hierarchy, buttons…)

a) Nice colors, shape and size! F1 impression

b) Looks comfortable, the colors could match the rest of solar. Love the blinker buttons

c) Nice colors, compact everything. Seems to be reusable. Cool look

d)The design is nice and it´s a good size. But it looks like you can get a good grip with your hands around it

e) Looks nice. All buttons seem to fit but maybe not needed on the wheel

f) Good grouping the MPPT. Color feels Finland. Nice blinkers

2. Could you identify the buttons and their function? Is there any button that you don't know its function or use?

a) Yes, the symbols and letter are really informative

b) I know all the buttons from before someone explained them for me, not the buttons but the functions

c) Yes, but don't know the use of the MPPT

d) I can identify all the buttons except the red wheel and the JU logo

e) Yes, I think I can identify all buttons. The "J" is the horn?

f) Don´t know what: R off, Solar (blue). The red button is it on off for all MPPT

3. Indicate the movement of the buttons (Up/Down/Left/Right/Pull towards the user/ Push/ rotate clockwise/rotate anticlockwise/…)

a) Wrong direction in SOLAR, ECO, SPEED and Reverse.

b) No answer in the JU logo

c) Wrong direction in REGEN

d) Wrong direction in REGEN

e) Wrong direction in SOLAR, ECO, REGEN and Reverse

f) No answer in the JU logo

4. How would you describe the steering wheel from 1 to 5 in this pairs of words?

Lower word	A	B	C	D	E	F	Higher word		Chosen word
Exciting	1	2	2	1	2	2	Boring	1,6	Exciting
Confident	1	2	2	2	2	3	Uncertain	2	Confident
Control	1	2	2	1	3	2	Uncontrol	1,8	Control
Freedom	2	2	3	2	3	1	Confinement	2,6	-
Imprecise	5	4	4	4	2	4	Structured	3,8	Structured
Ambition	1	3	1	3	3	2	Indifference	2,1	Ambition
Adventure	2	3	2	2	2	2	Inaction	2,1	Adventure
Open/inviting	2	2	3	1	2	1	Close	1,8	Open
Secure	2	2	2	-	2	2	Unsecure	2	Secure

5. What is your impression about it? (conform, access to the buttons…)

a) Easy to understand and great tactile feeling. I think I could use the buttons without look at the wheel

b) The reach of the ECO and SOLAR buttons seems difficult

c) I like how the buttons close to reach. Everything seems to be accessible with the hands

d) Should you reach all the buttons with your thumbs or should you let go the of the steering wheel? In that case I can't reach all buttons. More space for your hands

e) All accessible, cool feeling

f) Blinkers buttons is really nice, access to MPPTs as well, hard to access SOLAR ECO, but usually you don't need them while driving

6. Compare to the old one, do you think it is an improvement?

a) So nice to have all the functions in the wheel. It´s a great improvement!

b) Yes!

c) Yes! Good features

d) Yes! Good with all buttons

e) Yes, just that all buttons are not needed on the wheel

f) The blinkers are an improvement for sure and its nice with everything overall. It looks neat! GJ

7. Other comments:

a) Great work

b) Some of the buttons seems “unnecessary” MPPT

c) Great job!

d) Good work!

e) -

f) One practical thing how does the cables from all the buttons etc. “twist” when turning. In a car is a flat cable