- SUNO -

THE SELF-ORIENTED SOLAR MIRROR

An EPS@ISEP Project

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ACKNOWLEDGEMENT

The team would like to begin by thanking the teachers for giving us the opportunity to participate in this project, but also for supporting us during it.

GLOSSARY

Table 1: Glossary

Abbreviation	Description
AC	Alternating Current
DC	Direct Current
EMC	Electromagnetic Compatibility
EPS	European Project Semester
EU	European Union
ISEP	Instituto Superior de Engenharia do Porto
LCA	Life Cycle Assessment
LVD	Low Voltage Directive
MDF	Medium Density Fibreboard
NREL	National Renewable Energy Laboratory
PVC	Polyvinyl Chloride
RACI	Responsible, Accountable, Consulted and Informed
RAM	Responsibility Assignment Matrix
ROHS	Restriction of Hazardous Substances in Electrical and Electronic Equipment
SA	Société Anonyme/Sociedad Anónima
SMART	Specific, Measurable, Achievable, Realistic and Timed
SOSM	Self-Oriented Solar Mirror
SWOT	Strengths, Weaknesses, Opportunities and Threats
US	United States
USB	Universal Serial Bus
WBS	Work Breakdown Structure

1. INTRODUCTION

Within the *European Project Semester* (EPS), the authors were Team Three (see **Fig.** 1), or better known as Team Tree. The motto of the Team was planting a tree, the Team planned to "plant a tree", build a project, and make it grow. Eventually, the Team hoped to profit from the fruit, taking the knowledge and experience gained to apply it in the future.

The Team consisted of five students, all with a different background of education and all from different countries. These five students spent the spring semester of 2017 in Porto working at ISEP. The Team were:

- Margot Gutscoven (Civil Engineering Technology) of Belgium
- Jan Latko (Computer Science) of Poland,
- Raymond Quinn (Electrical Power Engineering) of Scotland,
- José Hugo Valiente Saltos (Mechanical Engineering) of Spain
- Anna Simons (Industrial Management) of Finland.

The Team would draw on this diverse range of knowledge and experience to try and deliver a successful project. The aim of this report was to provide information on the all of the different challenges and considerations related to the project and to show how the Team has tackled these issues.

Figure 1: Team photo

1.2 MOTIVATION

The Team have spent their semester building a Self-Oriented Solar Mirror (SOSM). The solar mirror is a simple way to harness solar energy and to transform it into energy that can be used daily. Raw materials are overused and new sources of energy are needed. This was why the Team were drawn to the solar mirror project, this way the Team could contribute to a better and greener Earth. People are thinking more and more in an environmental way and it is necessary as engineers to facilitate this.

The Team hoped the EPS program would help them to become better engineers and give them experience of working in a multidisciplinary international team. The Team hoped to develop better English skills but also learn something about different fields of engineering. The members could apply their own knowledge but also learn from the others. It was also possible to learn about different cultures, how to interact with people from different parts of Europe and see how they differ, but also see the similarities.

1.3 PROBLEM

The goal of this project was to develop a Self-Oriented Solar Mirror (SOSM). The purpose of the mirror is to heat a certain object or to light up a room. The mirror must track the movement of the Sun and reflect the sunlight onto a predefined area. The creation of the sun tracking system was one of the main challenges for the Team. The team had to decide whether to track the sun with or without sensors. If it had been decided to make a solar mirror without sensors and put the location of the Sun in the software, this would have meant that there needed to be a way to input the address where the mirror is used and would lead to more challenges.

Also designing the mechanical parts was a big challenge. How to make the solar mirror move in two axes, what materials should be used for this and how should all the materials fit into our design were some questions that arose. The SOSM is also a device that has to be outside, therefore it has to be robust against the elements.

1.4 OBJECTIVES

The objectives of this project is to design a SOSM that detects the Sun by itself with the aid of software that knows the path of the Sun. The consumer would need to do a setup in the beginning defining, where the mirror has to be focused. The Team could contribute to a greener planet through the development of this product, therefore the product has to be sustainable.

Another objective was to cooperate well in a team and to learn to work in a multicultural environment. The deadlines were all to be taken seriously and to be respected. The team members should try to listen to each other and help each other. Also, arguments had to be resolved fairly and as soon as possible.

1.5 REQUIREMENTS

This project is part of the EPS at *Instituto Superior De Engenharia Do Porto* (ISEP) 2017. The EPS is a program that brings students together from all over Europe. The program is designed mainly for engineering students, but others may participate as well. The students were divided into small groups of five students, preferably from different countries, and with different fields of study. Every group had to choose a different project to work on during the semester. The students had to attend support classes on Ethics, Sustainability, Marketing and Project Management. The students were supported by a panel of supervisors that consisted of teachers from various fields. There were certain requirements that the project should fulfil.

These requirements were:

- Use low cost hardware solutions.
- Use open source software.
- Adopt the international system of units (NIST).
- Comply with the 2006/42/CE 2006-05-17; 2004/108/EC 2004-12-15, 2014/35/EU 2016-04-20, 2014/53/EU 2014-04-16 and ROHS EU Directives.
- Stay within the budget of 100.00 €.

1.6 FUNCTIONAL TESTS

In order to evaluate the project, certain functional tests have to be done. This way the product can be improved where necessary. Some functional tests are:

- Test if the solar mirror tracks the Sun correctly.
- Test if the sunlight is reflected at the correct angle.
- Test if the materials used can withstand heat.
- Test if the area that needs to be heated/illuminated, is heated/illuminated.

1.7 PROJECT PLANNING

Table 2 contains the different tasks to perform, as well as the person responsible for it.

Table 2: Task Identification and Allocation

Task	**Responsible**
Initial Planning	
Task Identification and Allocation	Margot
Gant Chart	José
Technical Research	Jan
Market Research	Anna
Initial Budget Planning	Raymond
Purpose Definition	All
Specific Planning	
System Diagrams	Jan and Raymond
Structural Drafts	José
Design	José
List of Materials and Budget Re-planning	Raymond
Interim	
Project Management	Anna
Eco-Efficiency Measures for Sustainability	José
Ethical and Deontological Concerns	Jan
Upload Interim Report and Presentation	Anna and Margot
Interim presentation	Anna and Margot
Upload Refined Interim Report	Anna and Margot
Complete List of Materials	Raymond
Construction	
Construction Hardware	José and Raymond
Construction Software	Jan
Testing	
Product Testing and Corrections	Jan, José and Raymond
Upload Functional Test Results	Jan, José and Raymond
Final	
Upload the Final Report and Presentation	Anna
Upload the Movie, Poster, Manual and Leaflet	Margot
Final Presentation, Individual Discussion and Assessment	Jan, José, Margot and Raymond
Upload the Wiki with all Correction Suggestions	Anna
Hand in a CD with all the Corrected Deliverables	Margot
Hand in one Printed Exemplar of the Corrected Report	Anna
Hand in the Prototype and User Manual to the Client	Margot

1.8 REPORT STRUCTURE

The report is divided into eight chapters, which include different subsections. The different chapters are detailed at **Table** 3.

Table 3: Report Structure

Chapter	Title	Description
1	Introduction	Short description of what the project is about, the objectives and requirements
2	State of the Art	Technological and market research. How the mirror should be built, which materials are best to use, how software will be used etc.
3	Project Management	The task and time allocation. How the tasks are divided and when they must be completed to be able to finish the task in time.
4	Marketing Plan	Who is going to buy the product?
5	Eco-Efficiency Measures for Sustainability	What the team have done to make the project eco-efficient and the measures the team have taken to make it sustainable.
6	Ethical and Deontological Concerns	The ethical concerns regarding the solar mirror.
7	Project Development	How the project was developed, the problems encountered and how they have been tackled.
8	Conclusions	A brief summation of the main conclusions of the project.

2. STATE OF THE ART

2.1 INTRODUCTION

In the state of the art, the technologies that are already on the market are going to be discussed; this topic refers to the highest level of general development of a device, technique, or scientific field achieved at a particular time. This is undertaken to foster ideas that could possibly be applied to the product. The different purposes of the solar mirror are also going to be discussed. This was done to find first of all, the purpose of these mirrors, understand where there is a gap in the market and which ideas have not yet been made a reality.

A solar mirror is a substrate covered with a reflective coating, this way it can reflect the sunlight to a certain point. The substrate can be flat, but can also have a parabolic form. The goal of the SOSM is to reflect the sunlight and to achieve a significantly higher concentrated reflection factor.

2.2 PURPOSE

A solar mirror can be used for many purposes. Mainly it is used to heat things. The heat can be used directly in homes for warm water, but can also be transformed into electrical energy. Another way to use the solar mirror is to use it for light. The solar mirror could be put in a garden and aimed through a window to bring more light into a room. In this chapter the different purposes of the solar mirror are going to be explained.

2.2.1 HELIOSTAT

2.2.1.1 PURPOSE

The heliostat is a mirror targeted mainly at small scale or personal use. It can light up rooms, work areas, desks, small gardens, etc. depending on the size of the mirror. The mirror is universal, not task specific, but focused on providing light rather than heat or electrical energy [1]. **Fig.** 2 illustrates a room before and after reflecting sunlight with a mirror. It shows that such a device could make a room significantly brighter.

Figure 2: Room With and Without Light from a Heliostat [2]

2.2.1.2 TECHNOLOGY

For the technology of the solar mirror different parts will be needed:

1. Sensors or a Real Time Clock (RTC)
2. Controllers
3. Actuators

Sun Tracking

There are two different ways of following the route of the sun, using sensors that redirect the mirror to the sun or programming the route by prior knowledge of the known movement of the sun. In both cases the position of the Sun and the center of focus is needed. The position of the center of focus could be either set mechanically with a pointer or input digitally, for this, two angles and optionally a distance are needed. Some kind of positioning device could also be used as a target for the mirror.

For the position of the Sun two approaches could be considered. First is setting a date (day, month and year), time and geographical location and calculating the Sun position from that data. According to the authors of *Solar Position Algorithm For Solar Radiation Applications*[3] most of such algorithms do not achieve uncertainty smaller than 0.01 °, while their own algorithm is much more accurate. The advantage of this approach is that it does not require any additional sensors. The disadvantage is that it works only with sunlight and does not take into account light reflections, artificial sources of light nor objects that can eclipse the Sun, like trees and buildings.

The second approach needs several light sensors. What makes the case even more complex is that the mirror has to reflect the light in a specific direction rather than just turn itself towards the Sun. One way to achieve this would be not to place a Sun tracking sensor together with the mirror, but instead move them separately with the mirror position depending on the position of Sun tracker[4], the mirror's normal should be the bisector of the angle between the Sun tracker and the focus direction. This solution involves much more complicated mechanics, but simplifies electronics and computation and involves components that might be easier to find.

Another way is to build a sensor that would tell exactly where the light is. There are different ways to do this. First of all several light intensity sensors could be used to approximate where the light intensity is at its strongest. An alternative option is using a box with a hole and detecting where the Sun spot is on the bottom of the box (shown in **Fig.** 3) [5]. There might be some sensors that would provide this functionality out of the box, nevertheless these are not easily available and may be more expensive.

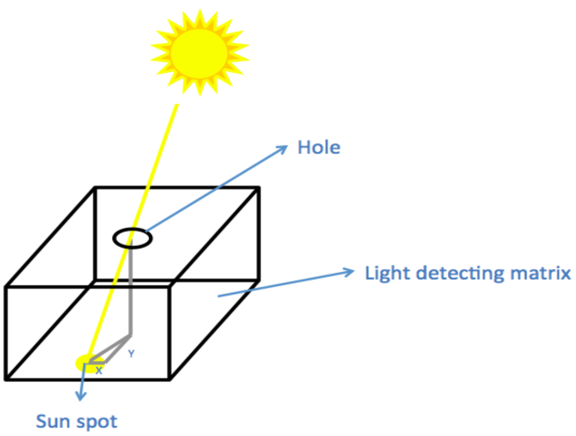


Figure 3: Box with Holes

Controller

The controller receives the input of the sensors and processes it into actions that are sent to the actuators. The microcontroller board is necessary for the angles calculation, unless a movable sensor with some mechanical way of moving a mirror and setting the target is present, in which case a simple electronic circuit can be used as a controller.

Actuators

The mirror needs to be rotated in two axes, therefore two motors, some construction and most probably some angle monitoring are needed.

2.2.1.3 BUDGET

To build a prototype of a device that tracks the sun to make a proof-of-concept of our project, an Arduino controller will be needed. An arduino controller costs about 20.00-25.00 €, but some alternatives can be found for 10.00-15.00 €. Simple photocells would be needed if the decision is taken to work with light sensors. Light sensors can be bought for about 1.00 €. Quad photodiodes cost about 5.00-6.00 €. *Direct Current* (DC) motors can be bought from 2.00 € (depending on size and torque). A Display can be found for about 10.00 € or less and a 4-digit display costs 2.00 €. The device's cost depends mostly on the price of light sensors and mechanical components and materials [6].

2.2.1.4 MARKET RESEARCH

The Sunflower is shown in **Fig**. 4.

Figure 4: Sunflower (Heliostat) [7]

"Sunflower" is a heliostat for home use [8]. It costs 299.00 $, but it is not available for the moment because it is sold out. Its price could be considered affordable. Other heliostats on the market are larger and significantly more expensive, they cost around 1 840.00 € [9]. There are not so many heliostats easily available on the market, the H1 Heliostat [10] that costs 2 000.00 € is the only one that can be easily found on the internet. That means that with good marketing there is a possibility to compete with the currently unavailable Sunflower and create an affordable heliostat for home use. The price of the device should therefore be less than 275.00 € for a small size mirror or more for a larger one.

2.2.2 COOKING MIRROR

2.2.2.1 PURPOSE

A solar cooker could be used for outdoor cooking and possibly grilling. Such a device could also be used to heat food up or keep it warm. As such a function does not exactly need a solar tracking system it might be good to add some functionality such as temperature monitoring or a timer. On the other hand, if the cooking or heating takes a long time, self-control would be a useful feature.

2.2.2.2 TECHNOLOGY

There are three possible ways to heat food [11]. The easiest way is to reflect the sunlight by mirrors to an area, the cooking area, for example **Fig**. 5 a. The problem with this method is that it can provide temperatures from 65 °C, which is a good baking temperature to 400 °C on a sunny day, which is a high enough temperature to melt metal. A second possibility is to concentrate the sunlight onto a receiver, for example a cooking pan or pot. To maximize the heat absorption, it would be best to use a matte black pan or pot (**Fig**. 5 b). A third way would be to trap the heat, in this way one should make sure to isolate the air, this would ensure that on cold and windy days, one could also use the solar mirror. A windshield would also prevent the food from cooling down (**Fig**. 5 c).

Figure 5: Solar Cookers a) Concentrating Sunlight [12] b) Converting Light Energy into Heat Energy [13], c) Trapping Heat Energy [14]

2.2.2.3 BUDGET

A sensor system might be based on 2 to 4 light sensors for 1.00 € or one quad photodiode for 5.00-6.00 € and the device needs 1 or 2 motors (depending on the size 2.00-10.00 €). A controller costs around 10.00-25.00 €. Nevertheless, a cooker might involve more expensive materials as it needs to handle high temperatures.

2.2.2.4 MARKET RESEARCH

The solar cooker could be a suitable device for garden parties or barbecues and would suit a recent trend of “being green”. Such a device has to be rather big, so its mobility would be limited. Nevertheless, it could be easily transported with a car. There are several examples of solar cookers and ovens on the market. None of them are self-oriented nor have any additional digital functions. Therefore, there is a possibility to build a device that would be more convenient to use through automation and the possibility to add some helper functions, for example, putting a timer on the solar mirror and when the food is done, the device would turn away from the sun. The prices of the existing ones vary from 45.00 € for a rather simple and small version of solar cooker to 275.00-370.00 € for bigger and more advanced solar ovens [16]. The first price is low, but the cooker is also very simple, therefore our device could be much more expensive. Its price could even be higher, as it would provide much more functionality.

2.2.3 AGRICULTURAL SOLAR MIRROR

2.2.3.1 PURPOSE

Agricultural solar mirrors are used for growing plants, vegetables, tomatoes and so on. They can also be used to make plants grow larger, longer, more plentiful and better [17]. **Fig**. 6 shows an example of a solar mirror that is placed under a tree. This way the tree leaves that are normally always in the shadow, because they are covered by the upper leaves, can last longer. This can be done with and without a rotating disk [18].

Figure 6: Solar mirror for under a tree [17]

Another application of the solar mirror is to dry fruits and vegetables. It is very important to dehydrate fruit and vegetables, this ensures that they can be preserved longer and can add value to the produce by controlling the moisture content [18].

2.2.3.2 MARKET RESEARCH

There is a farm in the South Australian desert where they grow tomatoes by using just sunlight and seawater. They turn seawater and sunlight into energy and water, and use sustainably sourced carbon dioxide and nutrients to maximize the growth. After the seawater arrives at the farm, it is desalinated at an on-site, solar-powered plant that turns it into fresh, plant-ready water by 'scrubbing' the salt out of it. They have a field of mirrors that focus the Sun´s rays onto a fixed tower, where it powers a generator to create electricity. In this case, there is 180 000 tomato plants and 23 000 mirrors, and it cost 200 million $ to build. Therefore, in this case the mirror could be used to both desalinate the water for the plants and to help the plants grow [21].

2.2.4 DESALINATION

2.2.4.1 PURPOSE

Desalination signifies the removal of salt and other minerals from a substance. These minerals can be bad for human consumption, but also for agricultural purposes; therefore, it is best to remove them. In dryer countries desalination is particularly relevant. It is a fact that in regions where the clean water source is scarce, there is plenty of solar radiation. This is why it would be very advantageous to use solar radiation for the desalination of water; nevertheless, this requires large amounts of energy. Using solar radiation would be a way to produce emission free renewable energy. The solar radiation can be converted into electrical energy and used for the condensation of the water or it can be used directly to condensate water.

2.2.4.2 TECHNOLOGY

Most technologies to desalinate water involve the evaporation of water and after condensing the vapour back to its liquid state [22]. Commonly vacuum distillation is used, where the pressure is lowered so that a lower temperature can be used to evaporate the water.

2.2.4.3 MARKET RESEARCH

The demand for water desalination products increases by 9.30 % per year. The worldwide water distillation industry is worth about 8.60 10^9 $. Veolia Environment S.A., Acciona S.A. and General Electric Co. are some of the key players in the water market with a focus on the distillation industry. They cover Saudi Arabia, the United Arab Emirates and the United States of America [23].

The desalination of seawater is, in general, more costly than the desalination water from rivers or ground water. Currently, 1 % of the population depends on the desalination of water. Water is the major necessity of life, a lack of it can affect agriculture and lead to thirst and famine. Although this seems like a suitable solution, economically and environmentally it has appeared not to be so. Although it is beneficial for solving the drought problems, it is recommended to find other solutions to protect the economy and ocean life.

It is important to consider how this would affect the economy. For example, for the last decade people are suffering from drought in California, affecting around about 64 million people, due to changes in rainfall patterns. Because of the drought the agriculture has been seriously affected. Which has led to a weaker economy as agriculture is the main source of revenue. Desalination could be a solution, nevertheless there are flaws. Building the desalination installation will cost up to 1 10^9 $ or 0.90 10^9 €, which is too high for a community [24].

In this project, a small desalination system for home use could be produced. The target market would be developing countries, where they do not have clean water coming out of the tap, or can only buy water from a store. The people who need the water distiller are naturally not capable of buying the distiller themselves, that is why charity organisations are the main target group. Charities such as WaterAid, WellFound, WorldVision, Water.org would be perfect targets for this project [25].

2.2.5 WATER HEATING

2.2.5.1 PURPOSE

One solution could be to use the mirror for water heating. A lot of houses already have a solar water heaters on their roof. The mirror could help to heat it even more and produce even more energy to heat the water. A solar water system includes solar collectors and storage tanks. When adding the mirror more solar collectors should be added because the light will come from another point. **Fig.** 7 shows a picture of a solar water heater.

Figure 7: Solar Water Heater [25]

2.2.5.2 TECHNOLOGY

There are two kinds of solar water heaters, the active kind and the passive kind. The active kind has circulation pumps and controls and the passive kind does not. They both have two possibilities. In the first case, normal water can be pumped around, this can only be used in climates where it does not freeze often, otherwise the water will freeze and the system will be blocked. In the second case the pump circulates a non-freezing fluid through the system, this case is more expensive, but certainly necessary in cold climates [27].

The water in the solar collectors is heated and afterwards sent to the storage. The heat can be stored in a tank or in the masonry mass of a radiant slab system. The role of the mirror will be to heat the collectors more than they heat with only the Sun.

2.2.5.3 MARKET RESEARCH

The challenge here would be to make the water heater as efficient as possible so that people will save more money than they will use in paying for the energy. This also means that the product will have to be sustainable, it has to have a long lifespan, so it will last long enough to make profit out of it.

2.2.6 SOLAR ENERGY PRODUCTION

2.2.6.1 PURPOSE

The purpose of using solar mirrors in electricity production is to harness the power of the Sun. Most solar power plants use a vast field of hundreds to thousands of heliostats which reflect the sunlight up to a tower situated in the centre of the field. The mirrors focus the sunlight on one area of the tower and this focused light is many times more intense than regular sunlight (see **Fig**. 8). One plant in California can power over 75 000 homes [28].

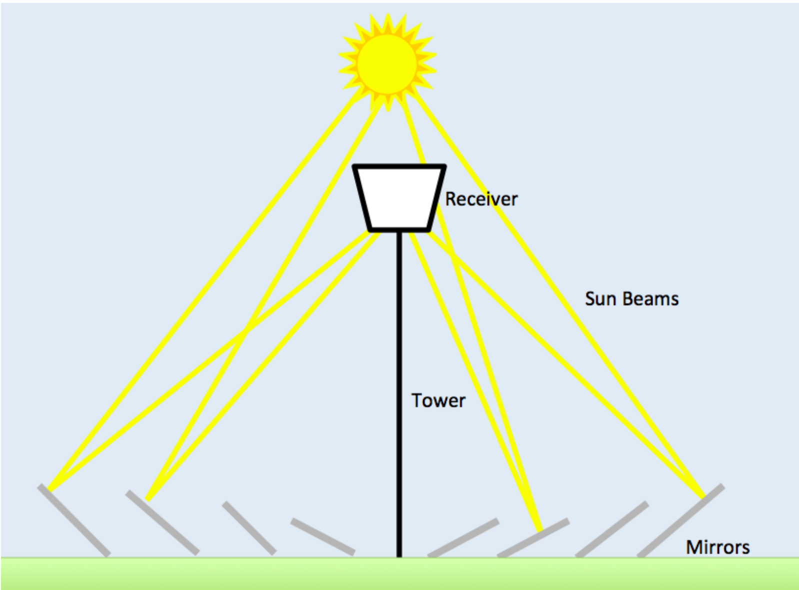


Figure 8: Reflection of Sun onto Solar Mirror

2.2.6.2 TECHNOLOGY

Some power plants use heliostats with light and heat sensors which can track where the Sun is in the sky in order to be in the optimal position to reflect the sunlight to the desired area. Other plants use a timed system where pre-recorded data about the Sun's position in the sky is used to position the mirrors, however the mirror's position can be adjusted by an engineer from a central control room in order to get as much energy from the Sun as possible [29].

At the top of the tower are tanks containing oil. This oil is heated by the reflected sunlight and can reach 500 °C and more. This heated oil is used to turn water into steam which drives a steam turbine to produce electricity much in the same way as a conventional power plant using a non-renewable fuel source. There are also other methods such as storing the heat energy in molten salt which allows the plant to produce electricity even during hours where the Sun has set, meaning the plant is operational 24 hours a day. The energy stored in the salt can drive a turbine for up to 15 hours [30].

2.2.6.3 ENVIRONMENTAL CONCERNS

There are a great many environmental concerns when it comes to concentrated solar power plants. Wildlife may need to be displaced in order to build the plant. There are also a great many avian deaths every year. When birds fly into the path of the concentrated light they can be burned and killed. Some plants are also not entirely powered by the sunlight. Many require natural gas to be burned each morning to get the plant started up.

2.2.6.4 BUDGET AND MARKET RESEARCH

Such systems for creating electricity from sunlight are very expensive. The Planta Solar 10 in Spain cost 35 000 000 € to build and can power 6 000 homes day and night [31]. The Ivanpah plant in the Mojave Desert cost 2.20×10^9 $. Building such a system on a small scale does not make sense financially. In terms of competitors there are many commercial power plants already in operation as well as many more planned developments. It is possible that a smaller scale plant would be a viable way to meet the energy needs of a small town in a more environmentally friendly way.

2.3 CONCLUSION

The advantages and disadvantages of using one of the different purposes for our project are summed up in Table 4.

Table 4: Purposes Comparison

Purpose	Advantages	Disadvantage
Heliostat	It will be possible to make it cheaper than the ones that are already on the market	The difficulty here is to reflect the sun always to the same point. For example, for the solar cooker, the object that needs to be heated will always move together with the mirror
Cooking Mirror	It will be possible to make a product that is not on the market yet, by adding gadgets like a timer	The things that need to be cooked, also the things they need to be cooked in (the pans and pots), are expensive, and out of our budget
Agricultural Solar mirror	There are not many devices like this on a small scale	The difficulty here is to reflect the sun always to the same point. For example, for the solar cooker, the object that needs to be heated will always move together with the mirror
Desalination	It is something new on the market, there are no self-oriented desalination devices	It will be difficult to build the device that desalinates the water It is expensive to build the part to desalinate water
Water Heating	Easy to build, because we don't have to reflect the sunlight to a certain point, the device that would need to be heated will move with the mirror	It will be difficult to build the device that heats the water It makes the project more expensive
Solar Energy Production	Easy to build	It will be difficult to build the device that conserves the energy It makes the project more expensive There are already a lot of them on the market

The derived requirements of the SOSM are:

- it has to be able to track the Sun without sensors
- it has to reflect the sunlight to a certain point, defined by the consumer

Building a solar cooker or a water distiller would take a lot of time and it would be very challenging technically. Therefore, it has been decided to focus on the mirror itself, not the object heated/lighted up as creating a Sun tracking system is a challenge on its own and there is not either time or budget to focus on the additional features. The mirror will be for home-use. Whether to use it to bring more light to a room or garden or to heat something is the customer's choice. Therefore, the mirror can be used in several ways. The challenge will be to follow the Sun and reflect the radiation to one point.

3. PROJECT MANAGEMENT

3.1 INTRODUCTION

Project management is the application of knowledge, skills, tools and techniques to project activities to meet project requirements. Project management is accomplished through the use of the processes such as: initiating, planning, executing, controlling, and closing [31]. The project team manages the work of the projects, and the work typically involves:

- Competing demands for: scope, time, cost, risk, and quality.
- Stakeholders with differing needs and expectations.
- Identified requirements.

3.2 SCOPE

Project Scope Management includes the processes required to ensure that the project includes all the work required, and only the work required, to complete the project successfully. Scope Definition involves subdividing the major project deliverables into smaller components to [33]:

- Improve the accuracy of cost, duration, and resource estimates.
- Define a baseline for performance measurement and control.
- Facilitate clear responsibility assignments.

A precise scope definition determines the success of project. Otherwise, the final project costs may increase, due to project changes, which involves rework and increases project time.

A fundamental tool used for Scope Definition is the *Work Breakdown Structure* (WBS). A WBS is a deliverable-oriented grouping of project components that organises and defines the total scope of the project. Its' hierarchical form allows an easy identification of the final elements, also called work packages [34]. For this Self-Oriented Solar Mirror Project, the WBS is shown in **Fig.** 9.

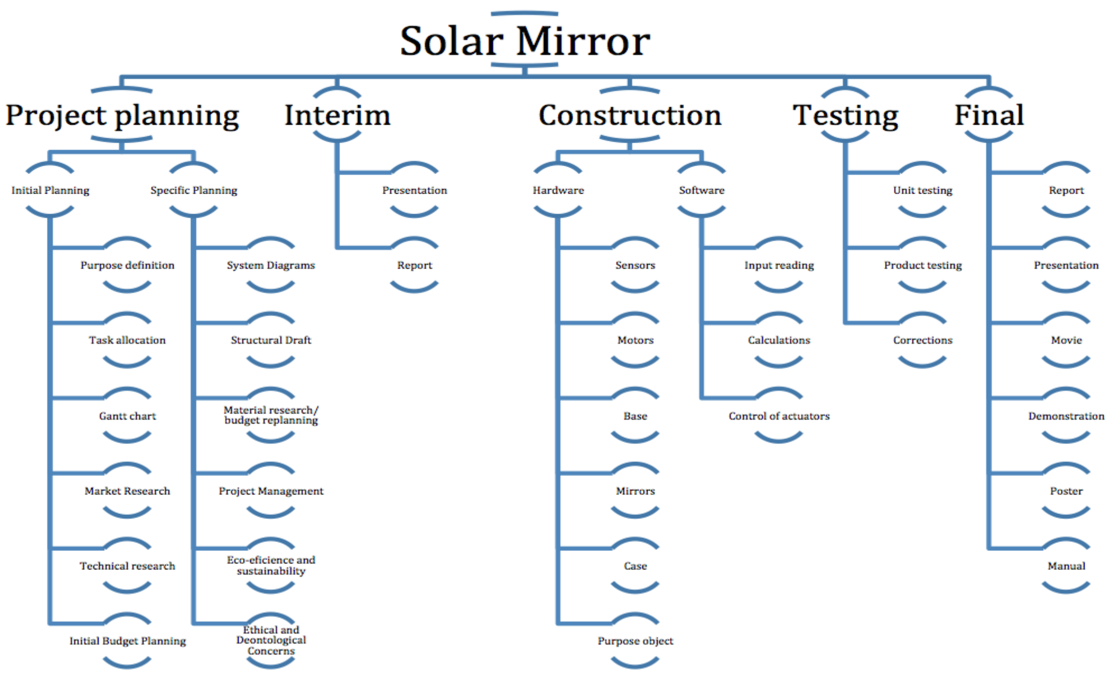


Figure 9: WBS

3.3 TIME

Project Time Management includes the processes required to ensure timely completion of the project [35]. These processes are described below:

- **Activity Definition**: This involves identifying and documenting the different activities to be carried out. In this way, it will be possible to produce the different deliverables identified in the WBS.
- **Activity Sequencing**: This involves identifying and documenting interactivity logical relationships. The mandatory dependencies are the most important; identify which activities are not possible to start unless other ones have finished, and vice versa.
- **Activity Duration Estimating**: This involves taking information on project scope and resources and then developing durations for input to schedules. At the beginning of the project, this may be a difficult task, unless the customer sets some deadlines for some of the work packages.
- **Schedule Development**: This means determining start and finish dates for project activities. This is directly related to the activity duration estimating.
- **Schedule Control**: This involves the detection of changes in the schedule and the management of these, in order to ensure that changes are agreed with the contractor.

In order to have this information in a simple and effective way, nowadays a tool called a Gantt Chart is used. Of all the information that can be obtained, the most important are:

- The duration of a given project, and each of the work packages.
- Knowing exactly the stage in which this is located.
- Identifying possible delays in lead times.
- The existing connections between the different activities.
- The different expected deadlines.

The Gantt Chart of the project described in this report is shown in **Fig.** 10 and **Fig.** 11. In **Fig.** 10, all the deliverables are displayed and how long it takes to realise every one of them. In **Fig.** 11, one will see the percentage of each of the team members time that was dedicated to these deliverables. As can be seen, the duration of the whole project had to take place between 02.03.17 to 29.06.17.

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Self-Oriented Solar mirror**	**86 days**	**Thu 02/03/17**	**Thu 29/06/17**
2	✓		**Initial planning**	**3 days**	**Thu 02/03/17**	**Mon 06/03/17**
3	✓		Task identification and allocation	1 day	Thu 02/03/17	Thu 02/03/17
4	✓		Gantt Chart	1 day	Fri 03/03/17	Fri 03/03/17
5	✓		Technical research	3 days	Thu 02/03/17	Mon 06/03/17
6	✓		Market research	3 days	Thu 02/03/17	Mon 06/03/17
7	✓		Initial budget planning	3 days	Thu 02/03/17	Mon 06/03/17
8	✓		Purpose definition	3 days	Thu 02/03/17	Mon 06/03/17
9	✓		**Specific planning**	**20 days**	**Tue 07/03/17**	**Mon 03/04/17**
10	✓		System diagrams	5 days	Tue 07/03/17	Mon 13/03/17
11	✓		Structural drafts	5 days	Tue 07/03/17	Mon 13/03/17
12	✓		Design	10 days	Tue 14/03/17	Mon 27/03/17
13	✓		List of materials and budget replanning	5 days	Tue 28/03/17	Mon 03/04/17
14	✓		**Interim**	**26 days**	**Tue 28/03/17**	**Tue 02/05/17**
15	✓		Project management	9 days	Tue 28/03/17	Fri 07/04/17
16	✓		Eco-effience measures for sustainability	9 days	Tue 28/03/17	Fri 07/04/17
17	✓		Ethical and deontological concerns	9 days	Tue 28/03/17	Fri 07/04/17
18	✓		Upload interim report and presentation	9 days	Tue 28/03/17	Fri 07/04/17
19	✓		Interim presentation	9 days	Mon 10/04/17	Thu 20/04/17
20	✓		Upload refined interim report	8 days	Fri 21/04/17	Tue 02/05/17
21	✓		Complete list of materials	2 days	Fri 21/04/17	Mon 24/04/17
22			**Construction**	**16 days**	**Wed 03/05/17**	**Wed 24/05/17**
23			**Construction hardware**	**16 days**	**Wed 03/05/17**	**Wed 24/05/17**
24			Construction 1st SubAssembly	14 days	Wed 03/05/17	Mon 22/05/17
25			Construction 2nd SubAssembly	14 days	Wed 03/05/17	Mon 22/05/17
26			Construction 3rd SubAssembly	14 days	Wed 03/05/17	Mon 22/05/17
27			Construction 4th SubAssembly	14 days	Wed 03/05/17	Mon 22/05/17
28			Final Assembly	2 days	Tue 23/05/17	Wed 24/05/17
29			**Construction software**	**16 days**	**Wed 03/05/17**	**Wed 24/05/17**
30			Planning and Scheduling	6 days	Wed 03/05/17	Wed 10/05/17
31			Setting up the environment	6 days	Wed 03/05/17	Wed 10/05/17
32			Implementing the code structure and the sun tracking algorithm	9 days	Wed 10/05/17	Mon 22/05/17
33			Hardware connection	2 days	Tue 23/05/17	Wed 24/05/17
34			**Testing**	**8 days**	**Thu 25/05/17**	**Mon 05/06/17**
35			Product testing and corrections	7 days	Thu 25/05/17	Fri 02/06/17
36			Upload funcional tests' results	1 day	Mon 05/06/17	Mon 05/06/17
37			**Final**	**18 days**	**Tue 06/06/17**	**Thu 29/06/17**
38			Upload the final report and presentation	9 days	Tue 06/06/17	Fri 16/06/17
39			Upload the movie, poster, manual and leaflet	9 days	Tue 06/06/17	Fri 16/06/17
40			Final presentation, individual discussion and assesment	4 days	Mon 19/06/17	Thu 22/06/17
41			Upload the Wiki with all correction suggestions	5 days	Mon 19/06/17	Fri 23/06/17
42			Hand in a CD with the corrected delirevables	1 day	Mon 26/06/17	Mon 26/06/17
43			Hand in one printed exemplar of the corrected report	1 day	Mon 26/06/17	Mon 26/06/17
44			Hand in the prototype and user manual to the client	1 day	Thu 29/06/17	Thu 29/06/17

Figure 10: Gantt Chart 1

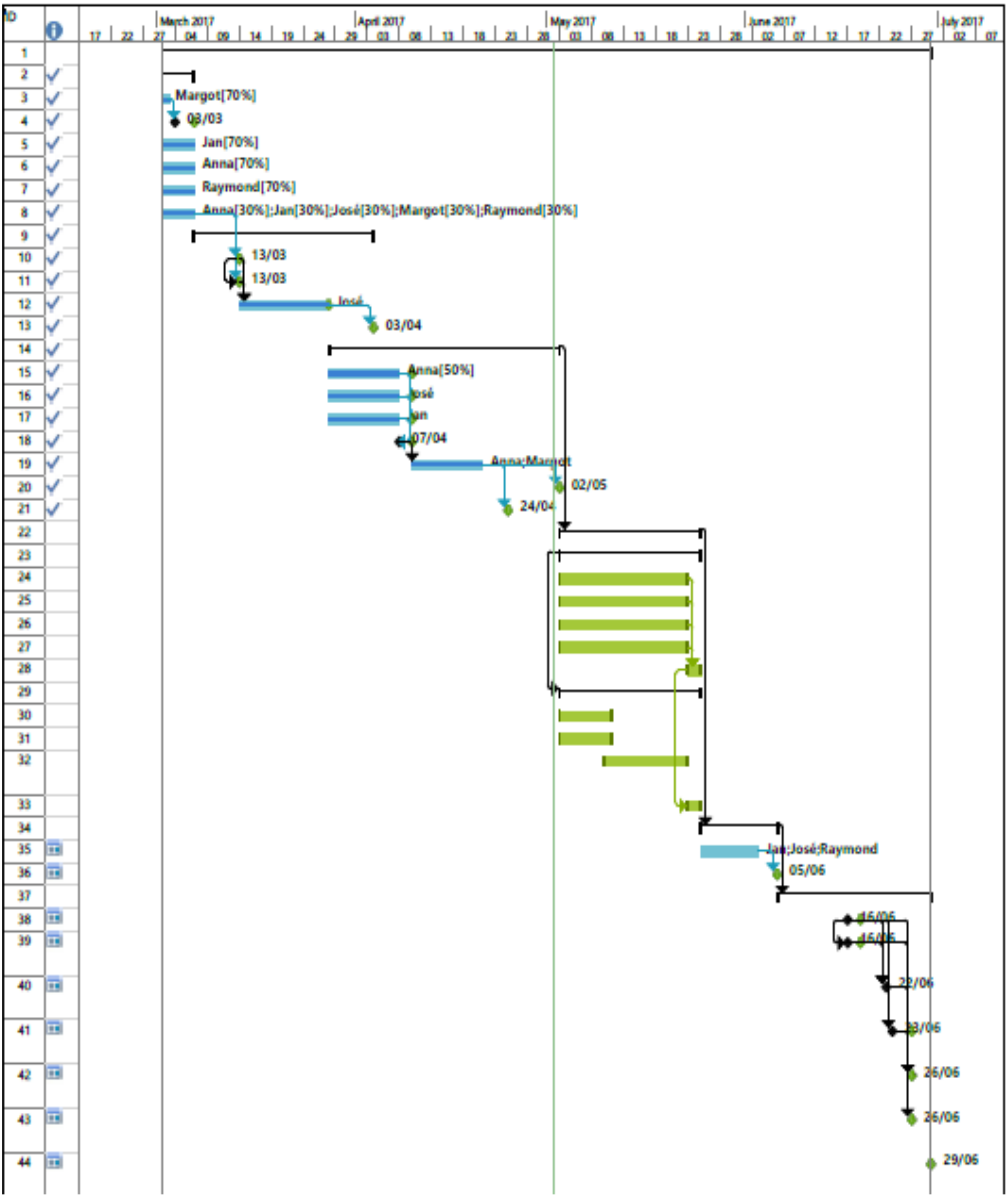


Figure 11: Gantt Chart 2

3.4 COST

Project Cost Management includes the processes required to ensure that the project is completed within the approved budget. These processes are described below [36]:

- **Resources Planning**: This involves determining what resources are required, and what quantity of each one, to complete all the project activities. There are three main types of resources [37]:
- **Human Resources**: It is important to determine the different human resources available and the assigned workload for each one. This assignment should be done based on the different work packages, and also the strengths and weaknesses of each of the human resources.
- **Capital**: The capital is essential to be able to carry out each of the different phases of the project. The same will be used to cover the salary of the different human resources, to launch the product to the market and for the different contingencies that may arise on the fly.
- **Material Goods**: Those assets, whether tangible or intangible, necessary for the achievement of the project.
- **Cost Estimating**: Cost estimates are quantitative assessments of the costs for each resource needed to perform the project activities.
- **Cost Budgeting**: This involves allocating the overall cost estimates to individual activities or work packages to establish a cost baseline. This cost baseline will be used to measure and control cost performance on the project.
- **Cost Control**: The cost control is important to detect the variances of the cost relative to the cost baseline. Only then, it is possible to correct or approve changes not included in the same.

Regarding the comment above, **Fig.** 12 **s**hows the different human resources available, as well as the total work hours and the baseline cost of the same ones. Besides, **Fig.** 13 shows the total cost of these resources, as well as the baseline cost. These estimates have been taken assuming a work resource price of 10.00 €/h.

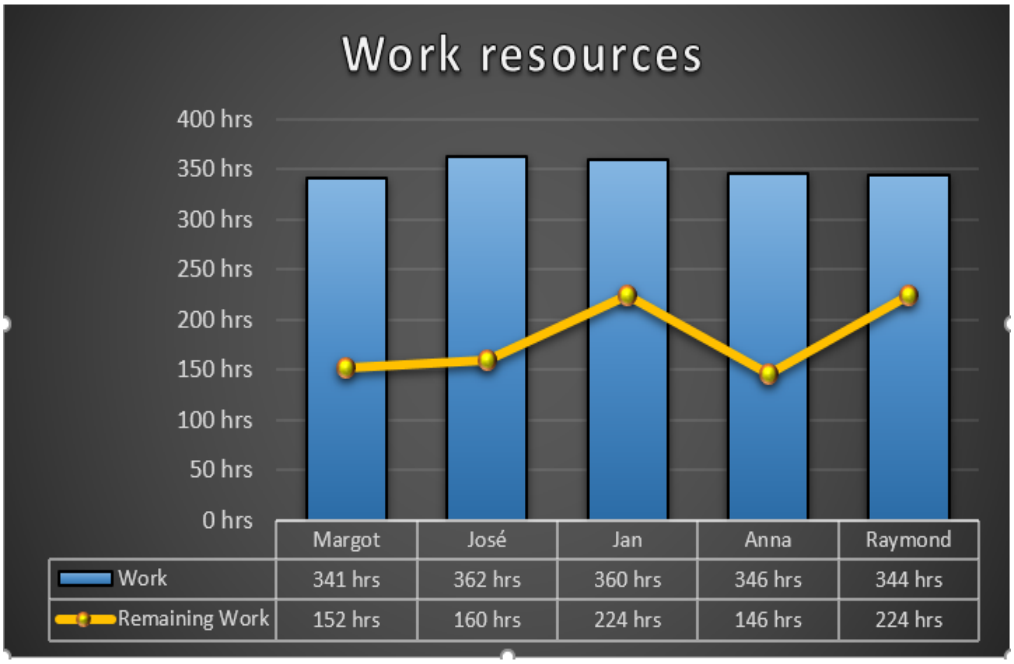


Figure 12: Work Resources

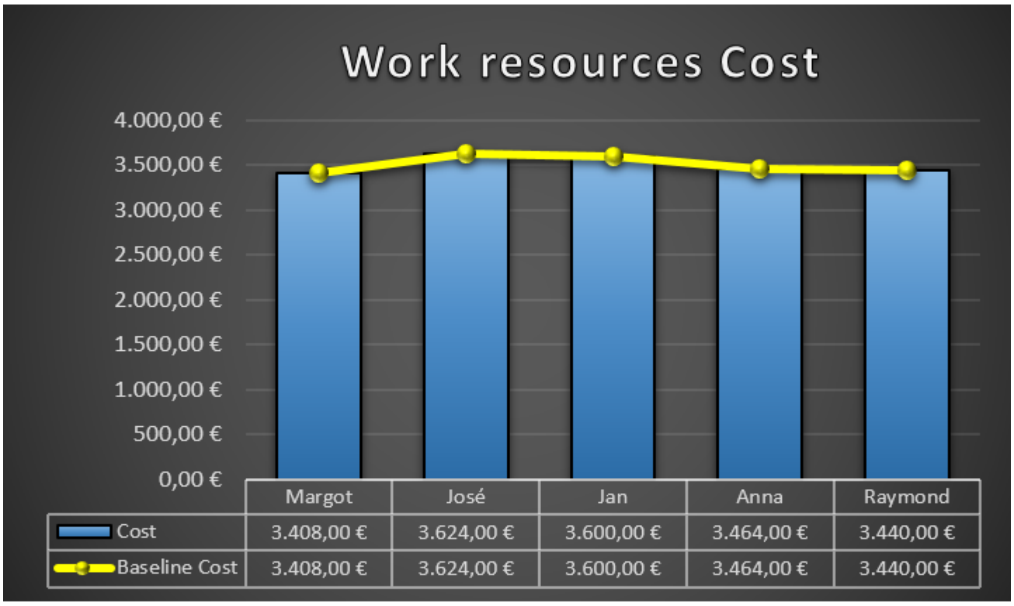


Figure 13: Work Resources Cost

A first approach, as shown in **Fig.** 14, has been made for the material resources needed for production of the prototype, since it is not known yet exactly what and how many of these are to be used. In this way, the cost baseline estimate can be made.

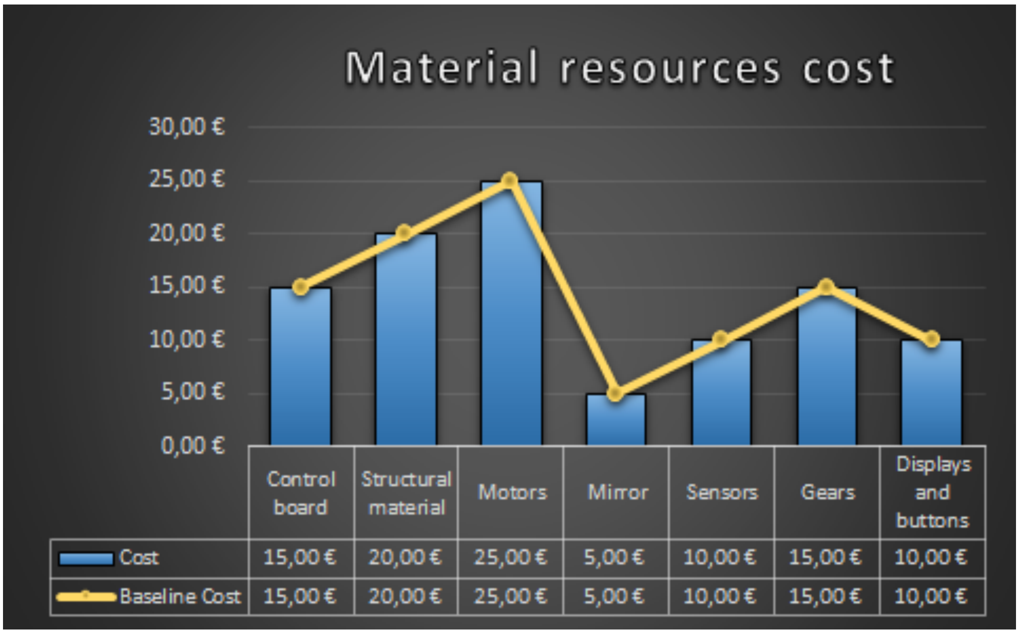


Figure 14: Material Resources Cost

As mentioned in section 1.5, it is mandatory to stay under the budget of 100.00 €, at least as far as manufacturing of the prototype is concerned. Nevertheless, looking for the best quality-price relation, the final product may be somewhat more expensive.

3.5 QUALITY

Quality means, at its most basic level, meeting the needs of customers. Project Quality Management includes the processes required to ensure that the project will satisfy the needs for which it was undertaken. There are three key quality management concepts to consider during the project execution [38]:

- **Customer Satisfaction**: It is important that the customer feels the product or service meets their needs, as well as meets them with the right quality. Otherwise, the customer will be unsatisfied. In order to avoid this inconvenience, it is necessary to consider the following two aspects:
    1. **Product Quality**: The product must be made of good quality materials, must be pleasing to the eye, and easy to assemble, disassemble and transport.
    2. **Service Quality**: Once the product has been sold, the consumer must be provided with all the necessary documentation to use the product. In addition, it will be necessary to provide an efficient after-sales service in case of operating problems.
- **Prevention Over Inspection**: The Cost of Quality includes money spent during the project to avoid failures, and the money spent after the project because of failures as well. These type of costs are shown in **Fig.** 15.

Cost of Conformance	Cost of Nonconformance
Prevention Costs • Training • Document Processes • Equipment • Time To Do It Right	**Internal Failure Costs** • Rework • Scrap
Appraisal Costs • Testing • Destructive Testing Loss • Inspections	**External Failure Costs** • Liabilities • Warranty Work • Lost Business

Figure 15: Cost of Quality Types

- **Continuous Improvement**: Continuous improvement is the ongoing effort to improve the product, in order to deliver the one deemed most convenient.

Those processes required to ensure the meeting of this quality need, are described below [40]:

- **Quality Planning**: This involves identifying which quality standards are relevant to the project and how to satisfy them.
- **Quality Assurance**: Evaluating overall project performance on a regular basis to provide confidence that the project will satisfy the relevant quality standards.
- **Quality Control**: This involves monitoring specific project results to determine if they comply with relevant quality standards, and identifying ways to eliminate causes of unsatisfactory results. For that, the supervisors' reviews and the testing explained section 7.6 are needed.

3.6 HUMAN RESOURCE

Project human resource management includes the processes required to make the most effective use of the people involved with the project. These processes are described below [40]:

- **Organizational Planning:** This involves identifying, documenting and assigning project roles (who does what) and responsibilities (who decides what). In order to assign both, a *Responsibility Assignment Matrix* (RAM) is widely used. The most typically used is called the *Responsible, Accountable, Consulted and Informed* (RACI) matrix. The description of each of the roles is as follows:

1. **Responsible (R)**: Individual(s) who complete the task.
2. **Accountable (A)**: Individual who is ultimately answerable for the activity or decision. Only one "A" can be assigned to an action.
3. **Consulted (C)**: Individual(s), typically subject matter experts, to be consulted prior to a final decision or action.
4. **Informed (I)**: Individual(s) who need to be informed after a decision or action is taken.
5. **Tester (T)**: Individual(s) testing the project, if everything is done right

Table 5 displays the RACI matrix for this project.

Table 5: RACI Matrix

Delivery	Anna	Jan	José	Margot	Raymond	Coordinator	Teacher	Supervisors
Gantt Chart			R		A	I	I	I
System Diagrams		A	R		A	I	I	C
Structural Drafts			R		A	I	I	C
System Schematics		R	A			I	I	C
Structural Drawings		R	A			I	I	C
Cardboard Scale Model			A		R	I	I	I
List of Materials		A			R	I	I	C
Interim Report	A			R		I	I	I
Interim Presentation	R			A		I	I	I
Structural Building		A	R		R	I	I	C
Software Building		R	A		A	I	I	C
Testing and Performance	T	R/T	T	T	T	I	I	C
Video		A			R	I	I	I
Paper	R			A		I	I	I
Poster	A			R		I	I	I
Manual	R			A		I	I	I
Leaflet	A			R		I	I	I
Final Report	R	A	A	A	A	I	I	I
Final Presentation	A	A	A	R	A	I	I	I

- **Acquire Project Team**: Processes of obtaining the human resources needed for completing the project.

  Due to the high number of participants in this project, the ISEP management team was responsible for selecting team members. For this, three factors were considered:

  - Nationality.
  - The field of specialty.
  - The role of each member.

  To determine the last one, a test called **Belbin Team Roles** was performed. This test goal is to bring the right people together, so that the teams are more likely to succeed and achieve their goals [41]. In total, there are nine different team roles, which descriptions of are shown in **Fig.** 16

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

Figure 16: Belbin Team Roles Description

Table 6 displays the results for each member of this group.

Table 6: Belbin Team Roles Results

Team member	Team role assigned	
Anna	Shaper	Team Worker
Jan	Plant	Team Worker
José	Completer finisher	
Margot	Plant	Team Worker
Raymond	Completer finisher	Team Worker

- **Team Development**: This includes both enhancing the ability of stakeholders to contribute as individuals as well as enhancing the ability of the team to function as a team. In order to enhance and promote this team development, different activities are carried out:

  1. **Team-Building Activities**: During the first two weeks of the project, different team-building activities were done, such as trust games, mascot building, etc. They were carried out to help the members to know each order and gain confidence.

  2. **Weekly Supervisor's Meeting**: Every Thursday, a meeting with the EPS supervisors is scheduled. Thereby, different concerns about project development and teamwork can be addressed.

3.7 COMMUNICATIONS

The main objective of communication management is to ensure that the communication between two people or a group goes smoothly [43].

The difficulty in the group is that every team member speaks another native language and everyone was raised in slightly different cultures. Also, the team members did not know each other before the beginning of the project, they have therefore never worked together and so do not know the other's strengths or weaknesses. A third problem or maybe an advantage can be that they have different backgrounds of education, so they might know a lot about some subjects but also some subjects can be totally new for them, when other team members take it for granted.

Taking these flaws and strengths into account, it is important the team members meet on a regular basis. Besides:

- The team members see each other every weekday at school and work on their part of the project.
- If they need help, they can always ask another team member to help them.
- They use a group conversation on WhatsApp to arrange those meetings.
- For bigger discussion, there is also a group made on Facebook to help them.
- The sharing of necessary documents is done through Google Drive, a file storage and synchronization service developed by Google.

If the problem cannot be solved within the group, the team members can always turn to their coordinator, Fernando Ferreira, this can be done by mail. Furthermore, there are also weekly meetings between the team members and all the supervisors of the EPS program. All questions can be asked here and also the project will be evaluated.

The things the team needs to communicate, from whom, are shown in **Table** 7.

Table 7: Communication Matrix

What?	Why?	Who?	When?	To whom?
Deliverables	Achieve the goal of the project	The team members	On the deadlines	The supervisors, teachers and the other team members
Team meetings	Plan how to deliver the deliverables	The team members	A few times a week	The team members
Meeting with coordinator	Get feedback on the project	The team members and the coordinator, Fernando Ferreira	Every two/three weeks	The team members and the coordinator
Meeting with supervisors	Get feedback on the project and discuss our ideas	The team members and the supervisors	Every Thursday morning	The team members and the supervisors

3.8 RISK

Table 8 shows some of the risks to the project's success. The team has discussed each risk and the action to be taken should one of the risks occur. The risks are ranked by assessing the impact on the project as well as the probability of the risk occurring.

Table 8: Project Risk Assessment

Description	Cause	Effect	Trigger	Response	Impact	Probability	Rank
Materials - Late/Unavailable	Supplier/Bureaucracy	Delay in Work Commencing	Information from Supplier/ISEP	Provide List of Materials Early	High	High	1
Design Error	Lack of Knowledge/Human Error	Product may not Work	Noticing the Error	Repair Error/Find Alternative Solution	High	Medium	2
Manufacturing error	Lack of Knowledge/Human Error	Product may not Work	Noticing the Error	Repair Error/Find Alternative Solution	High	Medium	2
Bugs in Software	Human Error	Product may Work Improperly	Noticing the Bug	Test Code Frequently/Correct the Bug	Low	Medium	5
Going Overbudget	Delivery Costs/Unexpected Costs/Poor Budgeting	Being Unable to Purchase all Required Materials/ Justification of Additional Costs	Having Spent a lot of Money	Minimising Costs/Contingency Fund/Presenting Justification for Additional Costs	High	Medium	2
Missing Deadlines	Poor Project Management/Unforeseen Circumstances	Project Failure	Not Having the Work Done Close to the Deadline	Monitoring Deadlines/Setting our own Earlier Deadlines	High	Medium	2
Illness	Bacteria/Virus	Reduction in Working Hours	Beginning to Feel Ill	Living Healthily/Visiting a Doctor	Medium	Medium	3
Lateness	Public Transport/Other	Delay in Work Commencing	Looking at Watch/Travel Updates	Updating the Team	Low	High	4
Resources - Lab Unavailability/Tool Failure	Scheduling/Maintenance	Rescheduling Required	Information from ISEP	Good Organisation/Alternative use of Time	Medium	Low	5

3.9 PROCUREMENT

Procurement is the act of obtaining or buying goods or services. It contains also the management of this process, so the preparation and the processing of these goods and services [45].

In this project, there is a budget of 100.00 €, the aim is to stay within it. Regarding the actions that can be carried out for this purpose, are:

- Look at the different suppliers and at their quality-price ratio.
- Try to work as much as possible with the materials that are already at their disposal.
- Communicate with the other EPS teams, see which materials they need. Often it is cheaper to buy materials in large quantities, if they work together well and choose the same materials, it could have an effect on the final price.
- To reduce costs mainly local suppliers will be utilised; this is done to minimalize the shipping costs.

3.10 STAKEHOLDERS MANAGEMENT

Within stakeholders' management, the team members are going to try to analyse, plan and execute the actions to engage with stakeholders [46].

First of all, it is necessary to identify the stakeholders. Stakeholders are individuals or companies that are interested in this project, they are directly or indirectly involved in this project. Second of all, their interests and influences are going to be assessed. Departing from this a communication management plan has to be developed (see section 3.7). Lastly it is the intention to engage and influence the stakeholders.

Table 10 shows the stakeholders for this project.

Table 9: Stakeholders

Stakeholders	Role	Expectation	Power	Interest
Team Members	Execute the project	Develop the project, expand knowledge	High	High
Team Supervisor	Supervise the project	Help the project succeed	High	High
EPS Coordinators	Evaluating project and helping	Help the project succeed	High	High
Teachers	Expand the team members' knowledge and evaluate the project	Help the project succeed and expanding our knowledge	High	High
Suppliers	Providing materials	Selling materials	High	Low
ISEP	Sponsor	Developing interesting projects	High	Low

3.11 CONCLUSION

As can be seen, project management not only focuses on time control to ensure the project is completed within the established time frame. In addition, it is important to:

- Define accurately the resources, whether human or material, necessary to carry out the project.
- To carry out an exhaustive control of the expenses that derive from the project, in order to avoid incurring unnecessary expenses.
- Have well defined, the quality requirements that the product must meet.
- Identify all those situations that pose a risk to the successful completion of the project.

Taking into account all these aspects, and implementing the tools available for this, it can be ensured that the project can be carried out with the maximum rigor and minimum risks.

4. MARKETING PLAN

4.1 INTRODUCTION

Many organisations are becoming more and more customer-centric. For most marketing teams the experiences of the customers are a priority. The goal of marketing is to improve the performance of an organisation by responding to the needs of these customers or let the customers think they need the things that the organisation is selling. In this chapter, the marketing plan for the Self-Oriented Solar Mirror (SOSM) can be found. The marketing plan consists of a Market analysis including the micro and macro-environment; a *Strengths, Weaknesses, Opportunities And Threats* (SWOT) analysis; the Strategic objectives including the *Specific, Measurable, Attainable, Relevant and Time based* (SMART) principal; Market Segmentations; Positioning strategy; Adapted Marketing-mix as a 4P model; a Budget and a Strategy control.

4.2 MARKET ANALYSIS

Every business organisation is a part of the business environment within which it operates. No entity can function in isolation because there are many factors that closely or distantly surround the business. It is broadly classified into two categories (see **Fig.** 17) [47]:

- **Micro environment**: Affects the working of a particular business only, to which they relate to, it has a direct impact on the business activities.
- **Macro environment**: Affects the functioning of all the business entities, operating in the economy. It is a general business environment, which influences all business groups.

Figure 17: Micro and Macro Environment

4.2.1 MICRO ENVIRONMENT

Micro environment refers to the environment which is in direct contact with the business organisation and can affect the business directly [48]. It is a collection of all the forces that are close to the firm. They can influence the performance and day to day operations of the company, but for a short term only. Its' elements include suppliers, competitors, intermediaries, customers and the public. The firm itself is an aggregate of a number of elements like owners, shareholders or investors, employees and the board of directors.

Suppliers

Suppliers are defined as the ones who provide inputs to the business like raw material, equipment and so on. They can control the success of a business when they hold the power. For example, if some materials are needed and there is only one supplier for the specific material [49].

The SOSM contains a lot of electrical components like a real-time clock, controller, stepper motors, power supply and also building materials. All of these products can be bought here in Portugal. To choose the providers more research had to be done.

Competitors

Competitors are defined as the rivals, which compete with the firm in the market and for resources. The competitors are those who sell the same or similar products and services as SUNO, and the way they sell their product needs to be taken into account. New ideas have to be invented to have to get ahead of SUNO's competitors [50].

One of the competitors of SUNO is “Wikoda” which provide sunflowers to get more light into a home. This sunflower however is more expensive than SUNO's product. Our product provides the consumer a more natural lightning than the lightning industry.

Intermediaries

Marketing intermediaries may include wholesalers, distributors, and retailers and are defined as those that make a link between the firm and the customers [51]. SUNO would be mainly sold business to consumer (B2C) but can also be sold business to business (B2B). Customers and businesses can buy the SOSM immediately from SUNO's website.

Customers

Customers/Consumers are defined as the ones who purchase the goods for their own consumption. They are considered as the king of business. The customers depends on whether the business relations are Business-to-Business (B2B) or Business to Consumer (B2C) and what their reasons for buying the product are. Depending on the business relation and the reason, the approach at marketing has to be changed [52].

SUNO's customers as already stated will mainly be* consumers but also businesses. Consumers will use it for home use in their gardens or on their terraces probably to light up a room. Businesses on the other hand will probably use for energy purposes in their manufacturing, but can also use it for lighting in their offices.

Public

SUNO has a duty to satisfy the public and all the actions must be considered from the angle of the public and how they are affected. The public can either help reach the goals or prevent the company from achieving them [53]. The SOSM is presented as a green product, it is a way to create green energy by using the sun. Therefore, SUNO is making sure that the manufacturing and materials that are used are eco-friendly.

4.2.2 MACRO ENVIRONMENT

The definition of a Macro environment is the environment within the economy that influences the working, performance, decision-making and strategy of all business groups at the same time. It constitutes forces that are not under the control of the company but have a powerful impact on it. The study of Macro environment is known as Political, Economic, Social, Technological, Legal And Environmental (PESTLE) Analysis [54] [55].

Political/ Legal

The political and legal factor depends on the stability of the political environment and the attitudes of political parties or movements, government influence on tax policies or involvement in trading agreements. The political factors go hand in hand with the legal factors such as national employment laws, international trade regulations and restrictions, monopolies, mergers´ rules, and consumer protection. The difference between these two are that the political factors refer to attitudes and approaches whereas the legal factors are those which have become law and regulations and need to be complied with [56].

Many political parties support the production of green energy. The clean energy industry generates hundreds of billions in economic activity, and is expected to continue to grow rapidly in the coming years. There is tremendous economic opportunity for the countries that invent, manufacture and export clean energy technologies. [57]

Economic Factors

The economic environment can impact both the organisation's production and the consumer's decision-making process. It varies from one country to another. For the SOSM these economic factors may include economic growth rates, levels of employment and unemployment, costs of raw materials such as energy, petrol and steel, interest rates and monetary policies, exchange rates and inflation rates [58] [59].

The SOSM is also presented as a way to lower the energy bill. Therefore, the SOSM should cost less than the costs of the energy that the consumer gains by using the SOSM. To make sure this happens, the SOSM should be sustainable, it has to have a long lifespan and also shouldn't be too expensive.

Social

How a company's product impacts society must be considered, any elements that are harmful to society should be eliminated to show that the company is taking social responsibility. But the social factors also represent the culture of the society, that may include demographics, age distribution, population growth rates, level of education, distribution of wealth and social classes, living conditions and lifestyle [60] [61]. But also, social media is becoming more and more important these days.

SUNO will use social media as the main way to introduce the SOSM to the market. First of all, a website will be made, this will be distributed by social media like Facebook, google, etc. Next SUNO will place advertisements in newspapers, but also distribute flyers at local electronic stores and hang up posters there. Other social trends, like living eco-friendly and helping the environment will also help sell the SOSM.

Technological Factors

Skills and knowledge have to be considered in the production and the technology such as new inventions and development, changes in information and mobile technology, changes in Internet and e-commerce or even mobile commerce and government spending on research. The technological environment should also include materials needed for production of products and services, materials development and new methods of manufacturing, distribution and logistics [62] [63].

The technological factor is focused on the change in the use of technology. The solar mirror that SUNO is going to provide is self-oriented, so orientation will be automatically after the device is set up. SUNO will also keep in mind how they can in the future improve their product and keep up with the newest technologies.

Environmental

Country, age, ethnicity, level of education, culture and so on have a huge impact on the environmental issues but also the Earth's renewal of its natural resources and the natural non-renewable resources. It can also include issues such as limited natural resources, waste disposal and recycling procedures [64] [65].

The SOSM will use only recyclable materials and will optimize the reuse of the different parts of the product. The customer can always contact the company if something is not working. If one of the parts breaks, the customer can always buy new parts and even get a discount when they turn the old ones in. That way SUNO avoids having to replace the entire product and is making sure that the old parts are used in a proper way. SUNO can choose to refurbish the broken parts or recycle them properly.

4.3 SWOT ANALYSIS

SWOT analysis is an enterprise financial planning tool which attempts to find strengths, weaknesses, opportunities and threats in a strategic review. SWOT analysis maps the external and internal factors relating to the situation being analysed and whether or not the properties are good or harmful (see **Fig.** 18).

- **Strengths:** All of us have different knowledge and personalities and we all have different skills so we can help each other. We also have a panel of supervisors that provide us with feedback and help.
- **Weaknesses:** We all have different personalities which can make it harder to cooperate, even harder when we don't speak the same language. The language difficulties can also make it hard to communicate and mistakes also happen more easily. Our lack of knowledge can of course be a big problem.
- **Opportunities:** Nowadays people are more aware of the environmental problems and want to be more sustainable, it is very popular to think ecologically.
- **Threats:** There are already some products on the market, so we need to make our product different from our competitors as described in section 4.2.1. We didn't have a clear purpose for the project which makes it harder to find a market group and of course the limited budget of 100.00 € makes it harder again.

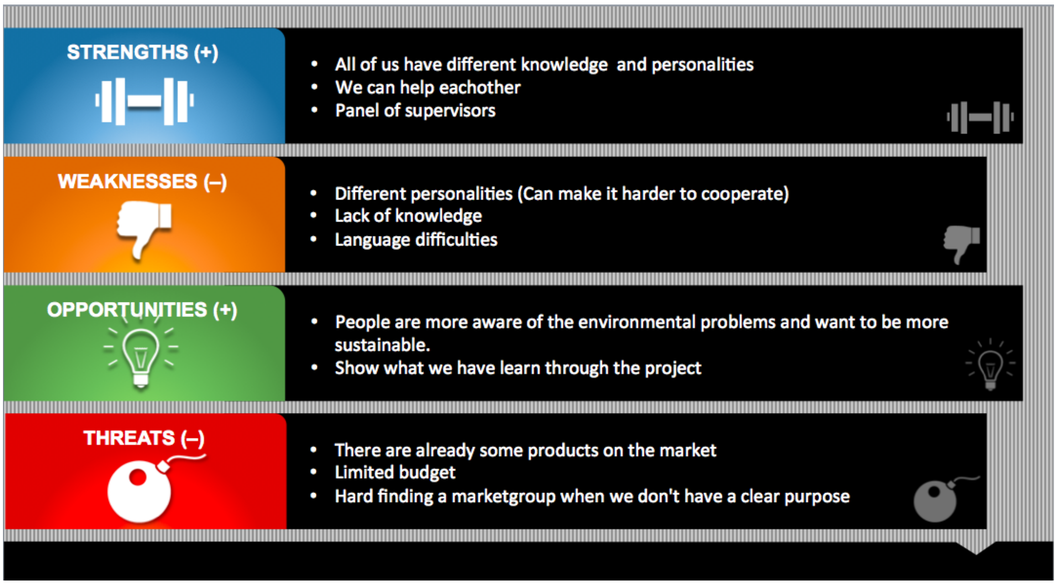


Figure 18: SWOT Analysis

4.4 STRATEGIC OBJECTIVES

When starting a company, it is first of all very important to know where the company is headed, in other words, to have a goal. These goals are mostly based on the SMART principal, the goal needs to be ***S**pecific, **M**easurable, **A**ttainable, **R**elevant and **T**ime* based [66].

For SUNO, next goals taken could be:

- Decrease expenses over the next 5 years by a certain percentage.
- Develop and use a customer database.
- Find cheaper and more sustainable resources.
- Ameliorate the solar mirror: make it more robust and more effective.
- Introduce the product outside of Europe.

4.5 SEGMENTATION

To get a clear image of the market for this project, the market is going to be divided into segments, these are homogenous groups. There are four market segmentation bases, the geographic, demographic, psychographic and behavioural segment. Each of those segments have to include the points that are shown in **Fig.** 19.

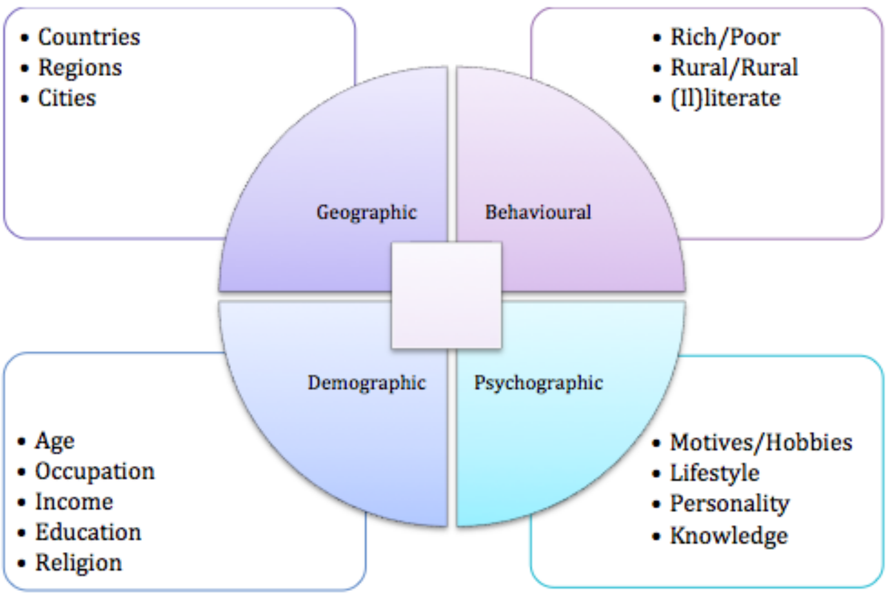


Figure 19: Market Segmentation

- **Geographic Segmentation**: Because SUNO is just starting, the geographic market target will be Portugal. After it grows bigger, SUNO could start expanding first to Spain, then to the rest of Europe and even outside. As it provides more solar energy, there are no countries where SUNO could not expand too. Developing countries could use it easily to cook or to heat water, Probably charity organisations will be the main target in those countries.
- **Demographic Segmentation**: For the demographic segmentation, the target group will be people who are moving out of their parents' homes and are possibly starting with a family of their own. Also, people who already have had their homes for a long time and are looking for a greener lifestyle or also just searching to save money. People with low income will probably not be able to buy it. The SOSM has a goal to provide

more energy for people that already have solar cells, so people with lower income will probably try to lower their energy consumption first before buying this product. The market target will have the following characteristics:

- Age: 30-70.
- Income: medium to high.
- Education: Higher Education.
- Religion/Nationality: All.

- **Psychographic Segmentation**: For the psychographic segmentation, the main target is people who care about the environment, but also people who want to save money on energy. People with a green or economical lifestyle will be the main target. A higher social class, people who have had a better education and have higher income, like already said in the demographic segmentation, will be more likely to buy this product.
- **Behavioural Segmentation**: Lastly there is the behavioural segmentation, how peoples' behaviour will influence the buying this product. The SOSM is an expensive device and not many people will buy it out of impulse. They will probably discuss it before buying it with their partner.

4.6 STRATEGY/POSITIONING

here are three steps (see Fig. 20) that have to be considered when choosing a positioning strategy [67]:

Figure 20: Positioning Strategy

SUNO have a few different competitors, companies that are producing solar mirrors and companies that are making lighting devices. Compared to the competitors on solar mirrors SUNO is going to focus on making the product cheaper but also on making it for a more general purpose. Looking at the lightning industry, SUNO will propose this product as a product that saves energy. In the long-term, the product will pay for itself.

The perceptual map (see Fig. 19) shows the connection between the price and the purpose of the product, specific or general. When we bring our product to the market it is important to know where we stand regarding these two values. All of the existing products that we have compared to have a more specific purpose and regarding price our product is cheaper compared to Wikoda (sunflower) but more expensive than the lighting devices.

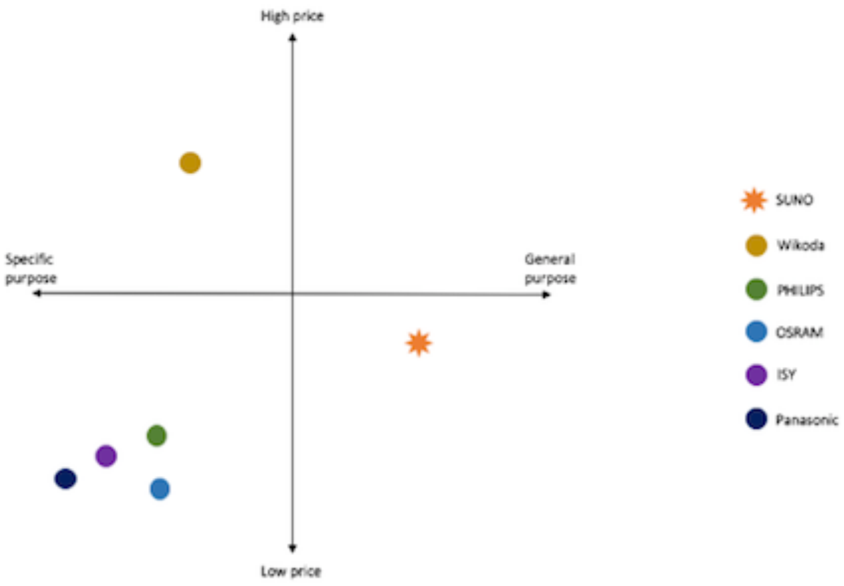


Figure 19: Perceptual Map

SUNO has some options on places where it can sell this product, one of them is online and this is also where the competitors of the SOSM are selling their product, but it can also been sold in electronic stores or garden stores.

4.7 ADAPTED MARKETING-MIX

In **Fig.** 20 an adapted marketing mix for SUNO can be seen, a 4P model: *Product, Price, Promotion and Place*. The model is used to show SUNO's positioning in the market.

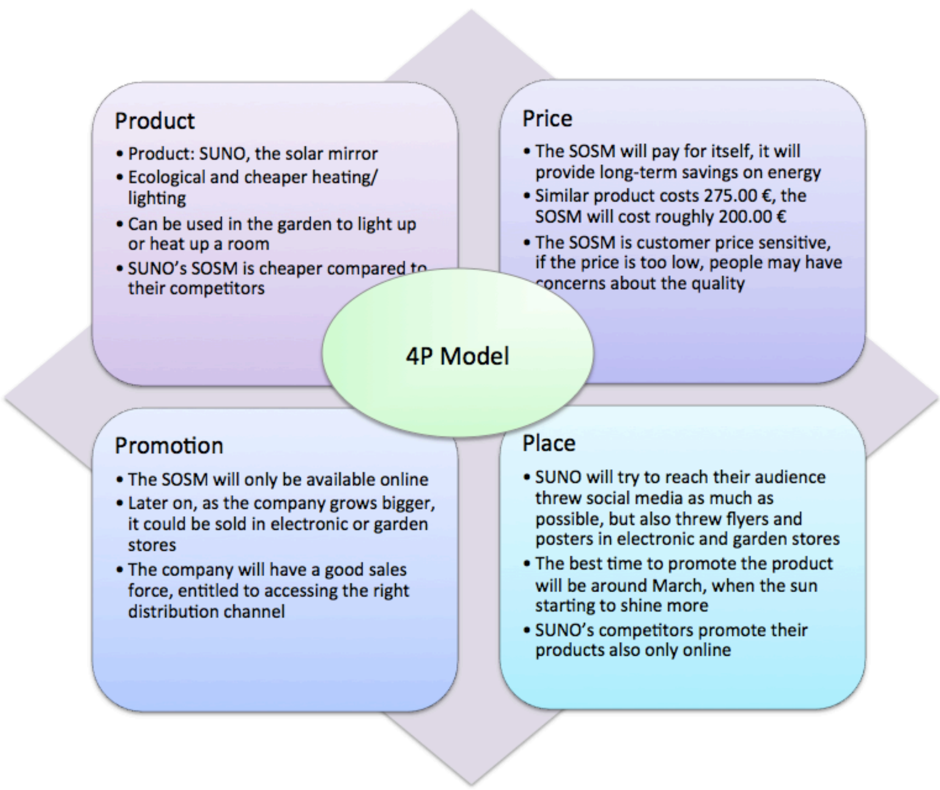


Figure 20: 4P Marketing Mix

4.7.1 PRODUCT

Figure 21: Logo

The product is a SOSM, the company and also the product are called SUNO (**Fig.** 21), which means Sun in Esperanto. The SOSM will help to get more ecological and cheaper heating/ lighting so the customer can save on both energy and unnecessary costs. The product can be used in the garden to light up a room or save energy by putting it near a solar panel.

The solar mirror is a simple way to harness solar energy and to transform it into energy that can be used daily. Raw materials are overused and new sources of energy are needed. The goal of this project was to develop a Self-Oriented Solar Mirror (SOSM). The mirror must track the movement of the Sun and reflect the sunlight onto a predefined area. Without a defined purpose for the mirror it was initially difficult to know the target market and how to proceed with the project. The creation of the sun tracking system was one of the main challenges for SUNO. The SOSM had to detect the Sun by itself with the aid of sensors or with software that knows the path of the Sun. The consumer will need to do a setup in the beginning defining where the mirror should be focused.

There are already some solar mirrors established in the market, nevertheless most of them are very expensive, and SUNO is going to ensure to make a cheaper product.

4.7.2 PRICE

Before SUNO sets a price on our product the Team need to check prices on existing market products and compare them with SUNO. SUNO can see that similar products cost around 275.00 €, and this product will cost around 200.00 €, but it is necessary to be careful because the product is very customer price sensitive, if the price is too low people may have concerns about the quality.

The product will pay for itself and it will provide long-term savings on energy. The customer should be able to pay for the product with PayPal, debit/ credit card etc.

4.7.3 PLACE

Before SUNO begin the selling, SUNO has to think about who they want to sell their product to, there were two main options, business to business (B2B) or business to consumer (B2C). If SUNO decides to sell their product directly to the consumers their main business market will be online on their own website, and this is where the customers will look for their product. SUNO could also decide to sell the SOSM directly to a business for example an electronic store or a garden store.

SUNO can make good use of a sales force of people that know the language and that have the right contacts that can help them to access the right distribution channels.

4.7.4 PROMOTION

The cheapest way for SUNO to promote their product is on social media, such as Facebook and Instagram, but social media is also good way to reach customers of all ages. Another good way to reach customers is by handing out flyers. The competitors of SUNO have only promoted their product on social media.

The best time for SUNO to start promoting their product would be around March. This is because the Sun is coming out more and more and people will think more of using solar energy. But also in the winter it will not be bad to promote our product as people will also look for solutions to get more warm water into their homes.

4.8 BUDGET

It is important to set a budget aside for marketing. People have to know that our product exists. SUNO has a budget of 5000.00 €, and want to put most of this into online advertising. SUNO has to have a good website, that appeals to people, for this purpose a budget of 1200.00 € is foreseen. The link to the website, SUNO wants to share on Google and Facebook. At social events SUNO wants to hang posters and distribute leaflets to people. The budget allocation is shown in **Table 10**.

Table 10: Budget Allocation

Action	**Budget**
Website	1200.00 €
Advertisements on Google	1000.00 €
Advertisement on Facebook	1000.00 €
Advertising in Newspapers	800.00 €
Poster	500.00 €
Leaflets	500.00 €
Total	5000.00 €

4.9 STRATEGY CONTROL

When executing a marketing plan, it is important to have a controlling unit. Marketing control is the process of monitoring the marketing plan and adjusting where necessary. If the marketing plan is being adjusted, an investigation has to be done to establish why this adjustment occurred. To perform a marketing control the steps in **Fig.** 25 have to be taken [68].

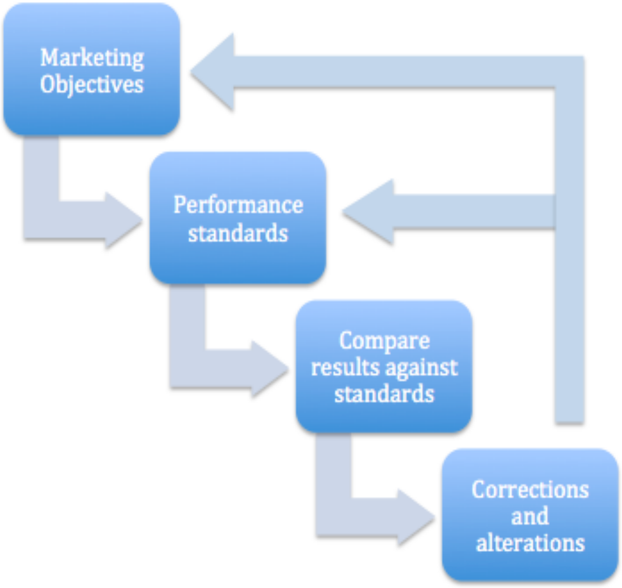


Figure 22: Process Marketing Control

4.10 CONCLUSION

SUNO have now explained the differences between micro and macro marketing and made a SWOT analysis where they set the company strengths, weaknesses, opportunities and threats. SUNO have set the SMART goals for their product and one of the goals is to decrease expenses over the next 5 years by a certain percentage. SUNO have adapted a marketing mix and a 4P model, where they explained the product, price, place and promotion of their company and our team have decided that the smartest way for them to promote their product is on social media.

5. ECO-EFFICIENCY MEASURES FOR SUSTAINABILITY

5.1 INTRODUCTION

Life on earth will be wiped out eventually - the question is how long will it take – human actions have a huge impact on this. It is human's task to cherish nature and be economic with all the raw materials the earth provides, but this has not been the case. Over the past century global warming has increased by 0.60 °C, and an even bigger increase is predicted [69]. Interest in "Eco-efficiency measurements and Sustainability" are starting to grow. There is the will to create a world where we can meet the needs of the present without compromising the ability of the future [70].

There are three main goals in sustainability, called the "Triple P" or the "Triple Bottom-line". The three P's stand for:

- **People**, the social development, this contains the well-being, health, safety, freedom of choice, … of a person.
- **Planet**, the environmental development, the conservation of the world, energy, water, materials, …
- **Profit**, the economic development, this includes prosperity, the gain, affordability and honesty.
- Some add a fourth P, **Politics**.

These 3 points are shown in **Fig.** 23.

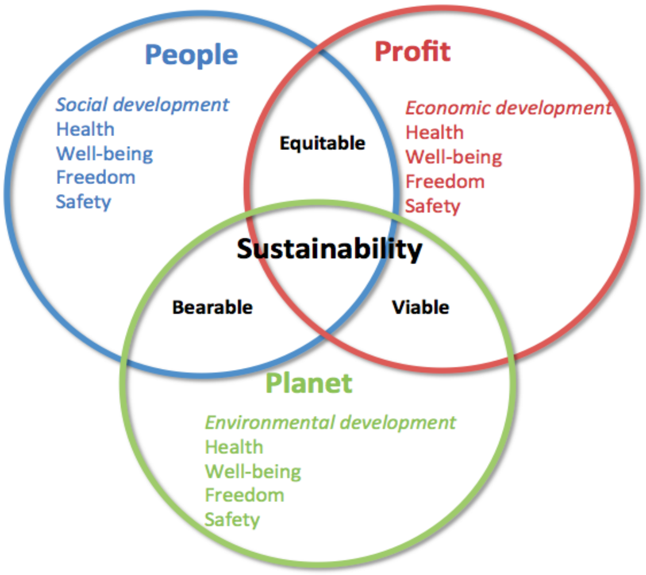


Figure 23: Triple P

5.2 ENVIRONMENTAL

Environmental impact is maybe one of the most disputed factors in society. This is probably one of the main reasons that when people think about sustainability, they immediately think of the environment. The environmental development, mentioned here, contains the right use of materials. The goal is, as already mentioned, to meet the needs of the people without harming the ability of the future. To make a product environmentally sustainable, three things have to be done:

- The rate of intake of renewable resources should be lower than the rate of reproduction.
- The rate of pollution should be lower than the assimilative capacity of the environment (the ability of the environment to clean itself).
- The reduction of non-renewable resources requires a comparable development of renewable substitutes.

5.2.1 CHOICE OF MATERIALS

When materials are being chosen, the environmental impact has to be taken into account. Materials have to be renewable at a certain rate; non-renewable resources have to be avoided at all times.

The materials that are going to be used are:

- **Polyvinyl Chloride (PVC)**.
- **Medium Density Fireboard (MDF)**.
- **Steel**.
- **Aluminium**.
- **Pine tree**.

PVC was considered for this project. PVC is a synthetically derived material derived from oil and salt, which are not good substances for the environment. In reality, people should stop using oil for everything, our resources are becoming depleted. PVC is also not particularly biodegradable, and recycling is not always easy because most of the time additives are added. Also, a lot of hazardous organochlorine by-products are formed with the production of chlorine gas [71]. Although PVC has disadvantages its' ecological footprint is far less than other substances like steel and glass used for the same application, because PVC is made out of 57% Chloride, which is derived from salt, of which we have plenty. In this way, PVC contributes to oil and gas savings, because a lot of materials depend entirely on oil and gas. See the graphics in **Fig.** 24 [72]. PVC also has a longer lifespan than most other plastics.

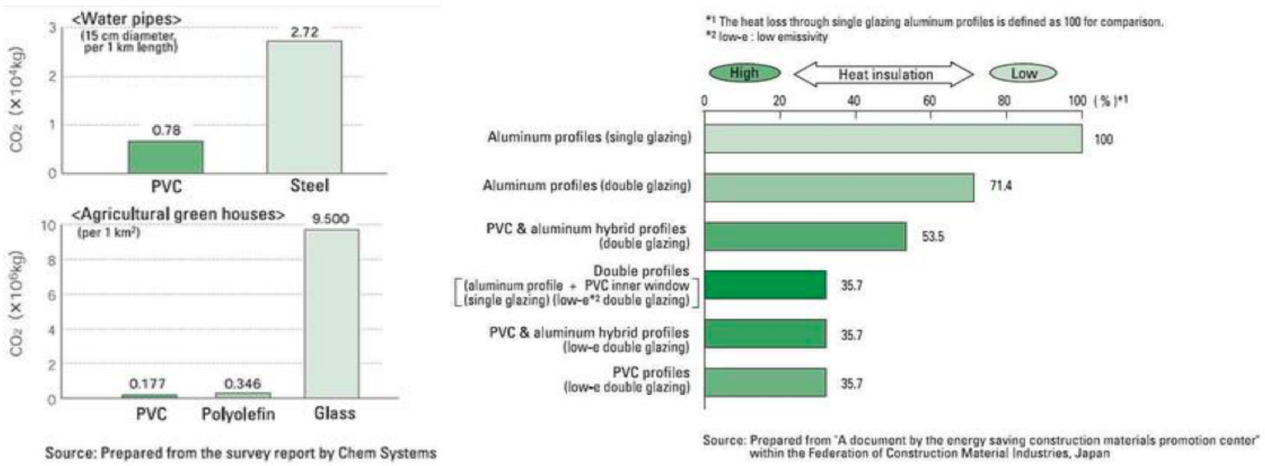


Figure 24: Ecological Footprint PVC, Steel, Glass, Aluminium [71]

MDF is a wood panel product made up of wood fibres (mostly from a pine tree) that have been bound together by heat, pressure and resin binders. The binders are often made from formaldehyde, a known carcinogen. Although it has recently been discovered that lignin (a naturally occurring substance found in plants) can be used as a binder, most companies still use formaldehyde. MDF is completely recyclable, although the recycling process is new and the recycling locations are not always close by [74].

Next, it has been decided that **Steel** will be used. One of the major advantages of this is that it can be used infinitely. Steel is a material that people use, not consume. It will never lose value, never lose its properties. Therefore, steel is the most recycled material on earth. It could be said that the non-renewable resources used to produce steel are not totally lost, because it can be used forever and should not be made again [75]. Although this may seem like an ecological solution, timber still remains the best solution. It is a renewable resource and it is bio-degradable. The carbon footprint of these two materials are shown in **Fig.** 25.

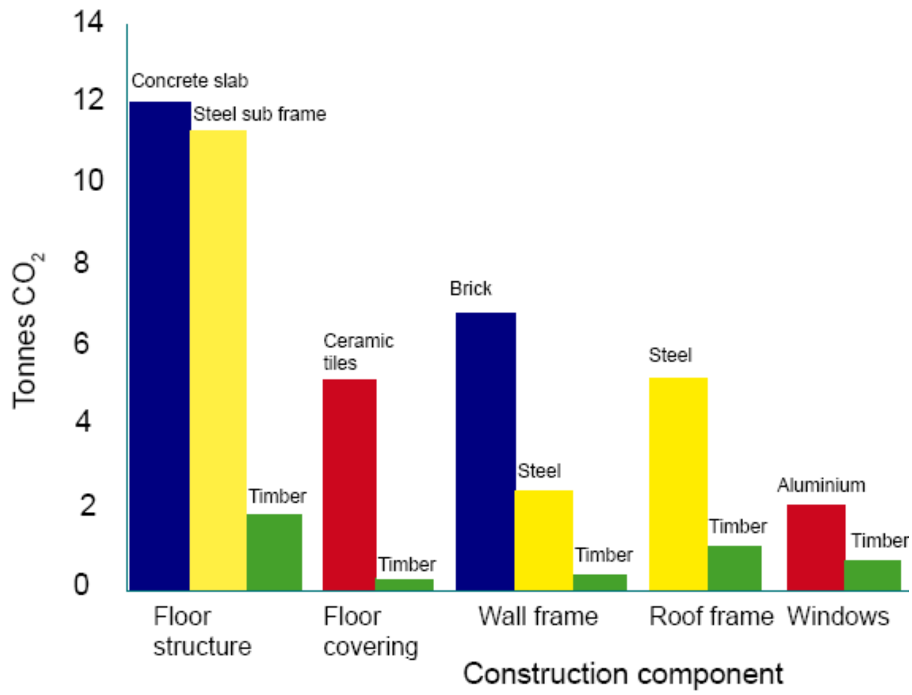


Figure 25: Carbon Footprint of Steel and Timber [74]

The SOSM is also going to consist of **aluminium**. Aluminium has similar properties to steel, as it can be used and recycled infinitely. Aluminium has one problem too, when it is produced with virgin sources it has an enormous ecological footprint. Nevertheless, when recycled sources are used the impact is far less, as shown in **Fig.** 26.

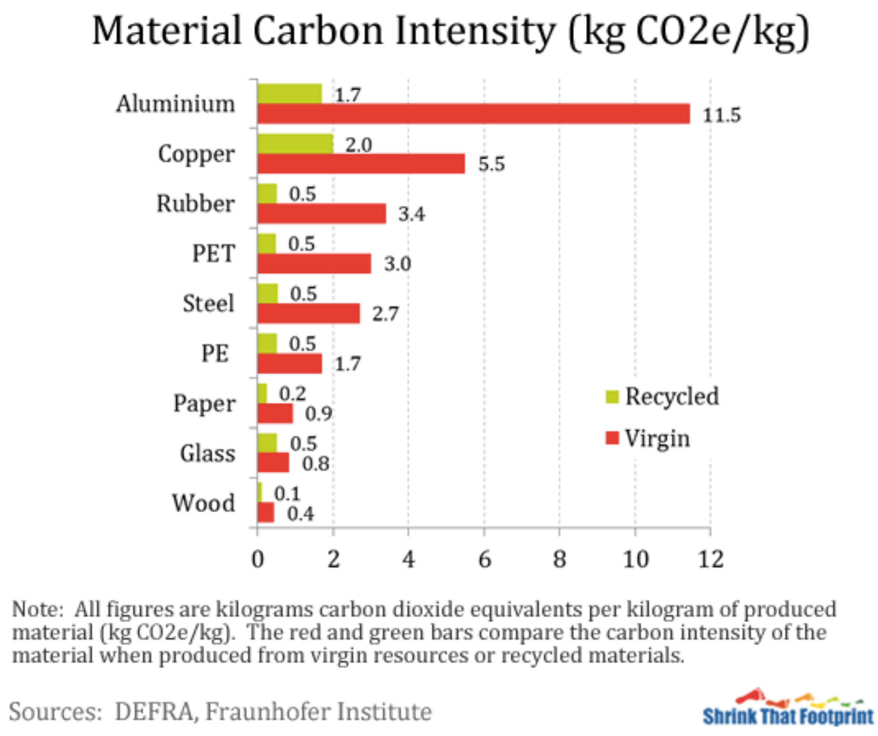


Figure 26: Virgin and Recycled Carbon Footprint of Aluminium in Comparison with Substitutes

As shown above, wood is the most sustainable substitute by far. Therefore, it is going to be used for many structural parts. As SUNO is an electrical device and the device will be outside, it must be robust against weather changes, not everything can be made out of wood unfortunately. PVC without any additives will also be searched for.

5.2.2 POLLUTION CONTROL

As there is a small budget to work with, it is not possible to work with solar cells, therefore is necessary to connect SUNO to the mains electricity supply. If the SOSM can be manufactured on a larger scale, it is possible to make it run on solar energy because the device will always follow the Sun, which will lead to a higher energy gain. Also, when there is no Sun, the solar mirror has no use, this means that energy will not be needed. In the manufacturing it would be best to use as much as green energy as possible.

5.3 ECONOMICAL

Economic development strategies will be made to optimize the use of existing resources. Everyone knows that sustainable business practices are necessary these days. Even people, whose main concern is business, are aware that the business depends on the resources of healthy ecosystems. The main reason is that a higher impact on the planet does not lead to a higher cost for the clients. Fortunately in most countries companies that are big polluters, have to pay more taxes to decrease this problem [78].

For the ecological footprint of the SOSM, it is important to:

- Use materials that are ecological, recyclable, long lasting, qualitative and as efficient as possible at a reasonable price.
- Reduce the electricity consumed during the construction.
- Manufacture with production methods and technologies focusing on sustainable production.
- Transport the SOSM in only one box to reduce packaging volume and the product should be sent unassembled, so less transportation and labour is needed.

5.4 SOCIAL

Social sustainability can be defined as follows [79]: *"social sustainability is a quality of societies. It signifies the nature-society relationships, mediated by work, as well as relationships within the society. Social sustainability is given, if work within a society and the related institutional arrangements: satisfy an extended set of human needs and are shaped in a way that nature and its reproductive capabilities are preserved over a long period of time and the normative claims of social justice, human dignity and participation are fulfilled".*

As a company, SUNO has to make sure that its' employees feel well incorporated into the company. To prevent employees feeling unsafe at work next steps will be taken:

- The workers will be trained and qualified for the job, this to guarantee the safety of the workers.
- Sustainable solutions will be sought to maintain a positive social influence.
- A code of ethics will be draughted.

As not everything can be prevented, the accidents that happen have to be taken into account. Therefore employees have to be able to report their problems, like bullying, too much stress related to the work, work incidents, to the department of human resources. All the things mentioned above will be written down. Every month they will be discussed in a safety meeting and they will discuss how they can improve the work environment so these things don't occur again. Everyone outside the company can also complain to the company itself in events of safety incidents and environmental accidents, accidents related to the product and consumer complaints about the safety of the product. All of these events should be written down, discussed and improved if possible.

Outside the company the product can have a social impact. As the product will be sent unassembled, there will need to be a user manual, explaining how to assemble the SOSM, and how to point it to the place the customer wants to heat/light up. It has to be as easy as possible, so that everyone can be able to build it, not only engineers.

At last the SOSM will be presented as an ecological device, because it will be using solar energy and also will help to use solar energy. This way more people will be tempted to buy the product. The product will also be presented as something the customer can earn money with. In the long-term, the customer is supposed to spend less money on the device than they would normally have paid for the energy the device has provided. SUNO should see to it that the product has a long lifespan to make sure this happens.

5.5 LIFE CYCLE ASSESSMENT

It is essential for the company's development to take into account the life cycle of the product for this is necessary to determine the next steps shown in **Fig.** 27.

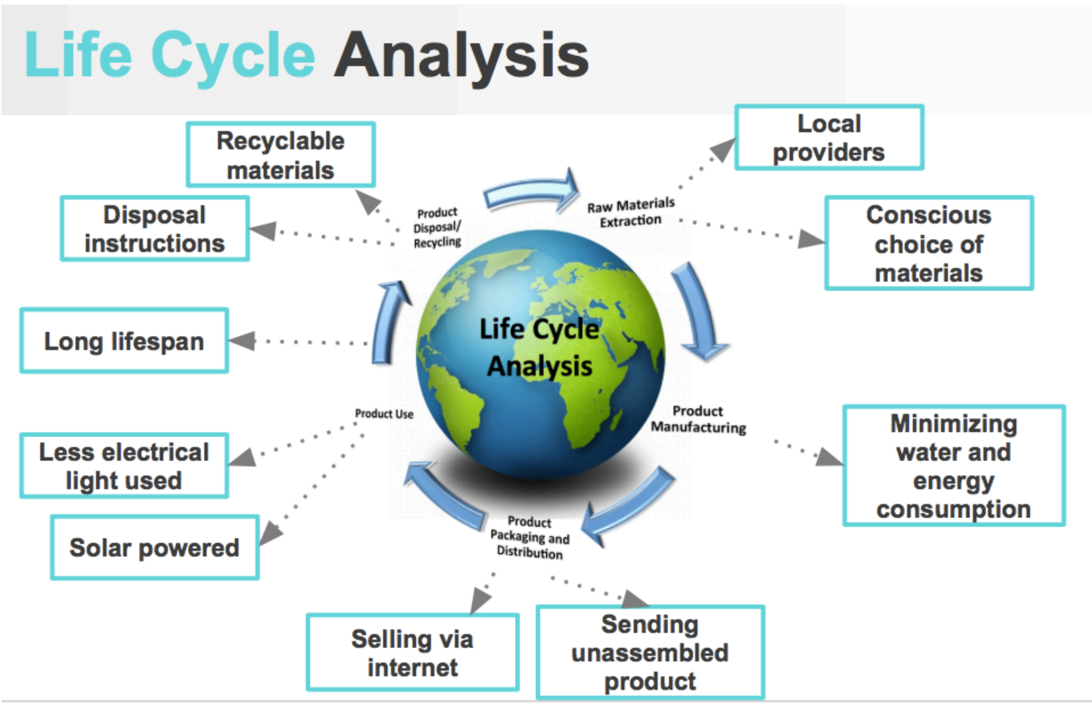


Figure 27: Life Cycle Analysis [80]

Supposing that SUNO is a large company making the SOSM on a large scale, the *Life Cycle Assessment* (LCA) will look as follows:

1. Raw Material Extraction

The materials that were chosen and their ecological impact were already described in section 5.2.1. These were chosen in a way that they would harm the environment as little as possible, but also considering that the product has to be robust and can withstand the high temperatures of the Sun and also the changes of the weather, like rain, snow and even hail. For the prototype, the lifespan of the product is not vitally important, wood can be used, as it is a sustainable product and resistance to the weather is not important here. The final product on the other hand, will need to be in metal and plastic.

SUNO will try to find the materials as close to the manufacturing site as possible (local providers), so the least amount of transport is needed.

2. Product Manufacturing

During the manufacturing, the biggest part of the construction will be performed by machines. Where necessary SUNO will use human labour. The electrical parts will be assembled in the manufacturing stage, as this would be too difficult and too time-consuming for most of the clients. The construction will not be assembled in the factory, this to decrease the hours of labour in the factory, but also to save packaging as will be discussed later.

During the manufacturing SUNO has to make sure that the least amount of material as possible goes to waste. As for the steel, aluminium and PVC that will be used, offcuts of these materials will be melted together and reused. To make sure this doesn't affect the quality of the product, the offcuts will be melted together with new materials, so the quality is not jeopardized.

3. Product Packaging and Distribution

After manufacturing the product will be packaged. For packaging, as mentioned in section 5.4, the product will be sent unassembled. This way less packaging is needed, because all the pieces can be positioned close to each other. Not only is the packaging is reduced with this method but also the labour will be decreased because the product doesn't have to be assembled in the factory, therefore, the cost of the manufacturing will also be reduced. By sending the product unassembled, the volume of the package will be reduced, this means that the transport costs will be reduced and also less pollution created through transportation.

The product will be sold by the website of SUNO and will not be available in shops. Customers will buy the product online and will receive the product by mail.

4. Product Use

The product is for home use. It can be used in the garden or on rooftops, in different ways:

- To light up or warm up a room.
- To point on a solar cell to increase its' efficiency.

The product will be sent unassembled, so there will be a manual explaining how to assemble the product. After assembly the solar mirror would have to be pointed at one point so that the software knows where it needs to be reflecting the sunlight. Spare parts will be available for the product, this way it is not required to replace the whole mirror if a part breaks. SUNO will also try to make the product as user-serviceable as possible, so the client doesn't have to spend time shipping the product to the company and also SUNO doesn't have to spend money on human labour to repair the product.

As shown in **Fig.** 328 the SOSM will provide:

- Less electrical light: SUNO provides natural light and therefore lowers energy consumption
- More energy: focused on a solar panel SUNO will boost the energy production
- More heat: SUNO can be used to improve the efficiency of a solar thermal water heater.
- The SOSM will need no energy: as SUNO operates only during the day it will be solar powered.

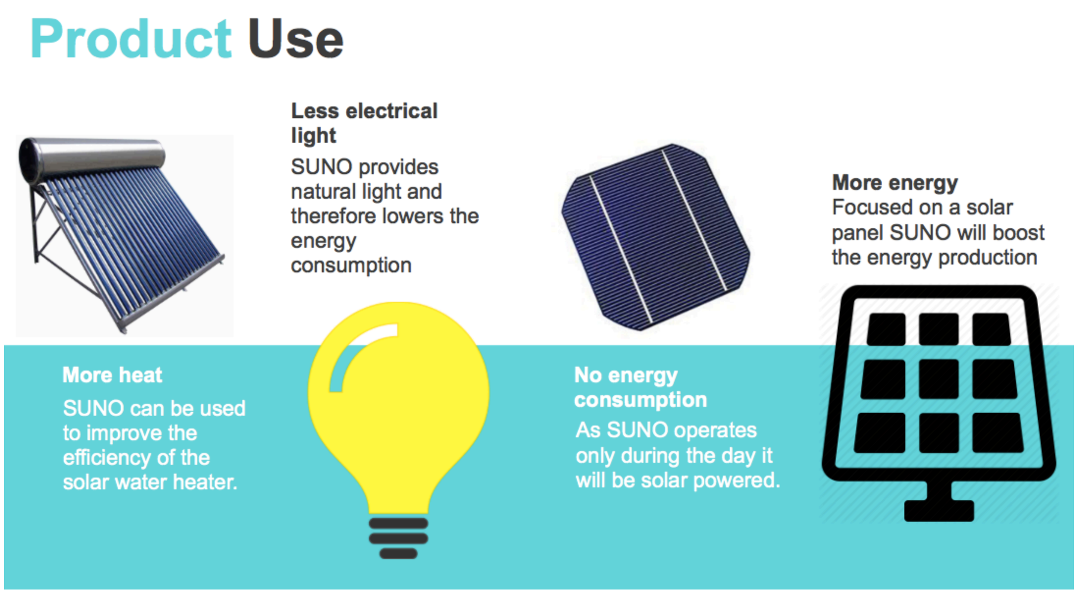


Figure 28: Product Use

Finally, for the product use, SUNO is trying to secure a product with a long lifespan, so the product eventually costs less than the savings that are made on energy by the product. The different ways SUNO tries to make this happen are shown in **Fig.** 29.

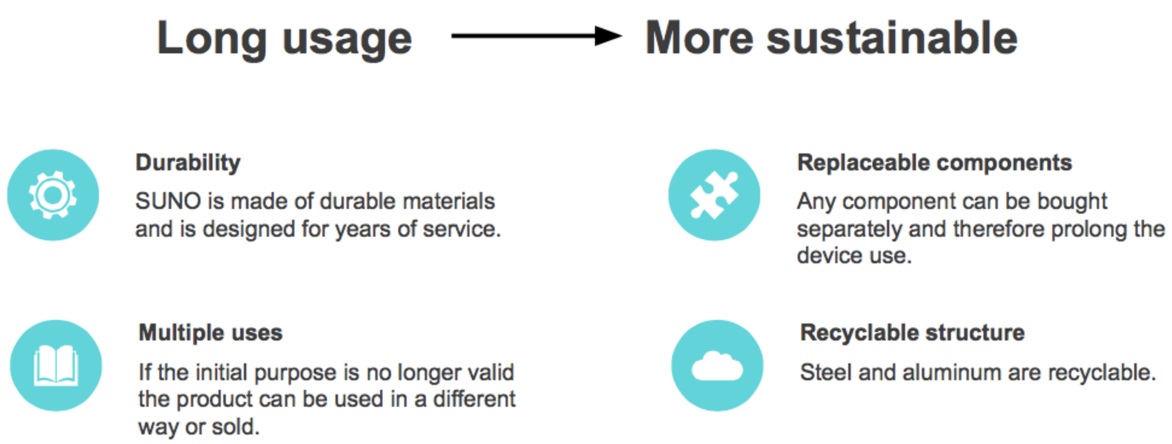


Figure 29: Lifespan

5. Product Disposal/Recycling

As already mentioned in section 5.2.1 all the products will be recyclable. PVC without additives are used, this way recycling will not be a problem. As the client their self can assemble the product, it will be easy to separate the different materials. Also, spare parts can be bought from a local supplier. The client can get a discount if he/she returns the broken part, this way SUNO can make sure the broken part is recycled the way it should be.

5.6 MEASURABLE SUSTAINABILITY INDICATORS

A lot of companies try to progress in sustainability, to help them with this a sustainability dashboard is made to identify the activities of the company. For SUNO important indicators could be:

- **CO2 Emissions:** from the machines in the factory

- **Transportation:** not only the assembling of the raw materials and the distribution of the final product (CO_2 emissions), but also how the employees go to work, the company should promote the bicycle and public transportation
- **Total Amount of Waste:** the amount that can't be recycled
- **Reduction in Resource Consumption Rates:** consumption of non-renewable recourses
- **Use of Leftover Materials from Previous Actions:** the renewable resources
- **Number of Safety Incidents:** employees that are injured at work
- **Number of Environmental Accidents:** e.g. a leak in the sewage that leads to pollution of the product
- **Number of Accidents Related to the Product:** e.g. a part of the structure breaks
- **Number of Consumer Complaints About the Safety of the Product**

All those indicators should be measured frequently and be documented. The head of the company should sit down at regular times and discuss them, and try to improve them in order to enhance the well-being of the company.

5.6 CONCLUSION

To conclude, it is not difficult to prove that the solar mirror is an eco-friendly device as it is used to provide more solar energy. Though this is not enough, if the manufacturing pollutes more than the energy the solar mirrors provide, it's not sustainable. Using green energy, renewable materials and also materials that do not have to be transported over long distances, can do this. To make the product as sustainable as possible we have to take in to account the 3 P's: people, profit and planet. Especially the planet, the environmental development is a high concern. To develop a sustainable product, it is also important to develop a good LCA. Next the ethics concerning the solar mirror will be discussed.

For environmental reasons the structure is made as much as possible out of wood. For the other parts of the product PVC was chosen because it is the most sustainable plastic on the market currently. SUNO has also made a point out of the fact that the product has to be sent unassembled. This way not only the packaging will be reduced, but also the transport and the labour.

6. ETHICAL AND DEONTOLOGICAL CONCERNS

6.1 INTRODUCTION

When discussing ethics, it is important to note that ethics is not always a simple case of right and wrong. It can at times concern "competing rights" or indeed two wrongs [81]. It is imperative that the project team analyses different approaches to ethics in order to deal with any ethical issues which may arise during the course of the project. A deontological approach would see the Team deal with issues based on a strict set of rules applied to each issue regardless of the consequence. A utilitarian approach would see the Team make decisions for the greater good. It is likely that the Team will use a mixture of both approaches when issues arise. From this analysis, the Team has created an ethical code of conduct to work by during the course of the project as can be seen next. Any unethical behaviour within the Team must always be challenged.

Team 3: Code of ethics:

- Always challenge unethical behaviour
- Do not perform hazardous work you are not trained to carry out
- Reference all sources of information correctly
- Do not manipulate data or present data in a misleading way
- Be honest and transparent
- Treat all team members equally and with respect

6.2 ENGINEERING ETHICS

The project team is made up of five members with different engineering backgrounds and experience. It is essential to draw upon this knowledge and experience when tackling ethical issues. In terms of the engineering of the product, steps are being taken by the team to ensure ethical conduct. These steps include correct referencing and crediting of sources of information to avoid plagiarism. The use of properly licensed software and only carrying out technical work which members have the appropriate level of knowledge and training to carry out. This will ensure the safety of everyone involved with the project. The product prototype will be made from various components from many different manufacturers and the team will be considering as much as is possible the ethical conduct of these manufacturers. The same applies to the suppliers, who undergo a vetting process carried out by ISEP.

6.3 SALES AND MARKETING ETHICS

As the product has multiple uses it will be of benefit to many different types of user, however in the marketing of the product the team has been careful not to make false claims about its capabilities. The product has been priced in such a way that all development and production costs are covered but also so that a profit can be made in order to support continued production and further product development. The product is priced fairly to provide value for money to the consumer. The price covers the costs of development, materials and labour/production and makes a reasonable profit to ensure commercial viability. This is an important issue for the team as the development of the product is not financially motivated but environmentally.

6.4 ENVIRONMENTAL ETHICS

Natural resources are being consumed at an alarming rate and global warming is becoming an undeniable reality. For many companies, sustainability and the environment are an afterthought and for others a mere marketing tool. As one of the objectives of the self-oriented solar mirror is to encourage the transition to clean energy, environmental ethics are at the forefront of the teams' vision. One purpose of the mirror is to improve the efficiency of solar thermal water heating systems and another is to bring light to dark rooms without using a lot of electricity from non-renewable sources. With this in mind and within the constraints of the 100 € budget the team have tried to develop the prototype using the most sustainable materials available. The team will also provide consumers with information on how to recycle the product at the end if its usable life, however, the product is designed in such a way that broken parts may be easily replaced so that a system may be repaired instead of wasted. The team intend to use as much recycled material as possible from previous projects to limit their environmental impact. The product may be powered from a small solar panel or battery.

6.5 LIABILITY

To satisfy the requirements of the project semester the product is developed in accordance with the following EU directives:

- 2006/42/CE 2006-05-17 (Machinery Directive)
- 2004/108/EC 2004-12-15 (Electromagnetic Compatibility Directive)
- 2014/35/EU 2016-04-20 (The Low Voltage Directive)
- 2014/53/EU 2014-04-16 (Radio and Telecommunication Terminal Equipment Directive)
- 2002/95/EC 2003-01-17 ROHS (Restriction of Hazardous Substances in Electrical and Electronic Equipment)

It is important to note that some of these directives do not apply to the SUNO Self-Oriented Solar Mirror. For example, the Low Voltage Directive (LVD) applies to electrical equipment with input or output voltages between 50 and 1000 V alternating current (AC) and 75 and 100 V DC [82]. The General Product Safety Directive is more relevant to the product being developed, however, the LVD may be relevant in the future if the product is upscaled somehow. As the product does not make use of any radio or telecommunication equipment this directive also does not apply, but as before it may apply in future iterations of the product.

According to the Machinery Directive definition of machinery, "Machinery consists of an assembly of components, at least one of which moves, joined together for a specific application. The drive system for machinery is powered by energy other than human or animal effort [83]". As the SUNO device is covered by this definition the team must refer to and comply with the directive. The aim of the directive is to protect workers and consumers who are involved with the product. Should the product reach the market, non-compliance with the directive would be illegal as well as unethical.

The Electromagnetic Compatibility Directive (EMC) is designed to ensure that electronic and electrical products do not interfere with each other and with radio and telecommunication equipment within reasonable limits. As the SUNO device contains electronic and electrical parts adherence to this directive is required.

The ROHS restricts the use of certain substances which are deemed to be hazardous to the environment and to human health in electronic and electrical equipment. Substances such as lead, mercury and cadmium. Producing products which do not contain these substances makes it easier for products to be recycled safely which reduces the impact of the waste of electronic goods on the environment. The team will not be producing any electronic parts but rather sourcing them from suppliers. Therefore, in order to comply with the directive, the team will have to ensure that each part purchased is ROHS compliant. Generally speaking, this will be an easy task as most products state that they are compliant and within the European Union (EU) it will be hard to find non-compliant products.

Compliance with these directives ensures the team are operating within the law and reduces their liability in the event of negative outcomes related to the product or its production. The team are also considering the consequences of misuse of the product as concentrated solar power may have harmful effects if used improperly and relevant safety information will be provided with the product.

6.6 CONCLUSION

There are many ethical issues to consider during the development of the project. Through research and through the support classes provided the team will try to navigate these issues in the most ethical way. The creation of a code of ethics is one solution the team has chosen to help them in this area. Environmental ethics and legal responsibilities have caused the team to think carefully about the selection of materials. Compliance with ROHS for example has the team ensuring they buy from certain suppliers. Also, the selection of wood instead of plastics for the construction of the product has come from the study of environmental ethics. Improving referencing skills has been needed to ensure ethical conduct from an engineering and academic standpoint and the marketing of the product in an honest and transparent way makes certain that the team acts ethically in the area of sales and marketing.

The next chapter of the report deals with the development of the project.

7. PROJECT DEVELOPMENT

7.1 INTRODUCTION

This chapter describes the product development process of the SOSM. The project development can be divided into four parts. In the first, the choice of the sun tracking system (section 7.2), the control system (section 7.3), power transmission and actuators (section 7.4) will be discussed. The second describes the functionalities of the SOSM (section 7.5) and the architecture (section 7.6), therefore also the selection of electrical (section 7.7), and mechanical components (section 7.8). Next the construction will be discussed, both mechanical construction (section 7.9) and software development (section 7.10). This chapter will end with the tests that were performed on the SOSM and their results (section 7.11) and a brief conclusion (section 7.12).

The SOSM is shown in **Fig.** 30. It consists of a base part, that makes the structure steady which is made out of wood. The base part is attached to the central rod with three metal rods. On top of the central rod there is a box that contains all the electronic parts to control the mirror in two axes: horizontally and vertically.

Figure 30: The SOSM

7.2 SUN TRACKING TECHNOLOGY

Fig. 31 shows the general principle of operation the heliostat. To result in a still spot of reflected light the normal to the mirror needs to be exactly half way between the Sun inclination angle and the line to the desired spot. That means that for each change of the solar elevation and azimuth angle the mirror has to rotate accordingly vertically and horizontally exactly half that much. In the following topics, we will discuss the three possible ways to make the mirror follow the Sun.

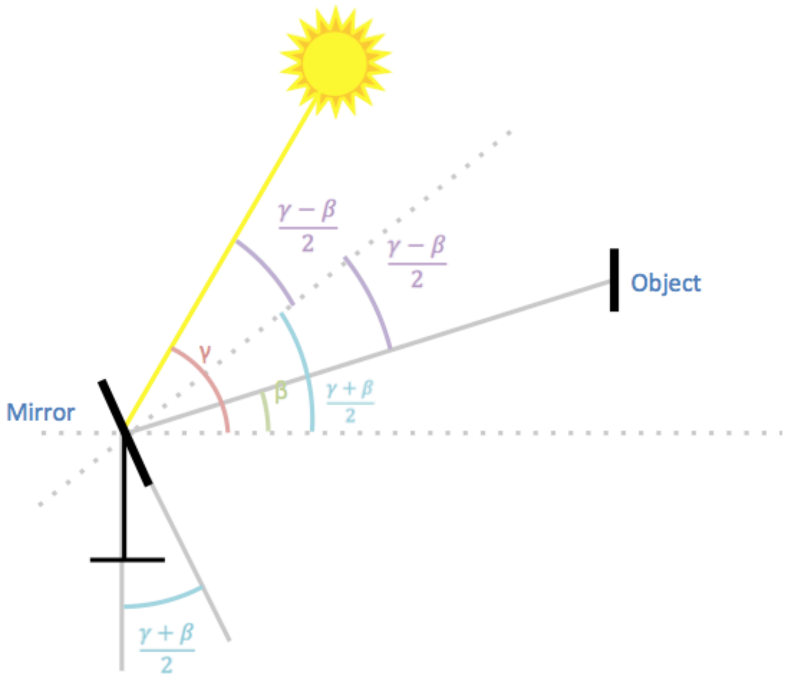


Figure 31: General Principle of Operation

7.2.1 SUN AZIMUTH AND ALTITUDE CALCULATION

The position of the Sun can be calculated if the exact date-time and geographical location is known. An example of such an algorithm is the *Sun Position Algorithm* (SPA) from *National Renewable Energy Laboratory* (NREL) [84]. For extremely precise calculations, elevation, temperature and air pressure can be used, nevertheless such a precision is not needed and obtaining that data would only cause unnecessary complications or costs. This solution does not involve any additional mechanics nor light sensors. On the other hand, it needs:

- An exact geographical location, either a *Geographical Positioning System* (GPS) sensor or a user input.
- A clock, because date and time has to be set by the user.
- A compass, though the orientation can be either constant or set by the user.

This means that the cost of such a solution is some additional setup and only optionally additional sensors.

7.2.2 MOVABLE SUN TRACKER

Sun tracking in 2-axis can be easily achieved by using 3 light sensors (one used for two axes, see **Fig.** 32), or two pairs of sensors. This system might not be reliable under foggy or dusty conditions and can also get stuck on some bright spot instead of following the Sun [85].

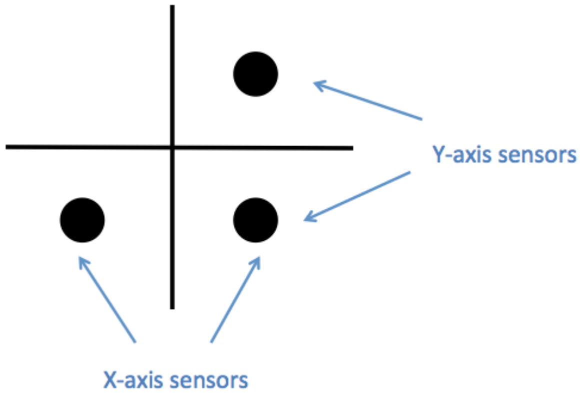


Figure 32: Sun Tracking Sensor

If a difference between the light intensity detected by the sensors occurs the tracker needs to be rotated in the direction of the higher intensity as shown in **Fig.** 33.

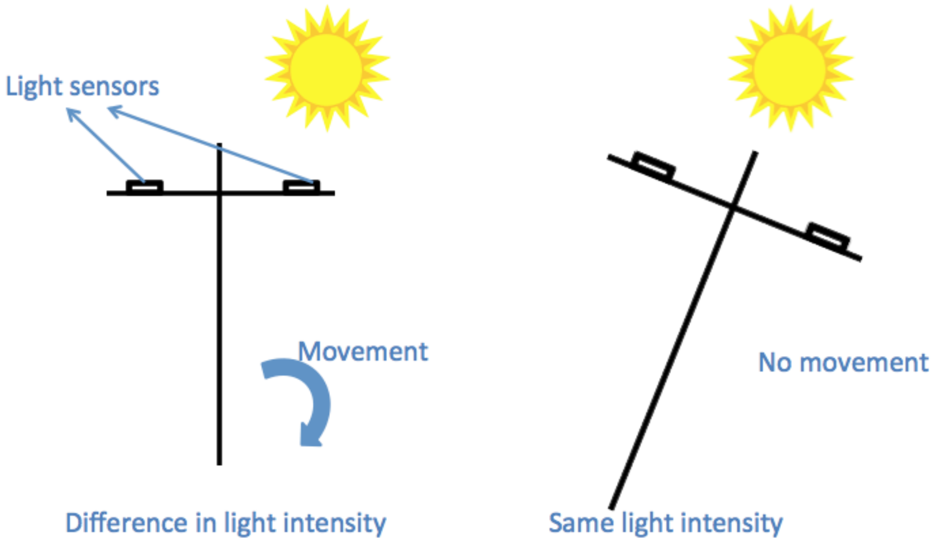


Figure 33: Tracking Sun with a Movable Sensor

The mirror only needs to be moved by half of the angle the tracker is rotated. This solution does not involve any additional setup and can be used with artificial light sources. On the other hand, it involves more complicated mechanics and costs (materials, sensors and motors).

7.2.3 LIGHT DETECTING MATRIX

Following that mentioned in section 2.2.1.2, a solution similar to the way the camera works can be applied to find the angle of light incidence. A light detecting matrix (active pixel sensor) placed inside a box with a hole, as shown in **Fig.** 34. It will detect the light spot coordinates from which the angle of incidence can be calculated [86]. Such a solution provides a simple way of finding the position of the Sun, but it involves costly and difficult to find sensors.

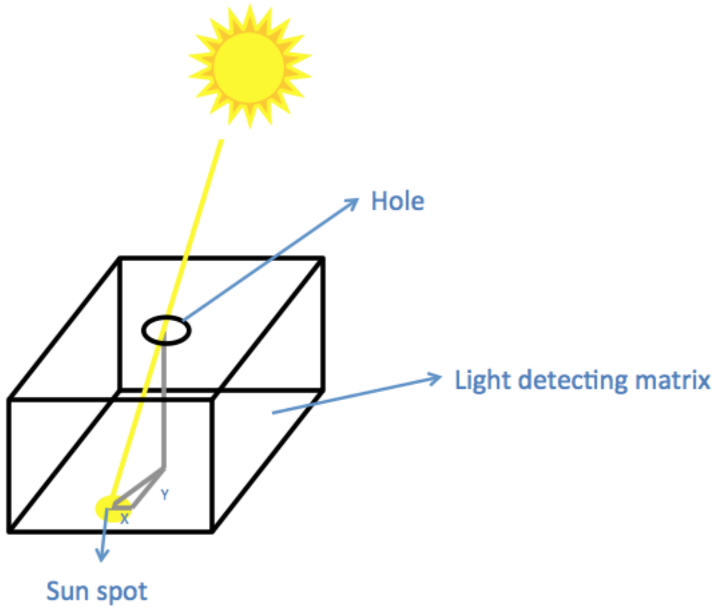


Figure 34: Finding the Angle of Light Incidence with an APS

7.3 CONTROL SYSTEM

7.3.1 CONTROL SYSTEM ANALYSIS

Fig. 35 shows the black box diagram of the system. It shows the input, output, system components and power supply. As it is just an initial draft, it might change during the process of development.

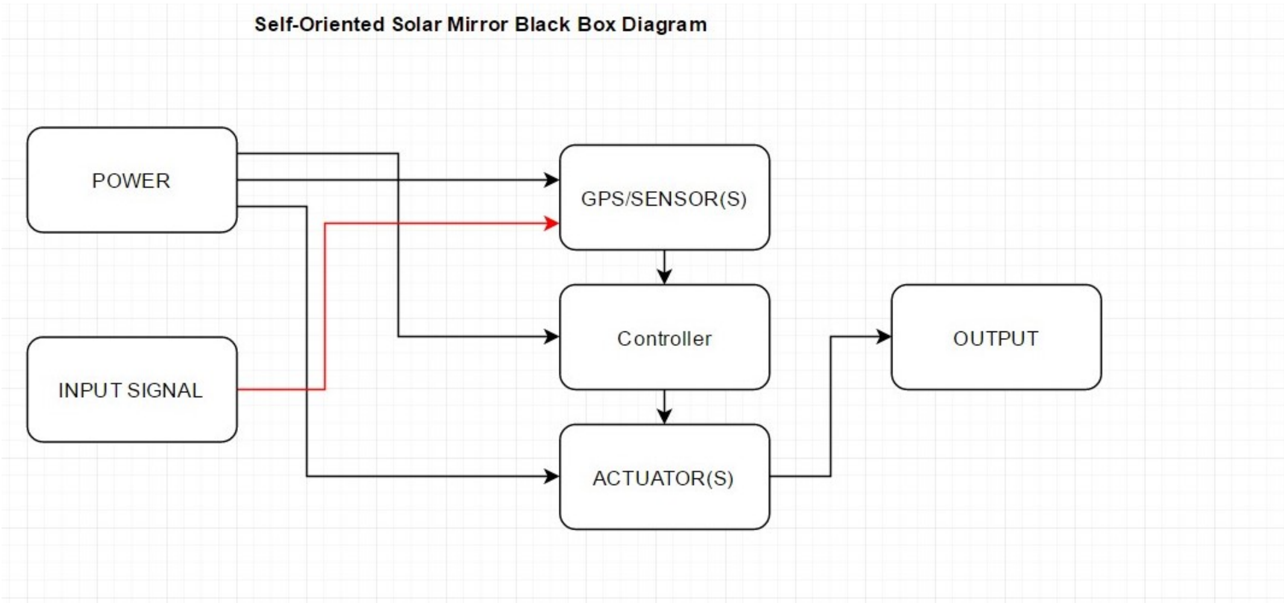


Figure 35: Black Box Diagram

As the operational principle of the control system is a crucial part of product development a significant amount of time has been allocated to the analysis and the final decision. After the initial research four solutions are proposed to choose from, each one is described in detail below.

7.3.1.1 TWO SENSORS - BOTH MECHANICALLY DEPENDENT ON THE MIRROR

As mentioned in section 7.3.2, two pairs of sensors (each for one axis) are enough to track the Sun. As the mirror has to move exactly half of the way that the Sun tracking sensor does, a system of gears can be used to achieve this. This way it is not necessary to calculate the desired angle, only make sure that the sensors are facing the Sun. One issue that this solution raises is that it is necessary to somehow detect the end of the movement range. This could be achieved simply using stepper or servo motors or by including rotary encoders in the system that would allow the monitoring of the mirror displacement. The other way would be to add sensors (touch sensors, buttons, magnetic field sensors plus magnets) at the end of the range that would trigger when the motors need to stop. Moreover, while it is relatively simple to place a pair of sensors at the side of the mirror and move it twice as much vertically, the problem is to transfer the rotary movement from the base of the mirror to its top (so the sensors are not covered by the mirror). This is because the mirror is moving in two axes and therefore a flexible shaft and a more complicated system of gears and bearings would be needed. The disadvantage is also that the sensor needs to be mechanically readjusted when the user wants to change the focus point.

7.3.1.2 ONE INDEPENDENT SENSOR PLUS ONE DEPENDENT SENSOR

The idea is to use an additional motor to move the top sensor independently of the mirror movement and move the side sensor as in the previous solution (see Section 7.4.2). This solves the issue of the rotary shaft, but makes the control system a bit more complicated and requires an additional motor, which makes the costs higher.

7.3.1.3 TWO INDEPENDENT SENSORS

This solution is simpler from the mechanical point of view and provides more control over the system. There is no need to move the sensors manually during the setup. On the other side it requires two motors and monitoring of the sensor angles. This makes the control system more expensive and complicated.

7.3.1.4 NO SENSORS

The position of the Sun can be calculated knowing the geographical location and date time. An example of such an algorithm is NREL's SPA [87]. For this it is necessary to keep track of the time and the position of the mirror. It is possible to use a real time clock and a 9-axis position/movement sensor (e.g. MPU9250 [88]). The problem is that such a sensor does not allow the location of true north with a good accuracy easily and therefore the mirror position will not be measured precisely [89]. This indicates that using a different way of tracking the position of the mirror is crucial (servo or stepper motors or rotary encoders). After more in-depth analysis it has been concluded that the initial position of the mirror is not needed to have a constant focus point. Only user calibration on setup is required to move the light spot to the desired position. The proof below (**Fig.** 36 and the Equations) shows that even if some reference angle is assumed (e.g. true north or normal to earth surface) incorrectly the light spot will be still. Therefore the user can set the focus point properly regardless of the mirror's initial orientation. That simplifies the whole system, as it only needs to track the Sun and the mirrors relative position.

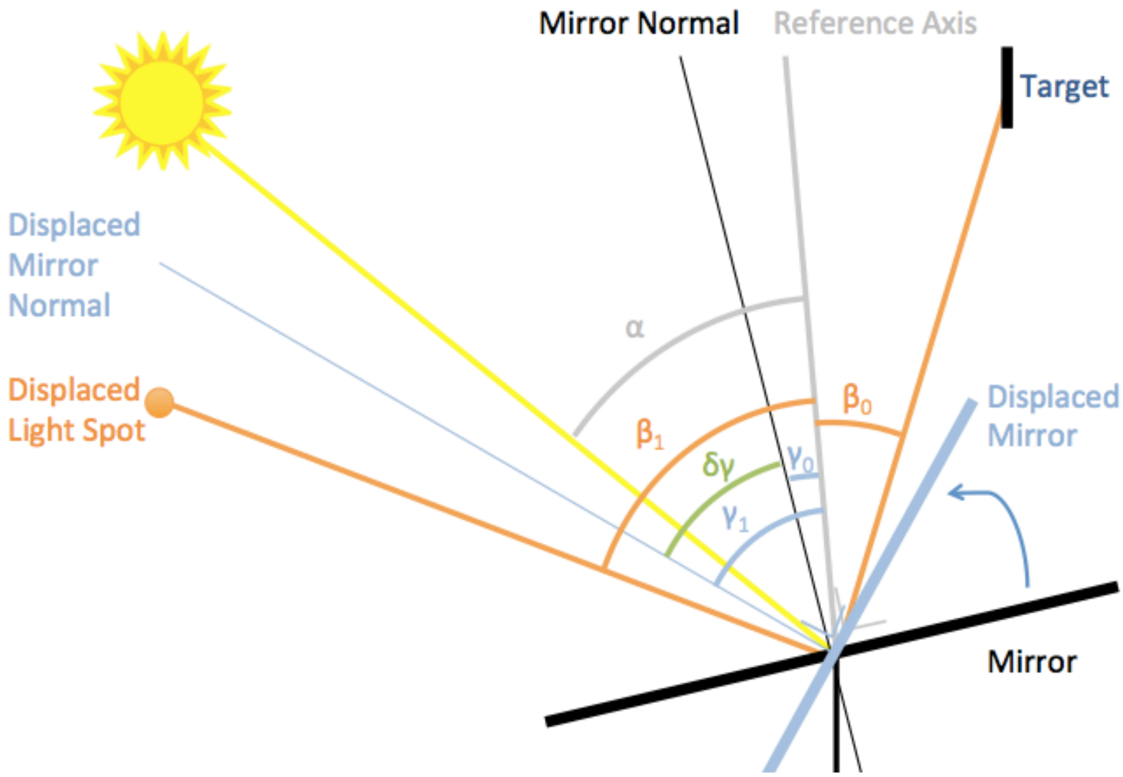


Figure 36: Pointing Sunbeams on Subject

- α−Sun inclination or azimuth angle
- β_0−Intended Sun spot position
- β_1−Sun spot position after displacement of the mirror
- γ_0−Intended mirror normal
- γ_1−Mirror normal after displacement
- $\delta\gamma$−Mirror displacement

From the picture and the law of reflection we get:

$$\gamma_0 = \frac{\alpha + \beta_0}{2}$$

$$\gamma_1 = \frac{\alpha + \beta_1}{2}$$

$$\gamma_1 = \gamma_0 + \delta\gamma$$

$\delta\gamma$ and β_0 are constant, now to show that regardless of the initial mirror position the Sun spot will not move (will be in different place, but this place will not change) we need to prove that β_1 is constant:

$$\beta_0 = \gamma_0 - \alpha$$

$$\beta_1 = 2\gamma_1 - \alpha$$

$$\beta_1 = 2(\gamma_0 + \delta\gamma) - \alpha$$

$$\beta_1 = 2\gamma_0 - \alpha + 2\delta\gamma$$

and finally:

$$\beta_1 = \beta_0 + 2\delta\gamma$$

Since $\delta\gamma$ and β_0 are constant, we know that β_1 is constant, which ends the proof.

7.3.2 CONTROL SYSTEM CHOICE

The team has decided not to use sensors as it allows for a very precise movement and provides more control over the system. Since it is not necessary to use any orientation sensor, it is vital to keep track of the mirror position to control its' movement. Even in using a stepper motor and counting the pulses there is a possibility of the motor doing more or less steps than desired.

Using incremental rotary encoders to count the turns done would be a more reliable way of monitoring the mirror's position, as it takes into account the movement that actually takes place. In this case it is necessary to store the information in the static memory not to lose it on the sudden power off. It is still not a robust solution as it is an open-loop system, so all the failures in proper counting will accumulate and the lost counts will be irreversible [90].

As a closed loop system is needed, some absolute reference of the mirror orientation has to be included [91]. The most suitable and robust would be to use a very precise absolute rotary encoder that would provide reliable mirror orientation measurement at any time, without the need of counting the turns. An example of such an encoder would be an optical gray-scale encoder.

As such a robustness is only necessary for the final product, a resetting mechanism for the prototype can be used. The idea is to place sensors at the end of the movement range. A mechanical trigger or a magnet with a hall effect sensor will be a suitable indicator of reaching the end of range. After the mirror moves too far the microcontroller will receive a signal that will trigger an interrupt stopping the motor and resetting the counter.

The final product might also include such a mechanism for safety reasons, nevertheless it is not necessary as the position can be checked with the absolute encoder.

7.4 POWER TRANSMISSION AND ACTUATORS

To make the structure of the SOSM move, power transmission and actuators will be needed. Power transmission will translate the software to movement.

7.4.1 POWER TRANSMISSION

Power transmission is when energy is moved from its' place of generation to a place where it can actually perform work. There are different ways of transmitting power; most of them can be classified in electrical, mechanical and fluid systems [92]. For this project, mechanical transmission will be used, due to:

- The limitations of an electric transmission.
- The little control offered by pneumatics, due to the absence of a force in the opposite direction.
- The expensive of the use of hydraulics, due to the low load to realise.

7.4.1.1 MECHANICAL POWER TRANSMISSION

Mechanical power transmission systems employ a variety of kinematic mechanisms such as belts, chains, pulleys, sprockets, gear trains, bar linkages, and cams. They are suitable for the transmission of motion and force over relatively short distances. The disadvantages of mechanical systems include lubrication problems, limited speed and torque control capabilities, uneven force distribution, and relatively large space requirements.

Within mechanical transmissions are the gears. A gear is a rotating machine part having teeth, which mesh with another part to transmit torque. Therefore, it is useful to transmit rotary motion. The different types of gears to be studied, are introduced below:

- **Spur gears** (**Fig.** 37): Are used to transmit rotary motion between parallel shafts. They are cylindrical, and the teeth are straight and parallel to the axis of rotation [93].

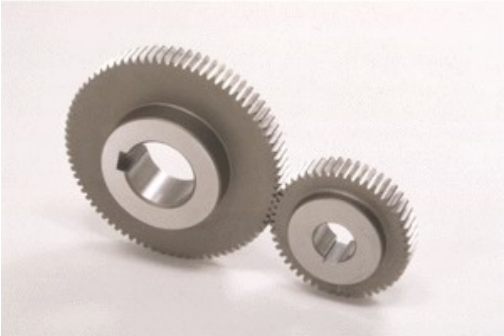


Figure 37: Spur Gears [94]

- **Worm gears (Fig.** 38**):** Are used for large speed reduction with concomitant increase in torque. The shafts are normally perpendicular. It is a species of helical gear, but the difference is that the worm may have as few as one tooth. In a worm-and-gear set, the worm can always drive the gear. However, if the gear attempts to drive the worm, it may not succeed [95].

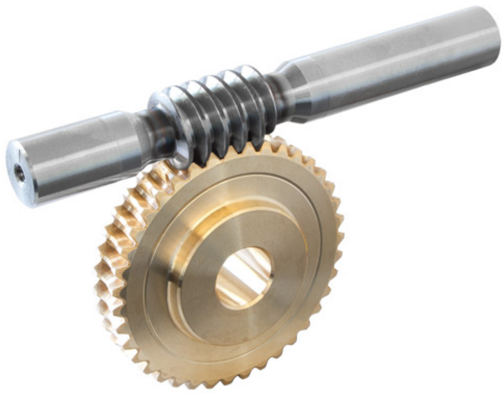


Figure 38: Worm Gears

- **Rack and pinion (Fig.** 39**):** It is a type of linear actuator that comprises a pair of gears which convert rotational motion into linear motion A circular gear called "the pinion" engages teeth on a linear "gear" bar called "the rack"; rotational motion applied to the pinion causes the rack to move relative to the pinion, thereby translating the rotational motion of the pinion into linear motion [97].

•

Figure 39: Rack and Pinion

7.4.2 MOVEMENT TECHNOLOGY

Once explained the different elements available that can be used in the design of the movement's mechanism, there are several options that can be implemented.

7.4.2.1 AZIMUTH MOVEMENT

The azimuth movement is the movement of the rising (or setting) sun against geographical features along the horizon. The best thing to do, to avoid the parallax problem, is to use horizon features located very far away from the observer, and it is necessary to carry out the observations from the exact same location from day to day through the year. This forms the basis of horizon calendars, which represents the most common practice of modern Pueblo people, and most likely of their Anasazi ancestors.

Fig. 40 shows one option to get the movement in azimuth. The mechanism has the following parts:

- **Stepper motor**: The stepper motor provides the power necessary to move the whole solar mirror.
- **Pinion**: The pinion is a spur gear, which is connected directly to the stepper motor. It actuates the toothed platform.
- **Toothed platform**: This platform supports the solar mirror, and it has an internal gear which is actuated by the pinion gear, in order to get the azimuth movement.
- **Bearing**: The bearing connects the fixed structure with the toothed platform. It allows the relative movement between both.

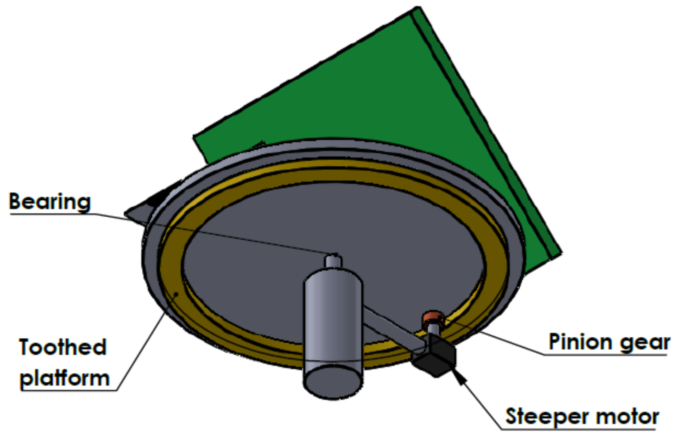


Figure 40: Toothed Platform Movement

Another option to get this movement, as shown in **Fig.** 41, it is to use and worm-and-gear arrangement. The mechanism is formed by:

- **Stepper motor:** The stepper motor provides the power necessary to move the whole solar mirror.
- **Worm:** The worm is directly connected to the stepper motor. It actuates the gear.
- **Gear:** This gear is coupled to the azimuth shaft and, actuated by the worm, it allows the azimuth movement.

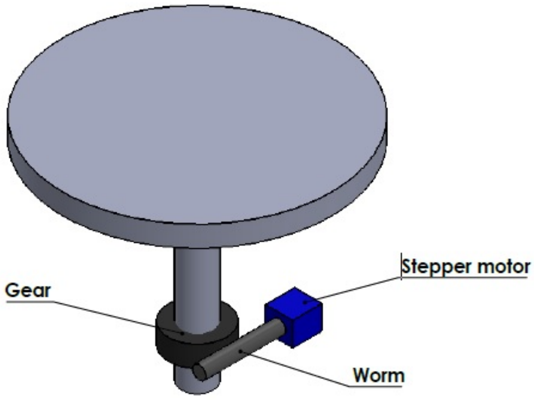


Figure 41: Worm-and-Gear Set Rotation

7.4.2.2 EAST-WEST MOVEMENT

As shown in **Fig.** 44, in order to raise the mirror, an option is use a rack and pinion system, with the following components:

- **Stepper motor**: The stepper motor provides the power necessary to move the solar mirror.
- **Pinion**: The pinion is a spur gear, which is connected directly to the stepper motor. It actuates the rack.
- **Rack**: The rack is connected to the said structure and, through the drive through the pinion, it allows to modify the angle's inclination of the same.

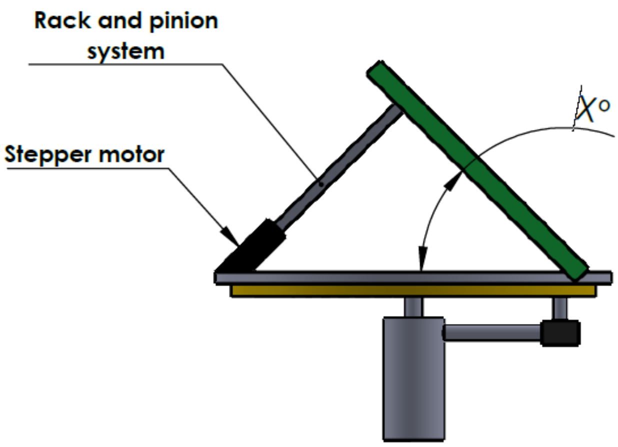


Figure 42: Rack and Pinion Mechanism Movement

Finally, another way to modify the inclination of the solar mirror, is using a leadscrew mechanism, shown in **Fig.** 43:

- **Stepper motor**: The stepper motor provides the power necessary to move the structure where the solar mirror is.
- **Drive wheel**: The drive wheel, which is usually a nut, is connected directly to fix part of the structure.
- **Screw**: The screw, which is actuated by the stepper motor, allows the modification of the angle of inclination of the solar mirror.

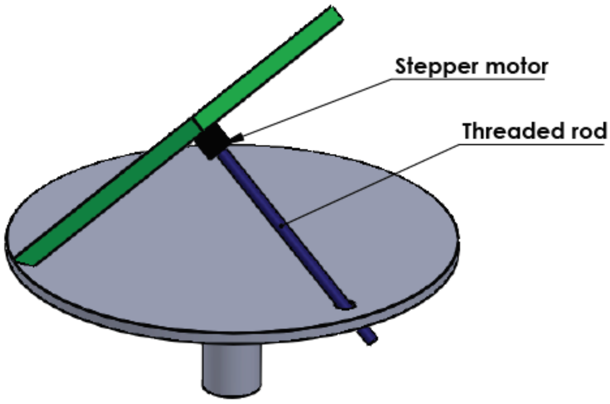


Figure 43: Leadscrew Mechanism Movement

7.2.3 CONCLUSION

Having seen the different possibilities in terms of movement technology, it is important to determine the advantages and disadvantages. This is shown in **Table** 11:

Table 11: Movement Technologies Comparison

Technology	Advantages	Disadvantages
Azimuth movement		
Toothed platform	The mechanism is robust	Toothed platform is expensive to manufacture
		Lubrication may be required
Worm-and-gear	The mechanism is robust	Expensive assembly
	High reduction rate	
East-West movement		
Rack and pinion	It is a cheap and robust system	A lot of space is necessary, due to the rack's length
		It exists a lot of friction in the mechanism, therefore much power is required
		Also, due to the friction, it is produced a big amount of heat
Leadscrew	Easy to design and manufacture, no specialized machinery is required	A lot of space is necessary, due to the length of the screw
	Smooth, quiet and low maintenance	It is a very low-efficient system
	Self-locking	

7.5 FUNCTIONALITIES

7.5.1 BASIC FUNCTIONALITY

The main purpose of the SOSM is reflecting the sunlight to one spot. The focus point can be a window to light up a dark room, a garden to provide flowers with more Sun or a solar water heater to improve its efficiency. Nevertheless, it is not suggested only one function for SOSM, actually the user can find his or her own application for the heliostat.

7.5.2 ADDITIONAL FEATURE

To target users that need more than just more light, they can be provided with some stickers or covers for the SOSM that will give the produced light spot a specific shape. **Fig.** 44 depicts the exemplary usage of such a cover.

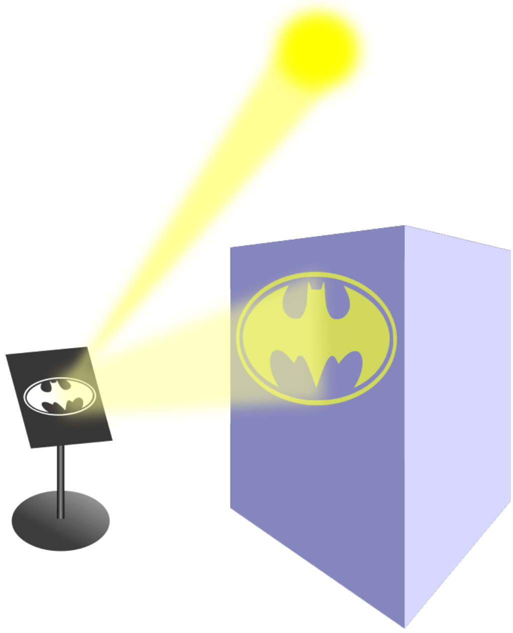


Figure 44: Example of using a sticker to change the shape of reflected light [99]

7.5.3 USE-CASE SCENARIO

After ordering a product and providing the required information (geographical location for the mirror initial setup) the user needs to put the SOSM in a sunny place facing approximately south (for the north hemisphere). The orientation does not have to be overly precise, but is recommended as it will allow the mirror to catch more Sun and this way it will not do unnecessary work while the Sun is out of range. After placing it, the user should turn it on and adjust the focus point placement using four buttons (left, right, up and down). This will end the setup phase and the SOSM will work on its own. The user should monitor whether the mirror is working properly and check LEDs and/or display panel for errors. **Fig.** 45 depicts instructions of how to setup the mirror.

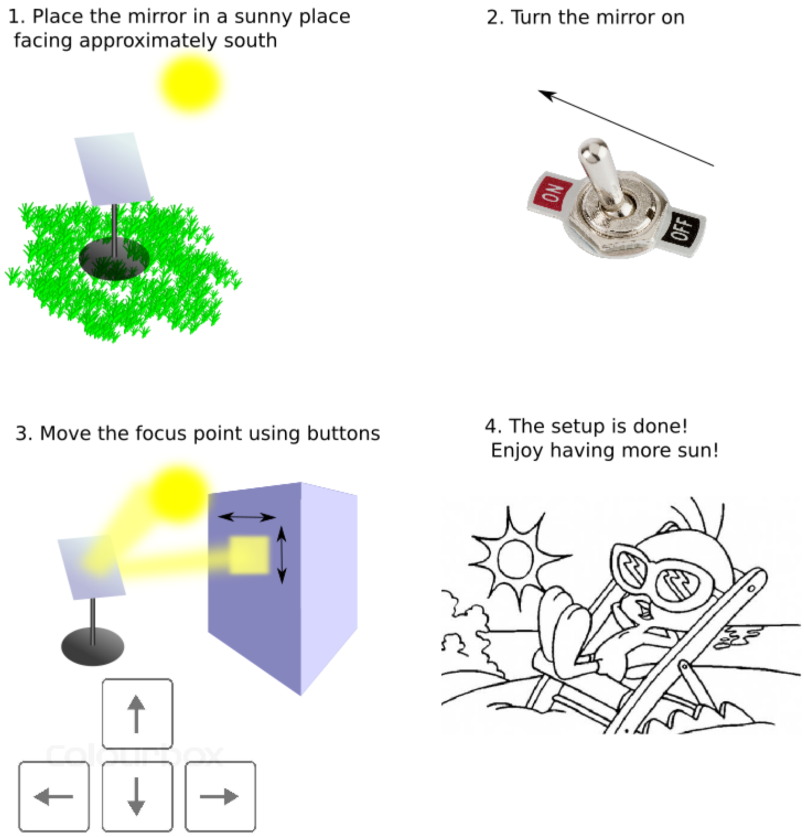


Figure 45: Setup Procedure [100][101][102]

7.6 ARCHITECTURE

7.6.1 STRUCTURAL DESIGN

Fig. 46 and 47 show the final prototype. For further information, the drawings are available at section 9.2.

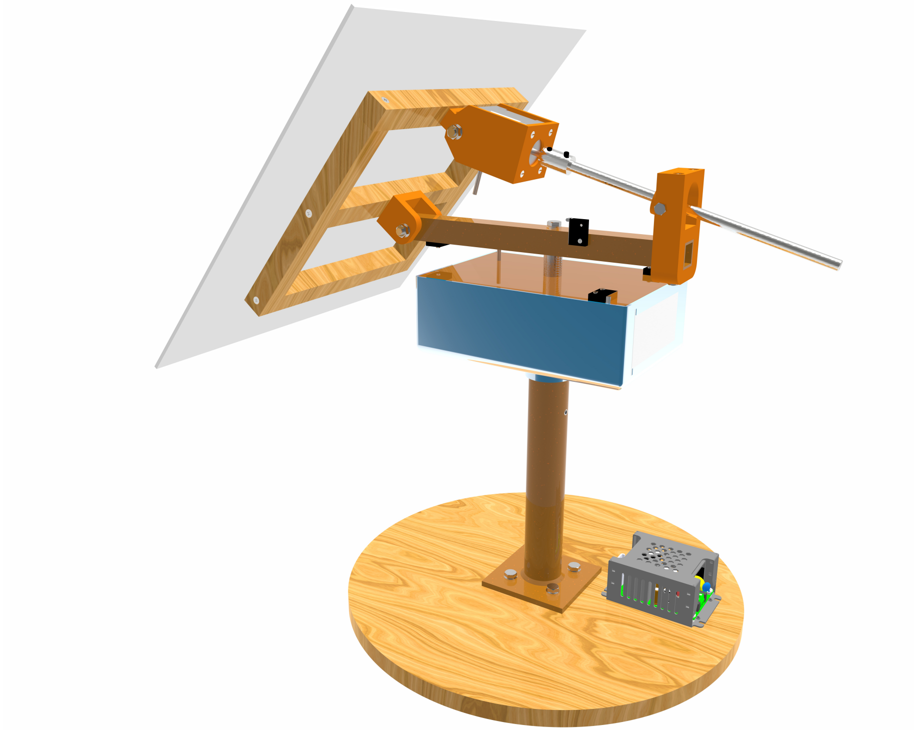


Figure 46: Structural Design

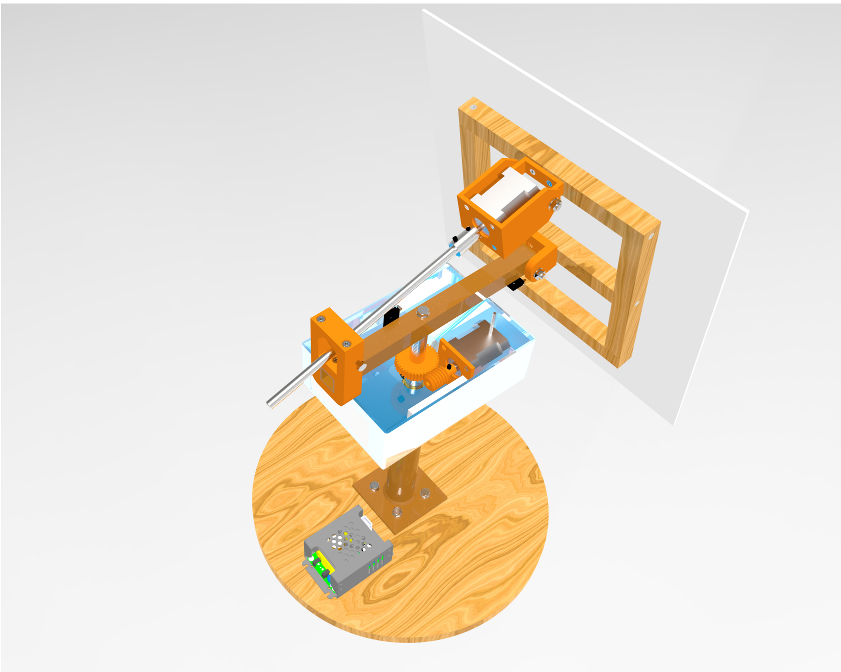


Figure 47: Structural Design

7.6.2 CARDBOARD MODEL

First of all, a cardboard model was made of the solar mirror. This was done to help to decide the dimensions and the ultimate movement system of the mirror. The model is shown in **Fig.** 48.

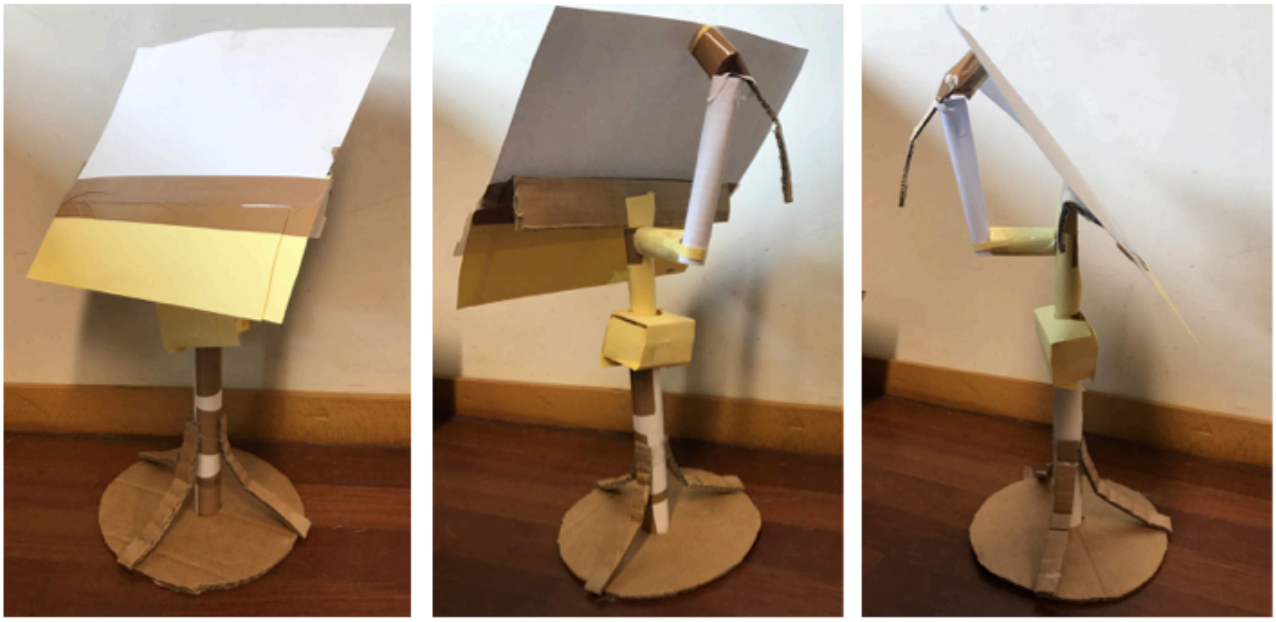


Figure 48: Cardboard Model

7.7 ELECTRICAL COMPONENTS

7.7.1 INTRODUCTION

The initial schematics of the system are shown in **Fig.** 49. The schematics are a general base for further development. As the 9-axis orientation sensor is not necessary, the final system will probably not include it. The motor control system is designed for controlling DC motors and might be changed depending on what kind of motors are selected (regular DC, stepper or servo motors).

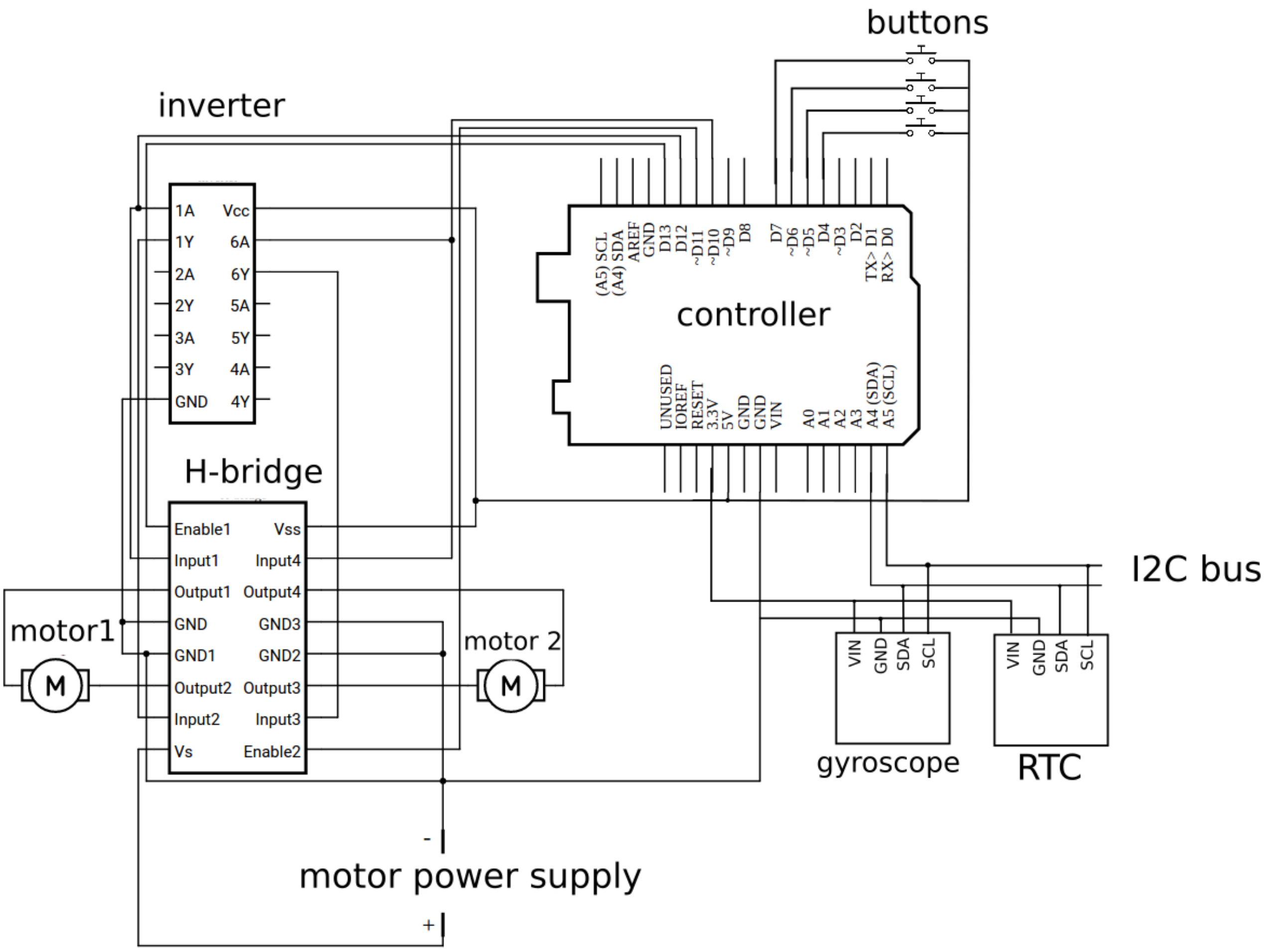


Figure 49: Initial System Schematics

7.7.1.2 MICROCONTROLLER BOARD

As the system requires calculation of the Sun position the choice of a suitable board is crucial. In **Table** 12 different microcontrollers are compared including their approximate price [103]. For the calculations, double support might be crucial and the price is an important factor, as the budget is limited.

Table 12: Microcontoller Board Comparison

Board	Technology	Price [€] (V.A.T. Not included)	Link
Arduino Uno	8-bit	21.00	Arduino Uno
Arduino Mini	8-bit	14.00	Arduino Mini
TI MSP-EXP430G2	16-bit	9.99	TI MSP-EXP430G2
TI EK-TM4C123GXL	32-bit	12.99	TI EK-TM4C123GXL
Funspark Redboard	8-bit	19.95	Funspark redboard
STM32VLDISCOVERY	32-bit	9.68	STM32VLDISCOVERY

Taking into account these factors, the Texas Instruments EK-TM4C123GXL will be a suitable board, as it is cheaper than Arduino Uno, while providing more pins and double precision numbers support.

7.7.1.3 TYPE OF MOTORS

For the SOSM system, the chosen motors need to allow for good precision, but the speed is not an important concern as the mirror will rotate very slowly (about 15 ° per hour). Also, a relatively high output torque will be crucial to move it during a windy day. As two-way movement is necessary, the motor has to be bipolar. Stepper motors and gear DC motors are mainly considered.

Gear DC motors with very low gear ratio will allow for the desired precision and torque. On the other hand, it would be more difficult to control such a motor as it is not possible to anticipate the exact angle it will turn, so you have to rely on feedback from the encoder. It is not a significant disadvantage though and it allows a continuous movement. A bipolar stepper motor with a good resolution will allow for precise movement and easy control, as it is known exactly how much it will rotate and it is only necessary to check whether it does not skip any step. Bipolar stepper motors also feature a high torque and a holding torque without power supply. Stepper motors are used when precise positioning is needed and it is in this case.

Considering all of this, stepper motors would be the most suitable for the final product as it allows for the precise positioning of the mirror. For the prototype, any of these would be suitable, but gear motors would require the usage of rotary encoders, which in the case of the prototype can be omitted for stepper motors. Therefore, stepper motors will be used in the scale model, unless such a solution is much more costly.

7.7.1.4 OTHER COMPONENTS

As it will provide user with more control over the mirror and also allow the mirror to inform the user about the need of calibration, it will be necessary to add some LEDs and LCD display. As for the display, it should have two rows with 16 characters each. It should support SPI or I^2C protocol to minimize the number of pins used, unless the board has enough pins to support a display with parallel control. One or two LEDs will be enough and five buttons and an on/off switch should provide enough input from the user. Some additional resistors might be needed for the buttons as a pull down and capacitors for debounce. As well as that the system needs a safety mechanism for sensing end of movement range. In the full scale and mass production mirror a magnet and a magnetic switch or some mechanical trigger designed for that purpose would be a suitable way of indicating the end of range (switch triggers when the magnet is close or the circuit is closed, which informs about reaching the end of range). In the prototype buttons will be enough as such a situation would happen extremely rarely, only when the controller loses count of the angle. Apart from that a real-time clock is needed. Any RTC with a place for its own battery and supporting I^2C protocol will be suitable.

7.7.1.5 POWER SUPPLY

As the product is supposed to work only during the day and changes its' position towards the Sun, it would be logical to use a solar panel to power the system. The motors drain would use much more power than the control system, however they do not work continuously, so they can be powered from a battery that would be charged by the solar panels. The system will hibernate when the Sun is out of range, which will minimize the power consumption.

For the prototype has been decided not to use solar panel nor rechargeable battery as they are expensive and the scale model needs less power. An external power supply is going to be used, as it can provide two different voltages. The external power supply will provide 12 volts for the motor and 5 volts for the controller board.

7.7.2 LIST OF ELECTRICAL COMPONENTS

Below in **Table** 13 the electrical components needed are listed:

Table 13: List of Electrical Components

Component	Supplier	Quantity	Unitary Price (€)	Total Price (€)	Link
Texas Instruments EK-TM4C123GXL	DIGIKEY	1	12.62	12.62	TI EK-TM4C123GXL
Stepper Motor NEMA 17	DIGIKEY	2	13.09	26.18	Stepper Motor
RTC	DIGIKEY	1	4.11	4.11	RTC
Rocker switch	DIGIKEY	1	0.68	0.68	Rocker Switch
H-bridge	DIGIKEY	2	3.65	7.3	H-bridge
Inverter SN74HC04N	DIGIKEY	1	0.49	0.49	SN74HC04N
Lithium Battery 3V CR1225	BOXELECTRONICA	1	0.75	0.75	Lithium Battery
Power Supply 12V 1A	BOXELECTRONICA	1	6.95	6.95	Power Supply
Small Push Button	ISEP	4	-	-	-
End of Range Sensor	ISEP	4	-	-	-
Capacitor 0.47µF (for button debounce)	ISEP	8	-	-	-
Breadboard	ISEP	1	-	-	
Jumper wires - compatible with the breadboard (probably male-male and some male-female for the board)	ISEP	Some	-	-	-
Wire	ISEP	-	-	-	-
33 kΩ resistor (for button pull-up)	ISEP	8	-	-	-
Power Supply	ISEP	1	-	-	
Total (€)			**59.08**		

7.7.3 FINAL SCHEMATICS

The **Fig.** below (50 and 51) show the electronic schematics drawn using Fritzing tool [104].

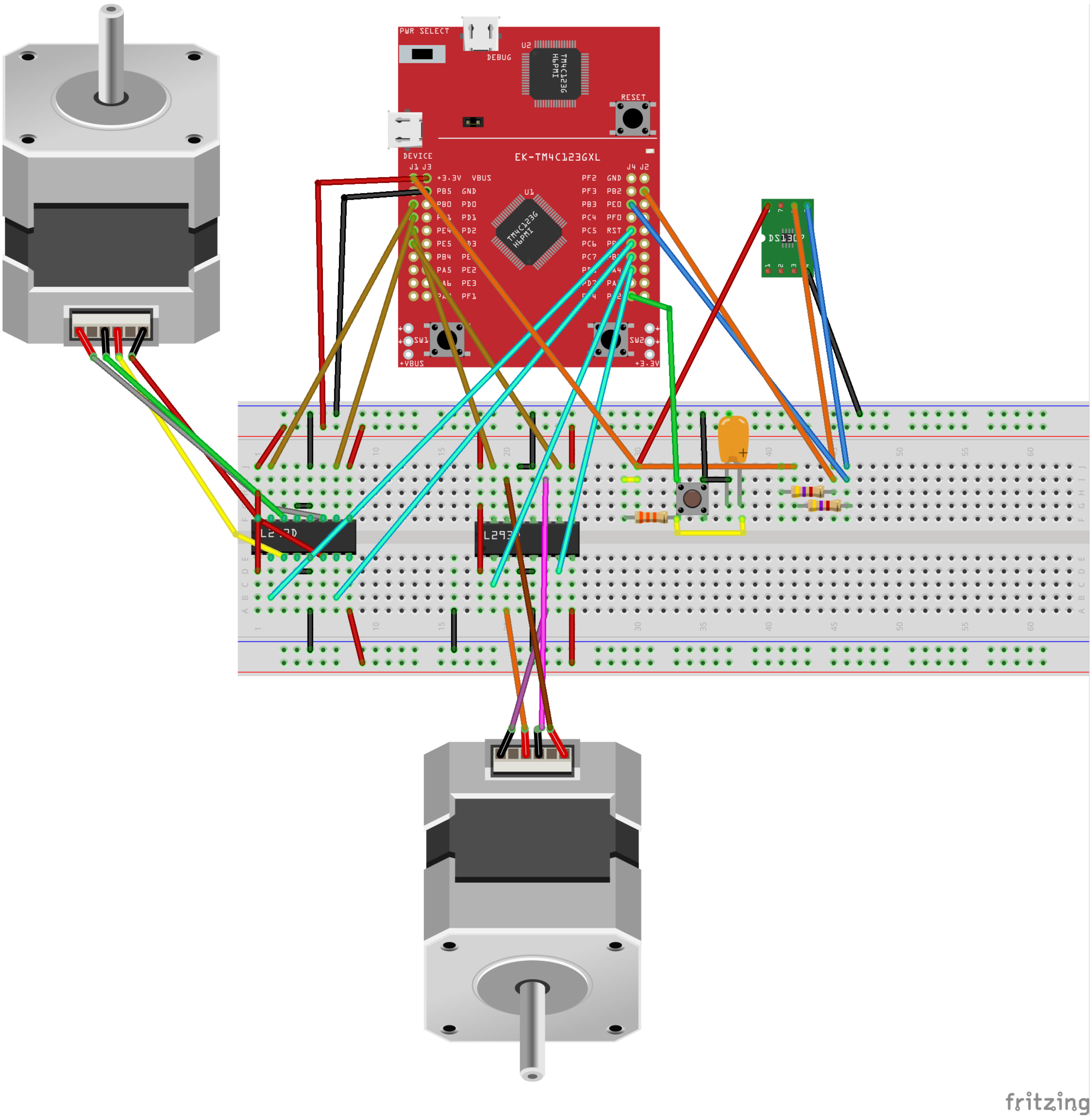


Figure 50: Electronic Components of the Solar Mirror

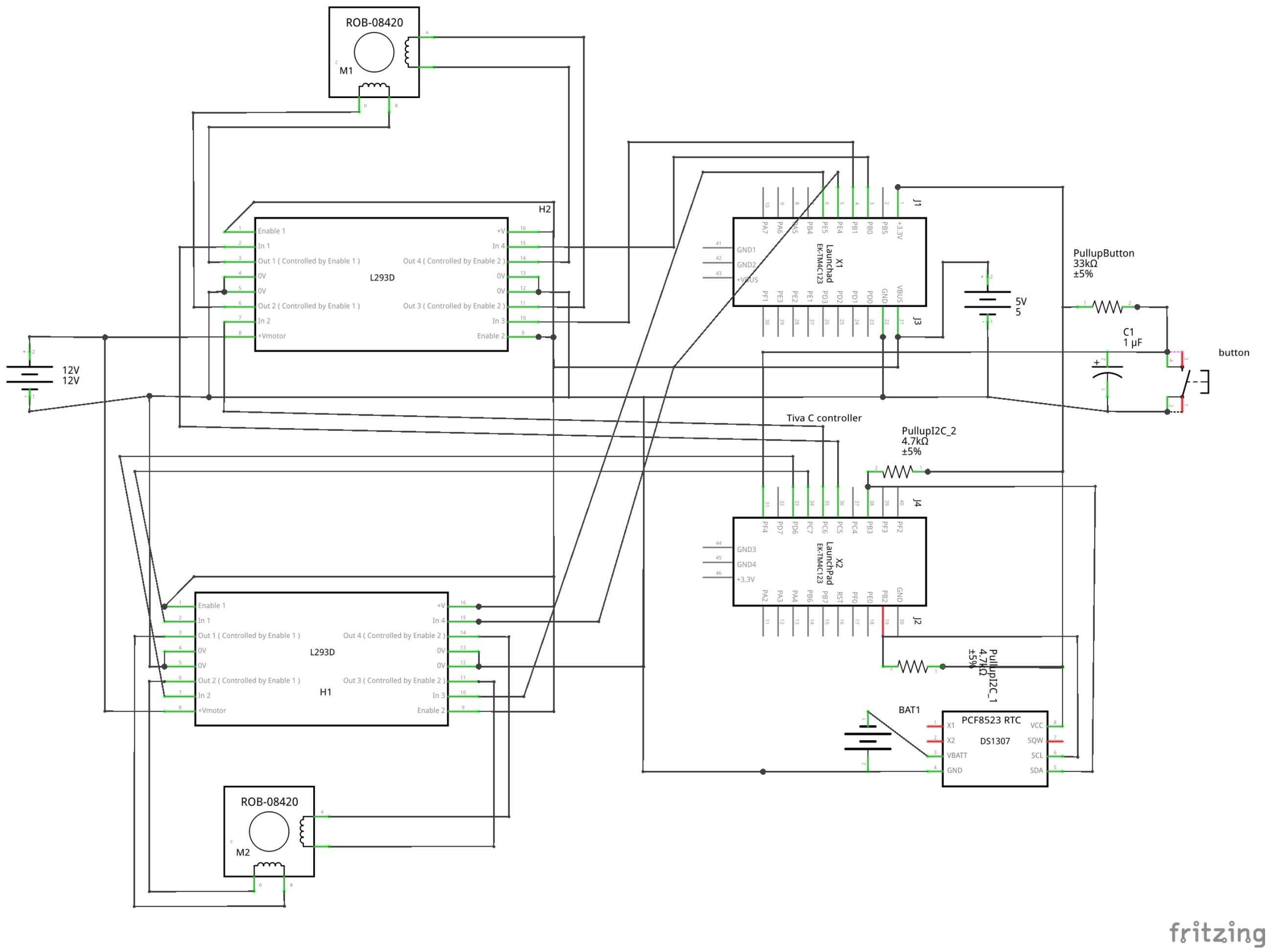


Figure 51: Electronic Schematics of the Solar Mirror

7.8 MECHANICAL COMPONENTS

7.8.1 PRELIMINAR LIST OF COMPONENTS

A first list of components was provided, to authorize the purchase of the components from the specified suppliers. This preliminary list is next: Preliminary list of materials.

7.8.2 FINAL LIST OF COMPONENTS

The complete list of components needed to build the prototype are included in **Table 14**. This list contains the components present in the 3D model, in the order they appear. The items marked with an asterisk are electrical components, mentioned in section 7.7.2

Table 14: Mechanical Components

Nº.	Description	Material (Standard)	Supplier	Component reference	Quantity (Uds)	Unitary Price (€)	Final Price (€)
001	Circular base	Pine tree	ISEP	ISEP@WS01	1	0.00	0.00
002	Central post	AISI 1015		ISEP@WS02	1	0.00	0.00
003	Hexagonal head screw DIN 933 M6 x 16	DIN 933	ARTIFIXO	93380616ZN	5	0.049	0.245
004	Flat washer DIN 125a M6	DIN125a		ANC06ZN	9	0.012	0.108
005	Grub screw DIN 916 M6 x 6	DIN 916		PER0606	2	0.05	0.10
006	Box	PP	ISEP	ISEP@WS03	1	0.00	0.00
007	Box cover	PP		ISEP@WS04	1	0.00	0.00
008	Box door	PP		ISEP@WS05	1	0.00	0.00
009	Azimuth shaft	AISI 1015		ISEP@WS06	1	0.00	0.00
010	Shaft spacer	Aluminium		ISEP@WS07	1	0.00	0.00
011	Shaft holder	PP		ISEP@WS08	1	0.00	0.00
012	Hexagonal head screw DIN 933 M5 x 12	DIN 933	ARTIFIXO	93380512ZN	1	0.04	0.04
013	Flat washer DIN 125a M5	DIN125a		ANC05ZN	1	0.01	0.01
014	Radial Bearing 6001 2Z	DIN 625	ABS ROLAMENTOS	T6001-ZZ	4	3.26	13.04
015	Philips oval countersunk machine screw DIN 963 M3 x 10	DIN 963	ARTIFIXO	09630310Z	8	0.025	0.20
016	Socket head cap screw DIN 912 M4 x 10	DIN 912		91280410	5	0.036	0.18
017	Flat washer DIN	DIN 125a		ANC04ZN	5	0.0125	0.063

Nº.	Description	Material (Standard)	Supplier	Component reference	Quantity (Uds)	Unitary Price (€)	Final Price (€)
	125a M4						
018 *	Stepper motor NEMA 17	NEMA 17	DIGIKEY	MTR-DC17T-275-F	2	13.09	26.08
019	Azimuth motor bracket	PLA	ISEP	ISEP@3DPRINT01	1	0.00	0.00
020	Worm wheel			ISEP@3DPRINT02	1	0.00	0.00
021	Worm gear			ISEP@3DPRINT03	1	0.00	0.00
022	Grub screw DIN 916 M4 x 6	DIN 916	ARTIFIXO	PER0406	5	0.036	0.18
023 *	Control system	-	-	-	1	0.00	0.00
024	Lateral square profile	Pine tree	ISEP	ISEP@WS09	2	0.00	0.00
025	Frontal square profile			ISEP@WS10	2	0.00	0.00
026	Central square profile			ISEP@WS11	1	0.00	0.00
027	Mirror joint	PLA		ISEP@3DPRINT04	1	0.00	0.00
028	Cross connector square profile	AISI 1015		ISEP@WS12	1	0.00	0.00
029	mirror's surface	LDPE		ISEP@WS13	1	0.00	0.00
030	Mirror joint's articulating shaft	DIN 975	LEROYMERLIN	ISEP@WS14	1	0.00	0.00
031	Leadscrew joint	PLA	ISEP	ISEP@3DPRINT05	1	0.00	0.00
032	Hexagonal nut DIN 934 M6	DIN 934	ARTIFIXO	934M06ZN	4	0.0116	0.046
033	Cross recessed countersunk head tapping screw DIN 7982 Ø3.5 x 35	DIN 7982		79823535	6	0.07	0.42
034	Cross recessed countersunk head tapping screw DIN 7982 Ø3.5 x 25			79823525	2	0.05	0.10
035	Cross recessed countersunk head tapping screw DIN 7982 Ø3.5 x 19			79823519	4	0.06	0.24
036	Leadscrew motor bracket	PLA	ISEP	ISEP@3DPRINT06	1	0.00	0.00
037	Motor coupling	AISI 1015		ISEP@WS15	1	0.00	0.00

Nº.	Description	Material (Standard)	Supplier	Component reference	Quantity (Uds)	Unitary Price (€)	Final Price (€)
038	Hexagonal nut DIN 934 M8	DIN 934	ARTIFIXO/ISEP	934M08ZN	1	0.05	0.05
039	Threaded rod M8	DIN 975	LEROYMERLIN	ISEP@WS16	1	0.99	0.99
040	M8 nut housing	PLA	ISEP	ISEP@3DPRINT07	1	0.00	0.00
041	Hexagonal Head Screw DIN 933 M5 x 20	DIN 933	ARTIFIXO	93380520ZN	2	0.05	0.10
042	M8 housing lower support	PLA	ISEP	ISEP@3DPRINT08	1	0.00	0.00
043	M8 housing upper support			ISEP@3DPRINT09	1	0.00	0.00
044	Socket head cap screw DIN 912 M4 x 25	DIN 912	ARTIFIXO	9120425	2	0.10	0.20
045	Socket head cap screw DIN 912 M4 x 40			9120440	1	0.12	0.12
046	Hexagonal nut DIN 934 M4	DIN 934		934M04Z	1	0.01	0.01
047	Motor joint's articulating shaft	DIN 975	LEROYMERLIN	ISEP@WS17	1	0.00	0.00
048 *	End range sensor	-	ISEP	ISEP@EL01	4	0.00	0.00
049	Slotted cheese head machine screw DIN 84 M2 x 12	DIN 84	ARTIFIXO	0840212Z	6	0.1255	0.753
050 *	Power supply	-	ISEP	ISEP@EL02	1	0.00	0.00
Total (€)						**17.20**	

Besides the components above there are other components that even if they do not appear in the components list shown above, have been used. These components are listed in **Table** 15.

Table 15: Other Components Used

Description	Supplier	Quantity (Uds)	Unitary Price (€)	Final Price (€)
Contact glue	ARTIFIXO	1	3.69	3.69
Shiny brown paint		1	3.50	3.50
Varnish for wood	ISEP	1	0.00	0.00
Total (€)		**7.19**		

7.8.3 PROVIDED MATERIALS

Fortunately, some raw materials were provided by ISEP. **Table** 16 include them.

Table 16: Provided Components and Materials

Description	Quantity (Uds)
Wooden plank, 15 mm. of width	1
Steel hollow circular section profile Ø34 x Ø28	1
Steel hollow circular section profile Ø40 x Ø36	1
Steel square plate, 5 mm. of width	1
Solid circular profile, Ø20 mm.	1
Aluminium circular hollow profile Ø16 x Ø13	1
Shaft holder	1
Polyethylene plank, 3 mm. of width	1
Steel hollow square section profile 20 x 16	1
Wood square 40 x 20 profile	1
M6 threaded rod	1

7.8.4 UNUSED COMPONENTS

Unfortunately, after several changes made during the construction of the prototype, as well as later suggested improvements, some of the specified components were not used. These components are listed in the **Table** 17.

Table 17: Unused Components

Description	Supplier	Quantity (Uds)	Unitary Price (€)	Final Price (€)
Hexagonal Head Screw DIN 933 M6 x 16	ARTIFIXO	5	0.049	0.245
Hexagonal nut DIN 934 M4		3	0.0125	0.0375
Hexagonal nut DIN 934 M6		2	0.0116	0.0232
Slotted Flat Head Wood Screw DIN 97 Ø2 x 10		37	0.088	3.21
Flat Washer DIN 125a M6		1	0.012	0.012
Socket head cap screw DIN 912 M4 x 10		1	0.036	0.036
Socket head cap screw DIN 912 M4 x 25		1	0.10	0.10
Socket head cap screw DIN 912 M6 x 25		1	0.10	0.10
Union Square 30 x 30	LEROY MERLIN	4	0.18	0.72
PLA Printing Filament	BOXELECTRONICA	1	19.99	19.99
Economic impact (€)		**4.48**		

Within this economic impact, it is not considered the price of the PLA Printing Filament. Although this material is not bought, the printed pieces were provided directly by ISEP, so its' price may be considered afterwards.

7.9 MECHANICAL CONSTRUCTION

7.9.1 EQUIPMENT AND TECHNOLOGY

Some of the components have to be built at the workshop. First of all, a quick overview of all the tools and the machines used will be provided. This information is shown in **table** 18.

Table 18: Equipment and technology

Name	Description	Image
Electric Driller	Making Holes in softer materials like wood and plastic	 Figure 52: Electric Driller
Industrial Driller	Making holes in harder materials, like metal and thicker plastics	 Figure 53: Industrial Driller

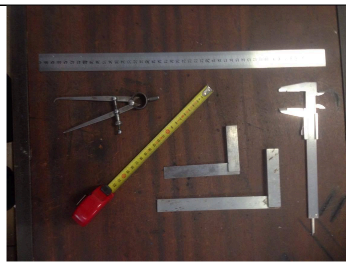
Continuation Table 18 - 1

Electric keyhole saw	Cutting wood and Plastic	 Figure 54: Electric Keyhole Saw
Manual saw	Cutting wood and metal	 Figure 55: Manual Saw
Lathe Machine	Machining Metal	 Figure 56: Lathe Machine

Continuation Table 18 - 2

Cutting machine	Cutting metal	 Figure 57: Cutting Machine
Welding workbench	Welding materials	 Figure 58: Welding Workbench
Screw tools	screwing	 Figure 59: Screwing Tools
Sanding paper and file	Sanding wood and metals	 Figure 60: Sanding paper and File

Continuation Table 18 - 3

Electric sander	Smoothing wood	 Figure 61: Electric Sander
Electric radial	Cutting and smoothing metal	 Figure 62: Electric Radial
Measuring tools	Measuring distances, lengths, etc	 Figure 63: Measuring Tools
Threading kit	Making metric threads	 Figure 64: Threading Kit

Continuation Table 18 - 4

Hammer and awl	Marking the position of the drills	 Figure 65: Hammer and Awl

7.9.2 COMPONENTS CONSTRUCTION

Described below is the construction process for each component. The detailed dimensions can be found in the drawings, in section 9.2. Besides, the reference of each component is the same as that of the list given in section 7.8.2.

- **001 - Circular base - Fig.** 66
    1. First, with the electric keyhole saw, the wood was cut with the round shape.
    2. Second, four M6 bores were made.
    3. Then, the wood was smoothed with the electric sander.
    4. Finally, the component was painted with two layers of lacquer.

Figure 66: Circular Base

- **002 - Central post - Fig.** 67
    1. First, the Ø34xØ28 mm tube was cut to the desired length.
    2. Second, four Ø6.5 mm clearances holes were made in the square metal plate.
    3. Then, it was welded to the round tube. The welding filler was sanded.
    4. After, two M6 bores were made. Above them, two Ø4.5 mm clearances holes were made.
    5. Finally, two layers of brown paint were applied.

Figure 67: Central Post

- **009 - Azimuth shaft - Fig.** 68
  1. This component was made almost entirely in the lathe machine by a technician.
  2. After the shaft was properly machined, the respective M5 and M6 threads were made.
  3. The last step was made with the M4 bore to attach the worm wheel.

Figure 68: Azimuth Shaft

- **010 - Shaft spacer - Fig.** 69
  1. For this component, it was only necessary to cut the raw material to the desired length.

Figure 69: Shaft Spacer

- **024/025/026 - Wood square profile**
  1. The wood was cut to the desired size, and filled properly.
  2. The hole positions where the screws go where made with the electric drill.

- **028 - Cross connector square profile - Fig.** 70
  1. First, the profile was cut to the desired length.
  2. Second, a M6 bore was made.
  3. Then a Ø4.5 mm hole was made where the profile is attached to the shaft. In the opposite face, a Ø15 mm hole was made as well, to fit the shaft.
  4. After, in the back, a Ø4.5 mm clearance hole was made.
  5. To finish, the profile was filled and painted with the brown paint.

Figure 70: Cross connector Square Profile

- **029 - Mirror's surface - Fig. 71**
  1. Using the electric keyhole saw, the plastic for the mirror was cut to the desired size.
  2. For the screws, two Ø4 mm holes were made, to attach the mirror to the wood profiles.

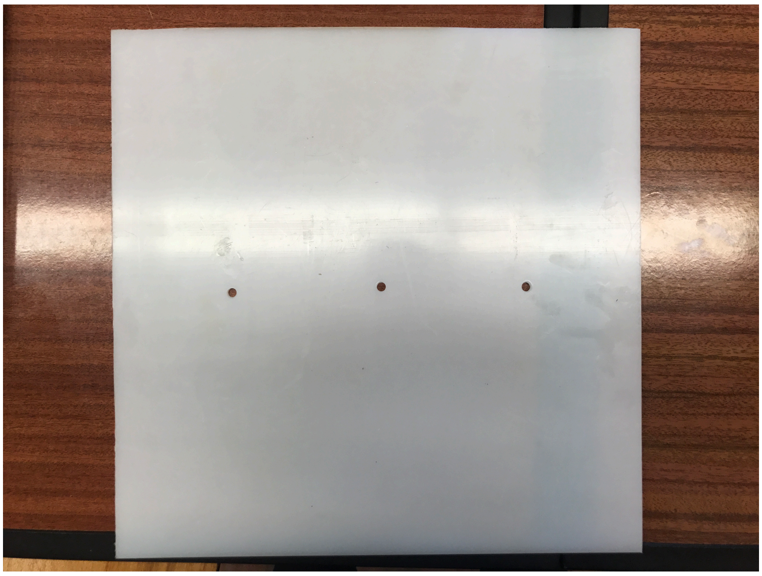


Figure 71: Mirror's Surface

- **030/047 - Articulating shafts - Fig. 72**
  1. For this component it was only necessary to cut the raw material to the desired length.

Figure 72: Articulating Shaft

- **037 - Motor coupling**
  1. First, the coupling was cut to the desired length.
  2. Second, a Ø5mm hole was made through all the component.
  3. Then, to attach it to the motor, a M4 bore was made.
  4. Finally, a M8 bore was made. The depth of this hole had to 10 mm.

- **039 - M8 threaded rod - Fig. 73**
  1. For this component, it was only necessary to cut the raw material to the desired length.

Figure 73: M8 threaded Rod

- **039 - Printed pieces**
  5. Despite the fact that the printed parts should have worked properly from the beginning, due to the lack of slack caused by shrinkage , some of them had to be either filed or drilled.

7.10 SOFTWARE DEVELOPMENT

7.10.1 INTRODUCTION

For the software development PlatformIO was used. The code is written in C++ with the use of Energia framework and is available on Github here: Suno-Heliostat repository.

7.10.2 SETUP

During the setup, all the components and interrupts are initialized and the user setup and step counter values are read from the memory. Then the DAY mode is set (if it happens during the night the system will detect it almost immediately however).

7.10.3 MAIN LOOP

The system is mainly based on several operational modes and button and end of range interrupts. The mirror takes a certain action after a specified period of time, which both depend on the current mode. The modes and actions are:

- DAY - During the day mode the sun position is recalculated and mirror is re-positioned. Also, the time is checked and compared with the sunset. If it is already after the sunset the mirror moves to the beginning position (a few steps away from the left and bottom end of range), updates the sunset and sunrise times and changes to NIGHT mode.
- END_OF_RANGE - This mode is activated when the mirror reaches the end of input and works the same as the day mode, but with a lower frequency.
- NIGHT - The system checks the time for the sunrise. When the action is triggered the mirror moves left and bottom until it reaches the end of input sensors to reset the step counters. Then the DAY mode is set and the mirror starts to follow the sun.
- EDIT - Edit mode is triggered when the user pushes the setup buttons. Then after a short delay the mirror re-positions itself and changes to DAY mode.

- MOVING – as the moving process is supposed to be synchronous this mode is turned on and off by the same moving function, therefore it is not checked in the main loop. It is used only to disable user interrupts during the mirrors movement.

Below is the flowchart of the main function (**Fig.** 74):

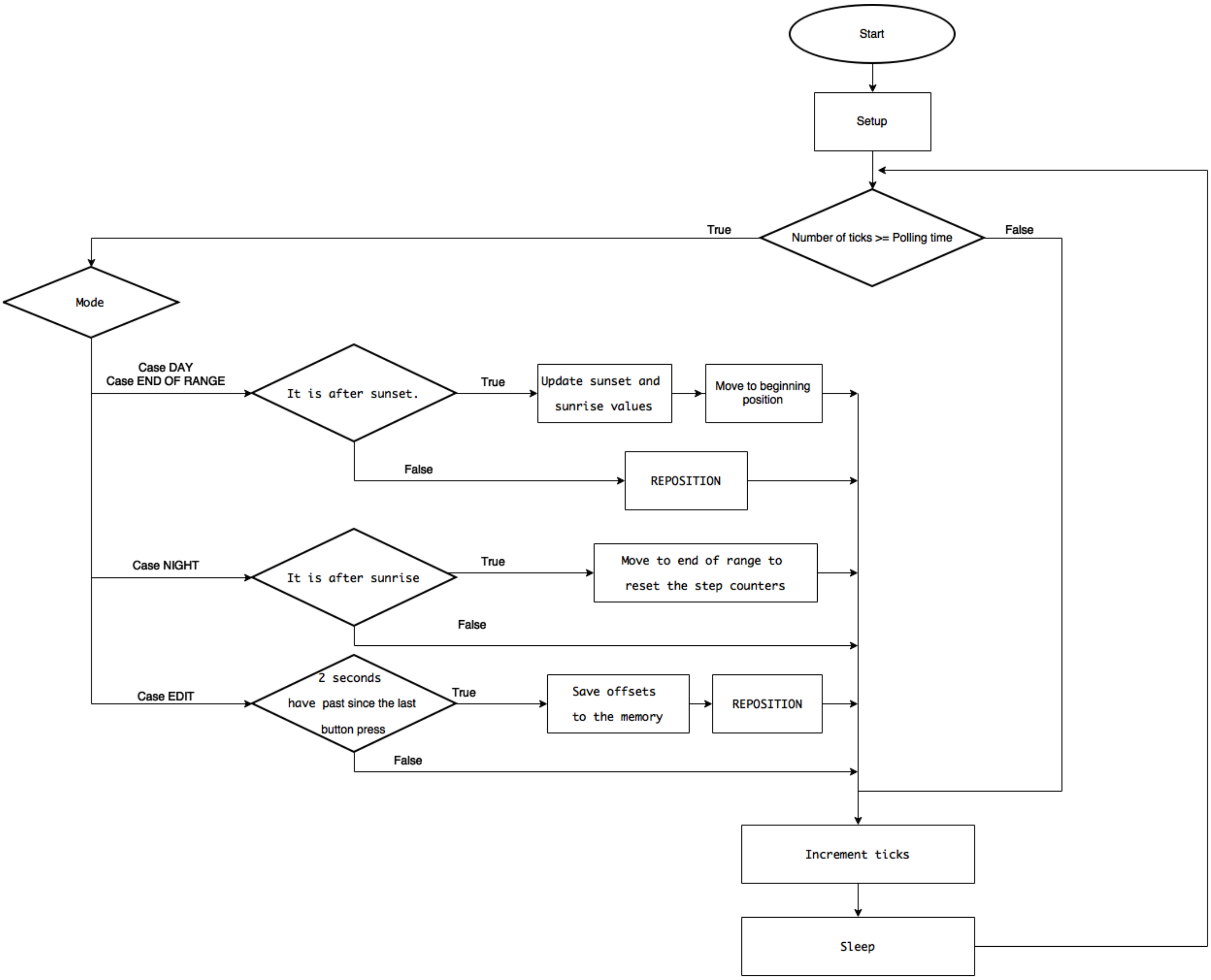


Figure 74: Main Loop

7.10.4 USER SETUP

To setup the mirrors focus point the user has to use the push buttons. It is not possible when the mirror is moving and also during the night mode, as the user would not be able to see the changes. Pressing the buttons triggers the following interrupts:

```
void setLeft() {
  PRINT("left");
  if( mirror.getMode() != Mirror::MOVING && mirror.getMode() != Mirror::NIGHT
){
    mirror.setMode(Mirror::EDIT);
    clk.updateEdittingEnd();
    mirror.setLeft();
  }
  blink(GREEN);

}
```

These functions set the mode to EDIT and update the editing end, so the user has a few seconds to press the button once again before the mirror re-positions itself. Pressing the buttons changes the offsetAngleH and offsetAngleV values which are used later to calculate the desired mirrors position. After a specified delay the offset values are saved to the EEPROM memory and the re-positioning process is started. The led blink is for the user to see some feedback and for the testing purposes. The PRINT() function is used only for the debugging and is not compiled in the production environment.

```
#ifndef DEBUG_H
#define DEBUG_H

#if DEBUG_ENABLED
#define PRINT(x) Serial.println(x); delay(20)
#define PRINT2(x,y) Serial.print(x);Serial.println(y); delay(30)
#define INIT_SERIAL() Serial.begin(9600); delay(10)
#else
#define PRINT(x) do {} while(0)
#define PRINT2(x,y) do {} while(0)
#define INIT_SERIAL() do {} while(0)
#endif

#endif
```

7.10.5 RE-POSITIONING

The re-position action shown below (**Fig.** 75) updates the desired mirror position values and moves the mirror.

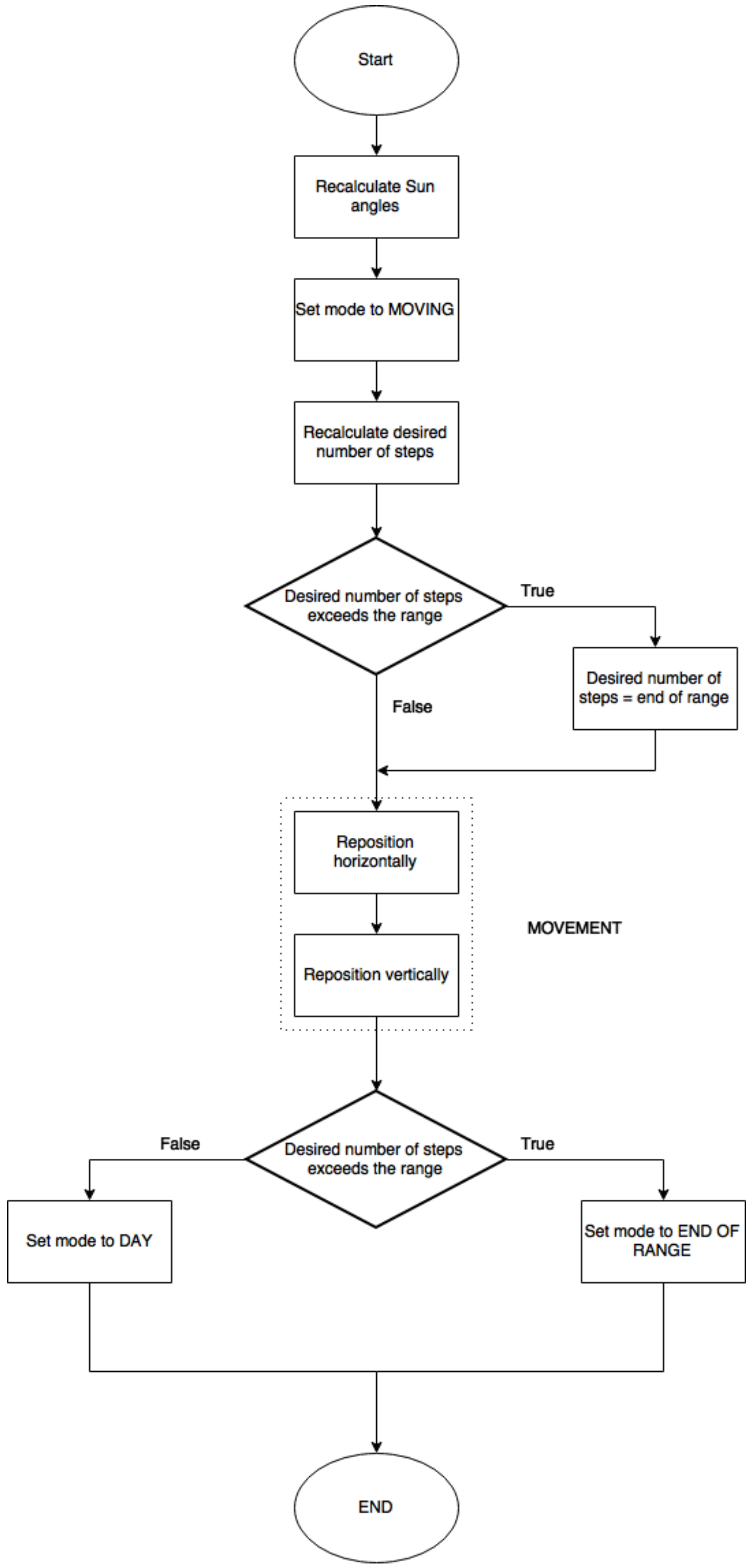


Figure 75: Repositioning

To calculate Sun altitude and azimuth angles the current time is fetched from the RTC and the NREL SPA algorithm [105] is used. Then the basic mirror angles (angles that result in focusing the light straight to the south) are calculated using the following equation:

$$Ah = \frac{Bh - 180}{2}$$

$$Av = \frac{90 - Bv}{2})$$

- Ah - basic mirror horizontal angle
- Av - basic mirror vertical angle
- Bh - Sun azimuth angle
- Bv - Sun incidence angle

Then the desired numbers of steps are calculated and move the mirror first horizontally, then vertically.

Horizontal and vertical re-positioning work in the same way, the only difference is the function that maps the step count to the mirrors angle. Below is the flowchart of the movement process (**Fig.** 76):

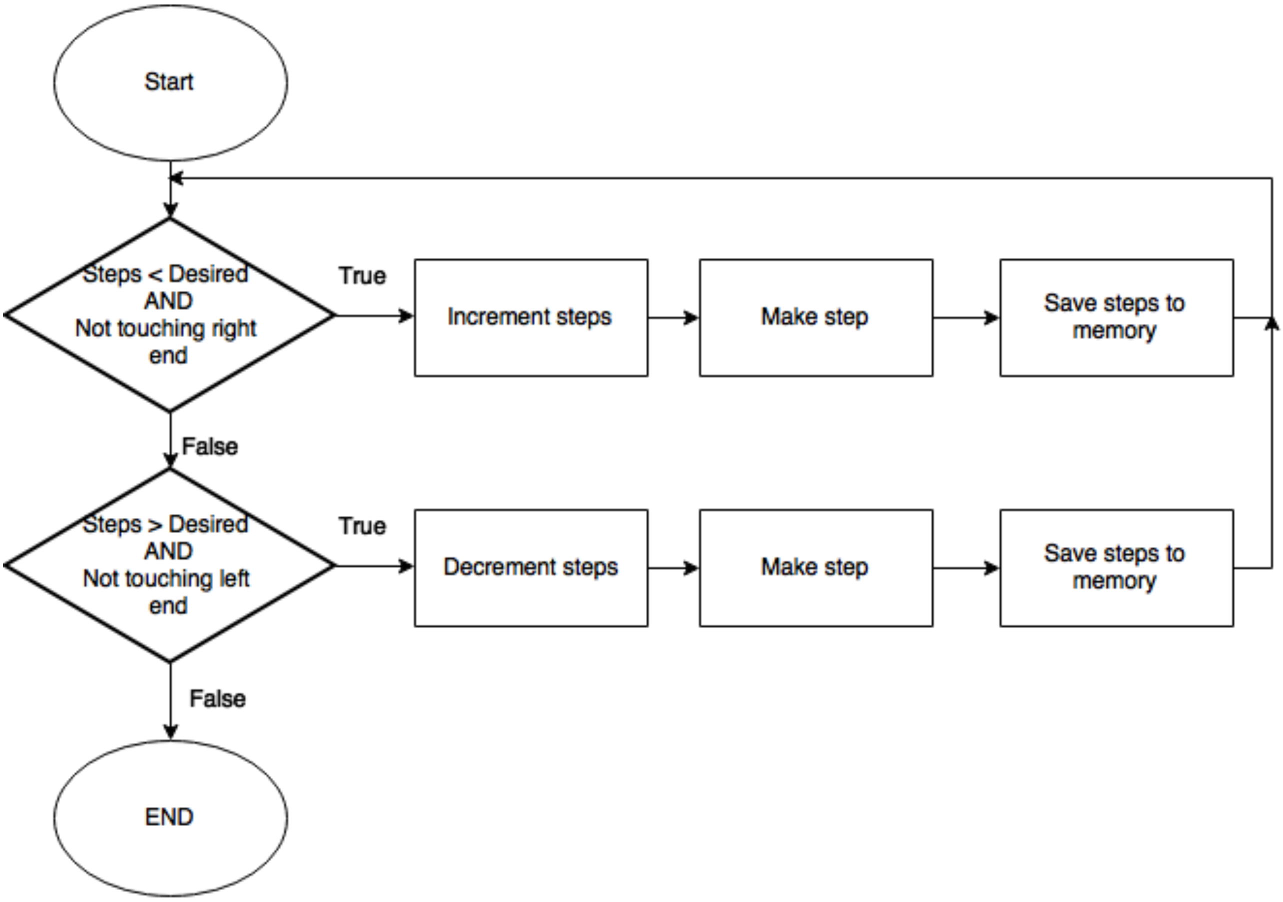


Figure 76: Movement Process

The mirror moves step by step until the desired step count is reached or until the end of range sensor is activated. The step count is saved to the memory, so that the mirror does not lose track of it, when the power is lost.

7.10.6 MIRROR ANGLE TO MOTOR TURNS MAPPING

While for the horizontal movement the dependency of the mirrors position to the number of turns that the motor has done is linear, for the vertical movement it is not. To convert the mirror angle to the desired number of steps the approximation function is needed. The bottom and top edges' positions were measured every 2 turns of the rod for the whole movement range. The difference between the two values was divided by the mirrors height and the angles were calculated by applying arcus sinus function. Then the values were transformed to get the altitude of the mirror's normal. Then the approximation function was chosen. Below (**Fig.** 77) is the plot of the calculated values (red dots) and the approximation function (blue line).

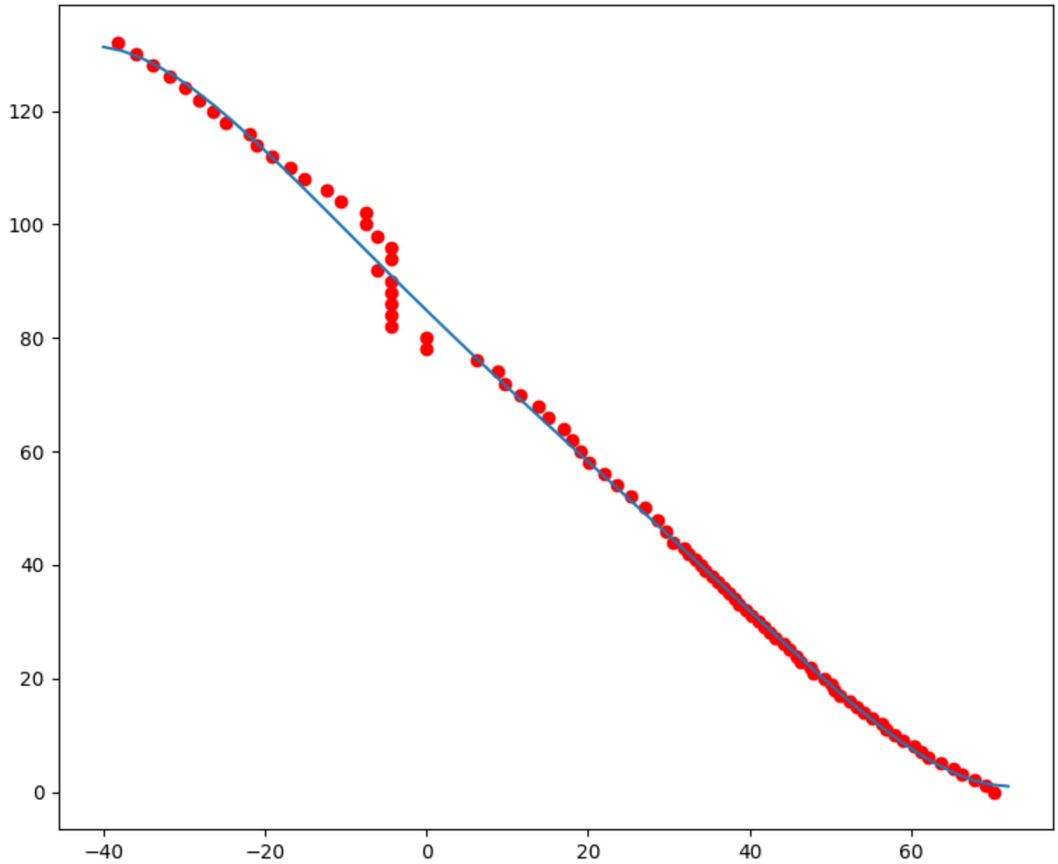


Figure 77: Angle to Turns

The big error for angles close to 0 ° is because the arcus sinus function values increase fast while approaching 90 ° (the value of 90 ° was subtracted from the calculated angles to get the altitude of the mirror's normal not the mirror itself. The function of the 5th degree was chosen to smooth out the error, as the higher degree function would fit the graph too closely. The function is then transformed so that 0 turns result in angle 0 ° and multiplied by -200 to match the step counter not the turns counter. The result function is the following: $200 * (-3.962e{-}08\, x^5 + 3.242e{-}06\, x^4 - 2.728e{-}05\, x^3 - 0.00314\, x^2 + 1.387\, x)$.

7.11 TESTS AND RESULTS

7.11.1 INTRODUCTION

Due to the complexity of the project the tests were being conducted during the whole process of the development and certain components and behaviours were checked before assembling the product.

7.11.2 COMPONENT TESTS

Each electrical component with related code has been tested separately before the final version of the software was created.

1. Motors

- **Method:** Rotating the motor shafts by a specific number of steps in both directions.
- **Expected behaviour:** Each motor should do 12 steps in one direction and then 12 steps in the opposite direction. Up to 4 first steps being improper is tolerable for each motor, as the initial polarisation is unknown.
- **Result:** Motors did 12 steps in both directions. Below is the video of the tests outcome. **Fig.** 78 shows an image of the motors during the test
- **Conclusion:** Motors rotate properly. Both the circuit and the software driving the motors are working.

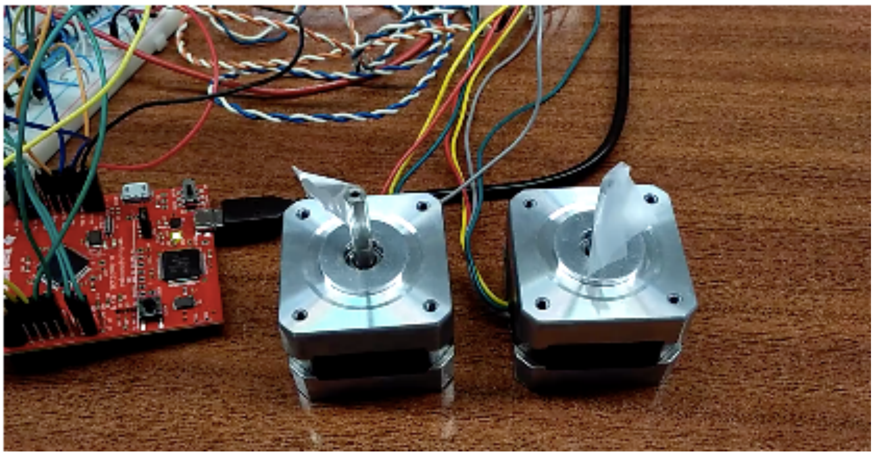


Figure 78: Motors during test

2. EEPROM Memory

- **Method:** The mirror data was printed on every controller start-up and on every change. The mirror was run several times, the step counters and offset values were checked before cutting the power off. After restarting the values were checked.
- **Expected behaviour:** After each restart the step and offset values should match exactly with the data before the restart.
- **Result:** The values printed on start-up matched the values printed on the last change before the power-off.
- **Conclusion:** All the values were properly written to and read from the memory and the data was not lost after the power-off. The software for the memory management is working properly.

3. Button/End of range sensors

- **Method:** Firing of a button or end of range sensor was signalled by an LED blink and a printed message. All the buttons and end of range sensors were pressed several times.

- **Expected behaviour:** Every button or end of range sensor press should result in an LED blink and a printed message.
- **Result:** Each time a button or end of range sensor were pressed an LED blinked and a message was printed.
- **Conclusion:** Every button and sensor triggered a proper interrupt when pressed. Buttons and end of range sensors work properly.

4. RTC

- **Method:** The clock was first set up using Arduino due to writing problems with Tiva-C. Then the time was read and printed by Tiva-C. The battery mode was checked by cutting the power off and checking the readings again after some time.
- **Expected behaviour:** The printed date and time are correct even after a power-off.
- **Result:** The time and date was printed several times, also after power-off and restart. The values were correct each time.
- **Conclusion:** The data was successfully read from the device. This indicates that the I^2C setup, the reading functions and the RTC work correctly. Time readings change properly and the device keeps track of time after a power-off.

7.11.3 SYSTEM TESTS

Before combining the control system with the hardware, the software was tested using LEDs, motors and console messages.

1. Clock and Sun Position Algorithm Tests

- **Method:** The geographical coordinates were predefined and the time was read from the RTC. The calculated data was then printed and compared with the values available on the internet.
- **Expected behavior:** The sun azimuth and altitude angles as well as the sunset and sunrise times should closely match the values checked on the following websites: https://www.timeanddate.com/sun/portugal/porto and http://www.satellite-calculations.com/Satellite/suncalc.htm
- **Result:** The sun azimuth and altitude values as well as the sunset and sunrise times were correct. Below is the console output with the data collected from the clock and calculated by the algorithm.

```
Recalculate SPA
year: 2017
month: 6
day: 1
hour: 11
minute: 28
second: 23.00
azimuth: 296.64
incidence: 32.24
sunrise: 6.13
sunset: 20.96
```

- **Conclusion:** Both the clock and the sun position algorithm work properly.

2. Independent repositioning

- **Method:** The desired angle and number of steps with the actual step count were printed. The polling mode was changed to 3 s and the systems behavior was being observed. The system was supposed to blink an LED and rotate the motor, when the change in the sun angles is enough for the next step.
- **Expected behavior:** The desired angles should update every 3 s and when the desired step values change the LED should blink and the appropriate motor should do one step.

- **Result:** The values were printed every 3 s. The Desired angles were changing slightly each time. After a few iterations the desired number of horizontal steps changed, the LED blinked and the motor made one step. Below is the console output from the moment the motor rotated.

```
stepsH: 83
stepsV: 48
desired angle H: 42.01
desired angle V: 24.26
desiredH: 84
desiredV: 48
```

- **Conclusion:** The difference between stepsH and desiredH triggered the repositioning process, as expected. The repositioning system works correctly.

3. Offset setup

- **Method:** Buttons were pressed several times and systems reaction was observed. The offset changes were printed.
- **Expected behavior:** The LED should blink and the motor should move a few steps in the desired direction, after a specific delay of pressing each button.
- **Result:** Offset values were changed on each button press. After the expected delay the LED blinked and motors rotated in the proper direction.
- **Conclusion:** The setup mechanism works properly.

4. Sunset behaviour

- **Method:** Method ISSUNSET was set to output TRUE to test if the systems behaves properly on the sunset. The end of range variables were set small to make the behaviour easier to observe. Print messages were used for that test.
- **Expected behaviour:** System should print correct sunrise and sunset times and reposition itself to the beginning of range (with a little offset, so that the end of range sensors are not yet used). As the beginning of range values were set to -8 steps, the system should stop when step counters are equal to -8 and print this value.
- **Result:** As expected the ENDOFDAY function was triggered immediately after reset. The SPA algorithm was used and the sunset and sunrise values were calculated correctly. Then the repositioning process took place to move the mirror to the specified position. The motors and LEDs stopped at the step counter values of -8 for both horizontal and vertical movement. Below is the console output describing the systems actions.

```
Hello
End of day
Recalculate SPA
Sunset:
h : 21
min : 0
Sunrise:
h : 6
min : 6
To beginning...
stepsH: 0
desiredH: -8
repositioned horizontal
stepsH: -8
stepsV: 0
desiredV: -8
repositioned vertical
stepsV: -8
```

- **Conclusion:** The BEGINING OF DAY behaviour works properly.

5. Sunrise behaviour

- **Method:** For this test both ISSUNSET and ISSUNRISE functions were set to output true, so that the ENDOFDAY and BEGINNINGOFDAY are triggered immediately after each other. The end of range sensors were activated manually at a random moment. The console output and the blinking led observed.
- **Expected behaviour:** The system should first move left until the left end of range interrupt is triggered and then do the same moving downwards. Movement should stop immediately after activating the end of range sensor. The movement is signalized by led blinks and console output. The system should print step counters with the value -20 for both axis.
- **Result:** On the BEGINNINGOFDAY function being triggered the system started repositioning itself towards the reset position. Rotating immediately stopped when the end of range interrupts were triggered. Below is the console output of the resetting process.

```
Beginning of day
To reset...
stepsH: 20
desiredH: -20
Touched left
repositioned horizontal
stepsH: -20
stepsV: 20
desiredV: -20
Touched bottom
repositioned vertical
stepsV: -20
```

- **Conclusion:** The end of range sensors stop the movement and the step counters are reset properly.

7.11.4 MOVEMENT TEST

When the hardware structure was ready the movement was tested for both axis.

- **Method:** For that test the software that rotates the motor to the direction of the pressed button was used. The buttons were pressed for over 10 s in the following order: left, right, up, down.
- **Expected behaviour:** The mirror should rotate to the specified direction on the button press.
- **Result:** The mirror was rotating to the specified direction. The mirror was not moving steadily. The vertical movement was slow. Below is the video showing the result of the test. (**Fig.** 79)
- **Conclusion:** The mirror does move, but the precision of the structure is not that high. This might be caused by a slightly crooked threaded rod and some parts not fitting each other perfectly. That might influence the precision of the system, which is however tolerable for the prototype

Figure 79: Movement test

7.12 CONCLUSIONS

After specifying precisely the product, the components and then building it, several conclusions have been drawn.

- The 3D model is a virtual representation about how the product may work. However, in reality things can go differently. Therefore, it is necessary to be realistic designing the product, according the available technology and equipment.
- During the construction process, the team realised that some of the parts of the prototype could be done in a different way. Therefore, several changes were made. This implies that some of the components that were supposed to be used were not. Therefore, other components had to be bought.
- All the changes made did not affect the electronic parts, but delayed the tests that could have been done because it took more time than expected.
- The workshop sessions helped the team to get used to working with some tools that are easily available to use at home, acquiring the necessary skills to work with them.
- At the beginning, the construction process was performed slowly. The main reason was because of the lack of experience regarding using the most of the tools that the workshop had. For instance, the technicians helped the team in some operations, such as the welding or the machining processes. For this reason, the team is aware that some of the components could be manufactured better. Even so, the team is proud of the final result, even if it is just a prototype.
- The product is slightly heavy, especially the leadscrew motor. Because of this, the product may tend to lose balance, especially when the wind is blowing. There are two possible solutions for the prototype. The first is to put more weight in the base. The second is to put a counterweight in the opposite side of the mirror.
- Because the size of the breadboard, the box is large. The size cannot be changed unless the electronics components are soldered in a breadboard cut to size.

8. CONCLUSION

By realising this report, the Team learned to work on multidisciplinary skills. They learned how to develop a product, in this case the SOSM, by first looking at what was already on the market in the State of The art. The Team learned how to manage a project by allocating the tasks, time and budget in the right way, but also by keeping in mind the risks that they could stumble upon during the project. They also kept in mind the sustainability and the ethics that play a part in developing the product. In the marketing chapter the Team developed the image of the product, they looked at the market and found where there was a gap for the product. For developing the SOSM sustainability was also considered. The product must have a long lifespan, but also use as much as possible renewable resources. Before beginning the development of the product they also looked at the ethics concerning the product and the people of the team, this in order to follow the law but also to make the right choices and to not harm anyone involved.

After all this research, the Team could start developing the product. The product started by researching how the solar mirror should move and which electronics they should use for this. Next a 3D model was designed, once this was done, the team started to build the prototype. Lastly, some tests were done, to make sure that everything worked as planned.

8.1 DISCUSSION

The goal of this project was to develop a Self-Oriented Solar Mirror (SOSM). The mirror must track the movement of the Sun and reflect the sunlight onto a predefined area. The creation of the Sun tracking system was one of the main challenges for the team. The SOSM had to detect the Sun by itself with the aid of software that knows the path of the Sun.

The Team is proud of what they accomplished, but if the Team had to do it again, the Team would do some things differently. First of all in the beginning there was a lot of indecision about the purpose of the mirror. If the Team had solved this earlier on, the Team would have had more time for the project development. Furthermore the purpose didn't really need to be decided because the automatic orientation had to be the Team's main focus.

At the end the Team lacked a little bit of time, the prototype was not finished before the report had to be handed in and so the Team couldn't do a 24 hour test. For the tests and results it would have been better to place the mirror with the software and see if it starts when the sun rises and moves during the day the way it suppose to and stops when the sun goes down.

The Team also mentioned some risks in the beginning of the report; the Team came in touch with a lot of them. During the building of the prototype, some materials arrived late, some holes were made too big/small, and the Team probably went a little over budget although the price of the 3D-printed parts is unknown.

On the other hand, the Team can certainly say that they achieved many things. Although the team members didn't know each other, the team members managed the work of 5 people. Every team member did their part and if there was a disagreement, the Team managed to solve them quickly. In the beginning of the project the Team made some rules, one of them was that every decision needs a majority of four to pass, and everyone kept that promise.

The Team lowered their environmental impact by choosing renewable resources but also by choosing to send the product unassembled. By sending the product unassembled, less transport will be needed, but also less packaging. The product can also be made solar powered; this was unfortunately not within the budget.

The Team designed a prototype and a control system; the Team built a moving structure, assembled the electrical components, developed the software and eventually finished the prototype. Although the mirror doesn't move as smoothly as the Team had wanted to, the mirror moves the right way and thus works the way it should.

8.2 FUTURE DEVELOPMENT

Working within the time and budget constraints of the EPS meant that the team focused on creating a proof-of-concept SOSM for domestic use while considering the features that the final commercial SOSM would have. One such feature would be the ability for the user to update the mirror's location using buttons on the device rather than having the device pre-set to one location only, without the possibility of editing the location easily. The team also wanted the device to be more sustainable – to be powered by a battery charged by a small solar cell instead of being powered by the mains supply. The commercial product would also have a liquid crystal display (LCD) to provide the user with information on the status of the mirror. The final product would also possibly have a larger mirror surface made from glass.

8.3 PROJECT CONCLUSIONS

The project is part of the EPS at Instituto Superior de Engenharia do Porto (ISEP) 2017. The EPS is a program that brings students together from all over Europe. The program was designed mainly for engineering students, but others can participate as well. The students are divided into small groups of five students, from different countries, and with different fields of study. The students had attend support classes on ethics, sustainability, marketing and project management. A panel of supervisors that consists of teachers from various fields supports the students.

Some of the team members' thoughts about EPS:

Anna Simons: *EPS was a very good experience for me and it was healthy for me to see what kind of person I am when I'm far away from home. I feel more secure to speak English and I think that my teamwork skills are better now. As the project is the main thing on EPS I think the focus should be more on the project, we had a lot of classes and too little time for the project. I am happy about my team and in my opinion, we have worked well together.*

Jan Latko: *EPS taught me a lot about teamwork. I learned how to compromise and accept the decisions of the group. As while working in a 5 people team one is not able to control everything going on in the project, I realised that sometimes you have to trust your team members to work efficiently. EPS also helps to develop presentation, project management and scientific writing skills. You get to search for solutions and resolve problems on your own, which teaches you how to work independently. Nevertheless, from the technical side I did not learn much, which is a major drawback if you already have a specific area of interests.*

José Hugo Valiente Saltos: *EPS is a program that has allowed me to improve different soft skills such as teamwork, communication, problem solving, etc. On the other hand, has made me realise that within a project it is necessary to consider different ethical, marketing, sustainability and organisation aspects, in order for it to be successful. Therefore, I can say that this experience has allowed me to obtain a more real world view, training me for the scientific-technological challenges that may arise in the future. The work methodology, although the load of the same has been very high, has allowed us to devote many hours to the project itself, having total freedom to take decisions.*

Margot Gutscoven: *EPS taught me to work in group with people I barely knew. You should stay positive and give them the benefit of the doubt. Also that in a project you have to think of more than just the obvious technical aspect, you have to think of marketing, project management, the ethics, etc. It also brought me out of my comfort zone of construction and showed me a little bit of programming, which in a way I find unfortunate, because I didn't always feel helpful. Nevertheless, I am glad I joined this program, I definitely made new friends, great memories and learned new things.*

Raymond Quinn: *I found the EPS a greatly rewarding experience. The opportunity to enhance my team work, communication and interpersonal skills in an international environment will prove invaluable. EPS also forced me to think about the less technical aspects of engineering project work – Ethics, Sustainability and Marketing – issues that I don't often thoroughly consider during project work. It was also rewarding to take on board the ideas of others, as often decisions I disagreed about or was unsure about turned out to be good ideas after a group discussion. My only disappointment during an enjoyable semester was that I found it difficult to apply my knowledge of power engineering to the project but this allowed me to take on other unfamiliar roles and also to learn more about electronics and computer science.*

9. APPENDICES

9.1 ELECTRIC MOTORS SIZING

One of the most important elements of the machine are the electric motors. These are responsible for providing the system with the needed energy to meet the required movement. Therefore, it will be necessary to analyse the different actions that oppose it, in order to size and select the electric motor available in the market that fits the needs. As is already known, there are two independent movements in the machine, which are discussed below.

9.1.1 AZIMUTH MOVEMENT

For the azimuth movement, those actions that oppose it are:

1. **Friction force**: The friction existing in the bearings of the mechanism, makes that part of the energy cannot be taken advantage of. For the bearings used in the same, the performance of the bearings is assumed to be around **η=0.90**.

2. **Wind load**: Wind is an important factor to consider. Depending on the speed and direction of the same and the position of the mirror as well, there will be a torque that must be countered when the whole system needs to move. To evaluate the effect of the same, EuroCode 1 will be used as a guide [103].

The wind force F_w acting in the surface of the mirror can be determined directly by using the **Eq.** [1] :

$$F_w(N) = c_s c_d \cdot c_f \cdot S_f \cdot q_p \cdot A_{ref} \quad [1]$$

Where:

- $c_s c_d$–Structural factor
- c_f–Force factor for the structural element
- q_p–Peak velocity pressure
- A_{ref}–Wind acts' area
- S_f–Security factor

The detailed procedure for calculating $c_s c_d$ factor can be done applying the **Eq.** [2] :

$$c_s c_d = \frac{1+2\cdot k_p \cdot z_s \cdot \sqrt{B^2+R^2}}{1+7\cdot z_s} \quad [2]$$

However, for buildings or structures with a height less than 15m the value of $c_s c_d$ may be taken as 1.

- The c_f factor may be taken as 1.
- The S_f factor consider another action that cannot be controlled by the designer. Thus, it is important to oversize the structure, in order to avoid the failure of the same. As design factor, S_f is going to be taken as 2.
- The peak velocity pressure q_p should be determined following the **Eq.** [3]:

$$q_p\left(\frac{N}{m^2}\right) = \frac{1}{2} \cdot \rho \cdot v_b^2 \quad [3]$$

Where:

- ρ –Air density (The recommended value is 1.25 kg/m^3)

- υ_b–Wind velocity (ms)

The wind velocity design is taken as 25.00 m/s, which is the yellow limit warning in Portugal [104]. According the **Eq.** [3], the value of q_p is:

$$q_p\left(\frac{N}{m^2}\right) = \frac{1}{2} \cdot 1.25 \cdot 25.00^2 = 390.63\,\frac{N}{m^2}$$

The A_{ref} area is the total area where the wind acts. It can be calculated by the **Eq.** [4] :

$$A_{ref}(m^2) = b \cdot h \quad [4]$$

Where:

- b–Height of the mirror
- h–Length of the mirror

Applying the **Eq.** [4] A_{ref} is equal to:

$$A_{ref} = 0.40\ m \cdot 0.40\ m = 0.16\ m^2$$

Once explained how to determine all the factors involved in the **Eq.** [1], it is possible to determine the wind force F_w:

$$F_w(N) = 1 \cdot 2 \cdot 0.16 \cdot 390.63 = 125.00\ N$$

The application's point force *e* is, according to **Eq.** [5], at a distance of:

$$e = \frac{h}{10} = \frac{0.40\ m}{10} = 0.04\ m \quad [5]$$

Therefore, the necessary torque to move the system in azimuth is, according the **Eq.** [6] :

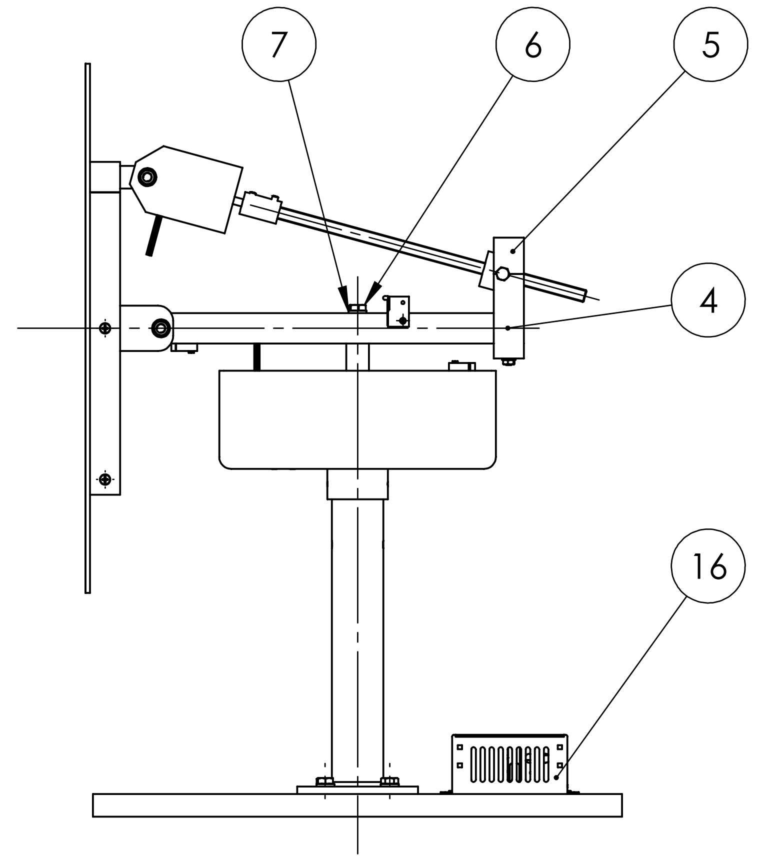
$$M_T(Nm) = F_w \cdot e = 125.00 \cdot 0.04 = 5.00\ Nm \qquad [6]$$

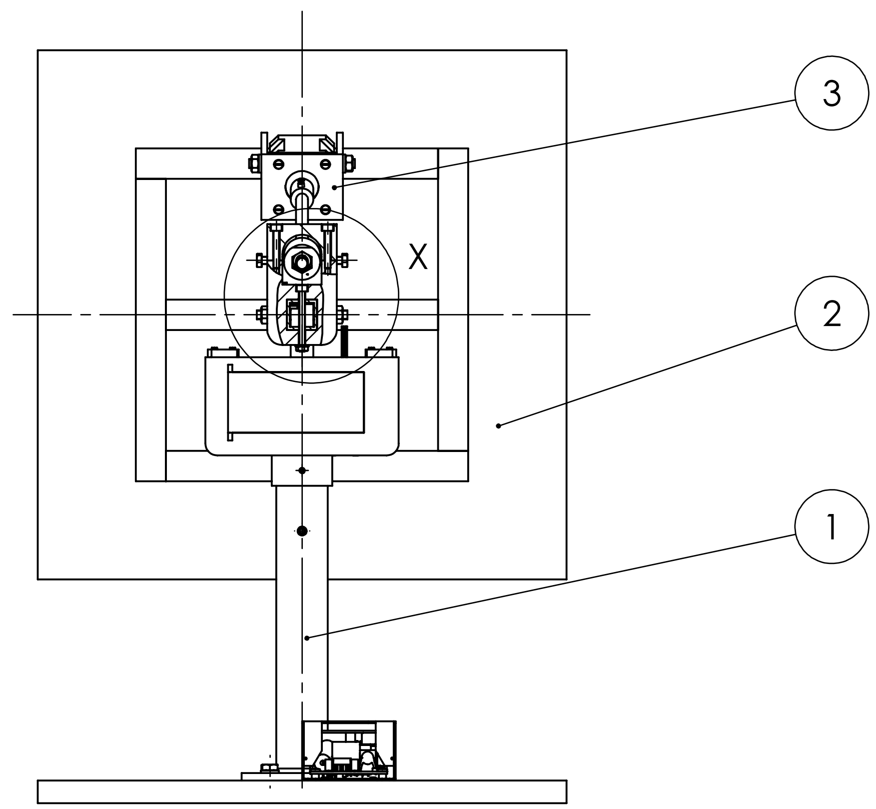
Considering the losses due to friction in the bearings discussed above, the torque needed at the output of the shaft, according the **Eq.** [7], is equal to:

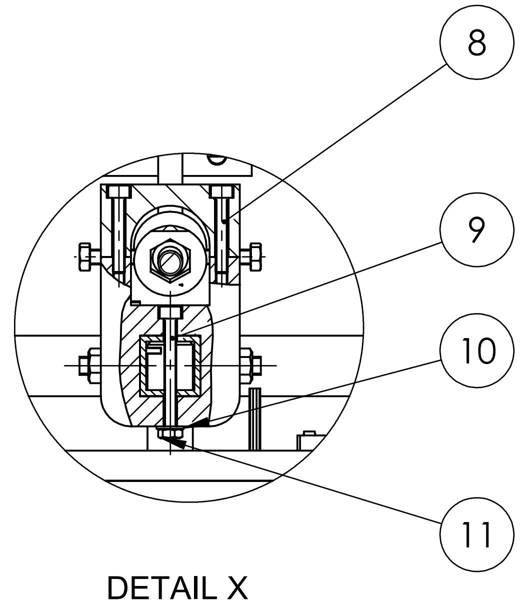
$$M_{T_r}(Nm) = \frac{M_T}{\eta} = \frac{5.00}{0.90} = 5.56\ Nm \quad [7]$$

It should be noted that this the torque needed **at the output of the azimuth shaft**. Because in order to transmit the movement from the motor to the axis a worm gear is used, the electric motor's torque is calculated taking into account this gear's reduction rate, ***i***. The same. according the **Eq.** [8], is equal to:

$$M_{em}(Nm) = \frac{M_{T_r}}{i} = \frac{5.56}{20.00} = 280.00\ mNm \quad [8]$$







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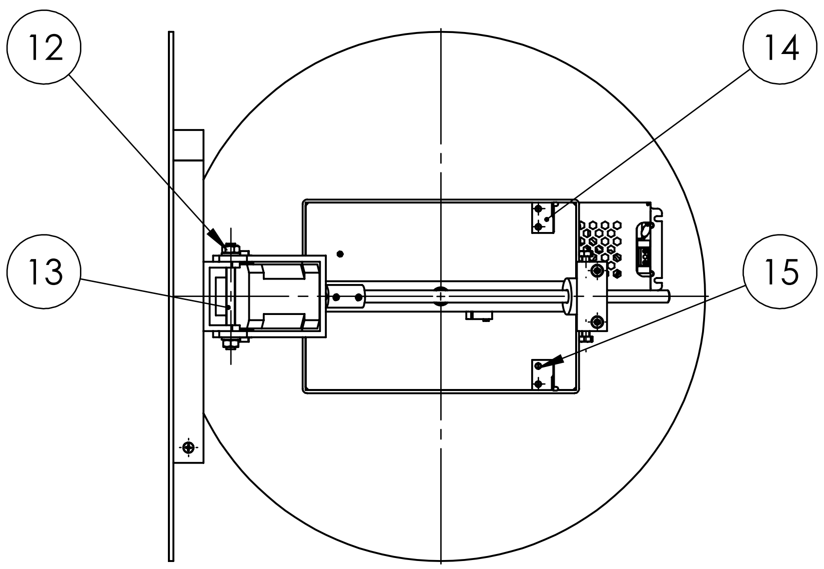

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8	T3.99.18	DIN 912	9120425	2
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6	T3.99.01	DIN 933	93380616ZN	1
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3	T3.04.00.A			1
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SUNO

isep Instituto Superior de Engenharia do Porto

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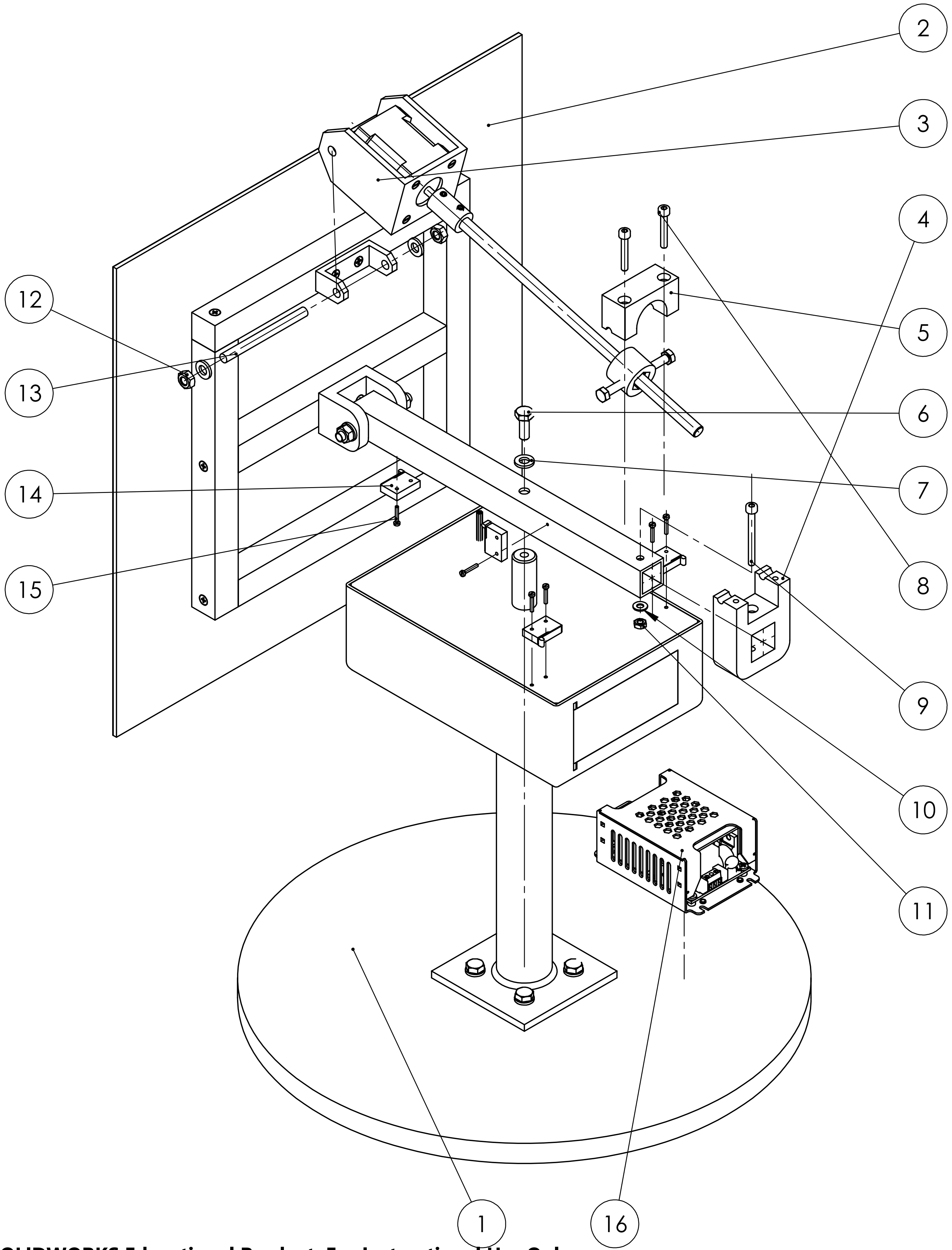

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12	T3.99.12	DIN 934	934M06ZN	2
11	T3.99.20	DIN 934	934M04Z	1
10	T3.99.09	DIN 125a	ANC04ZN	1
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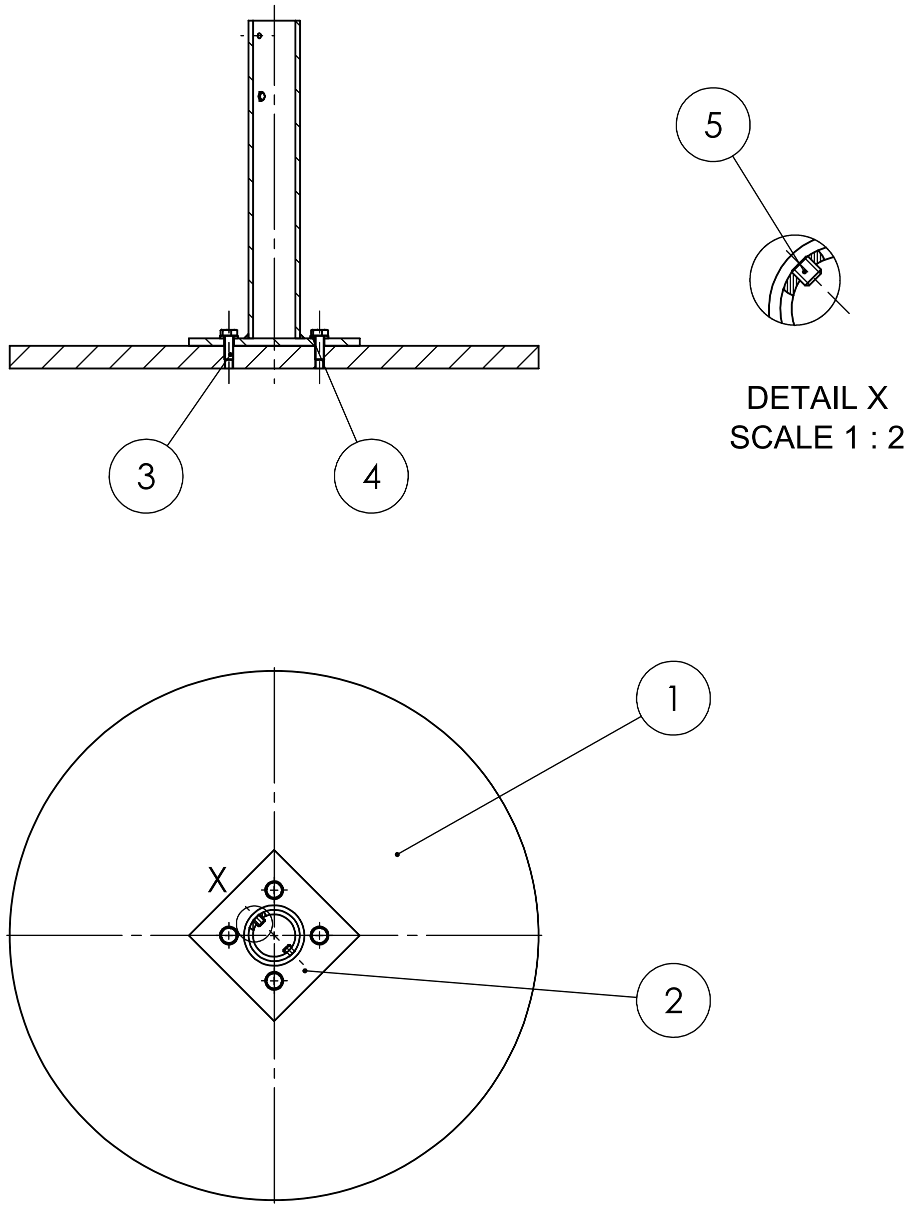

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Replace at		Replaced by	
	Name	Date	

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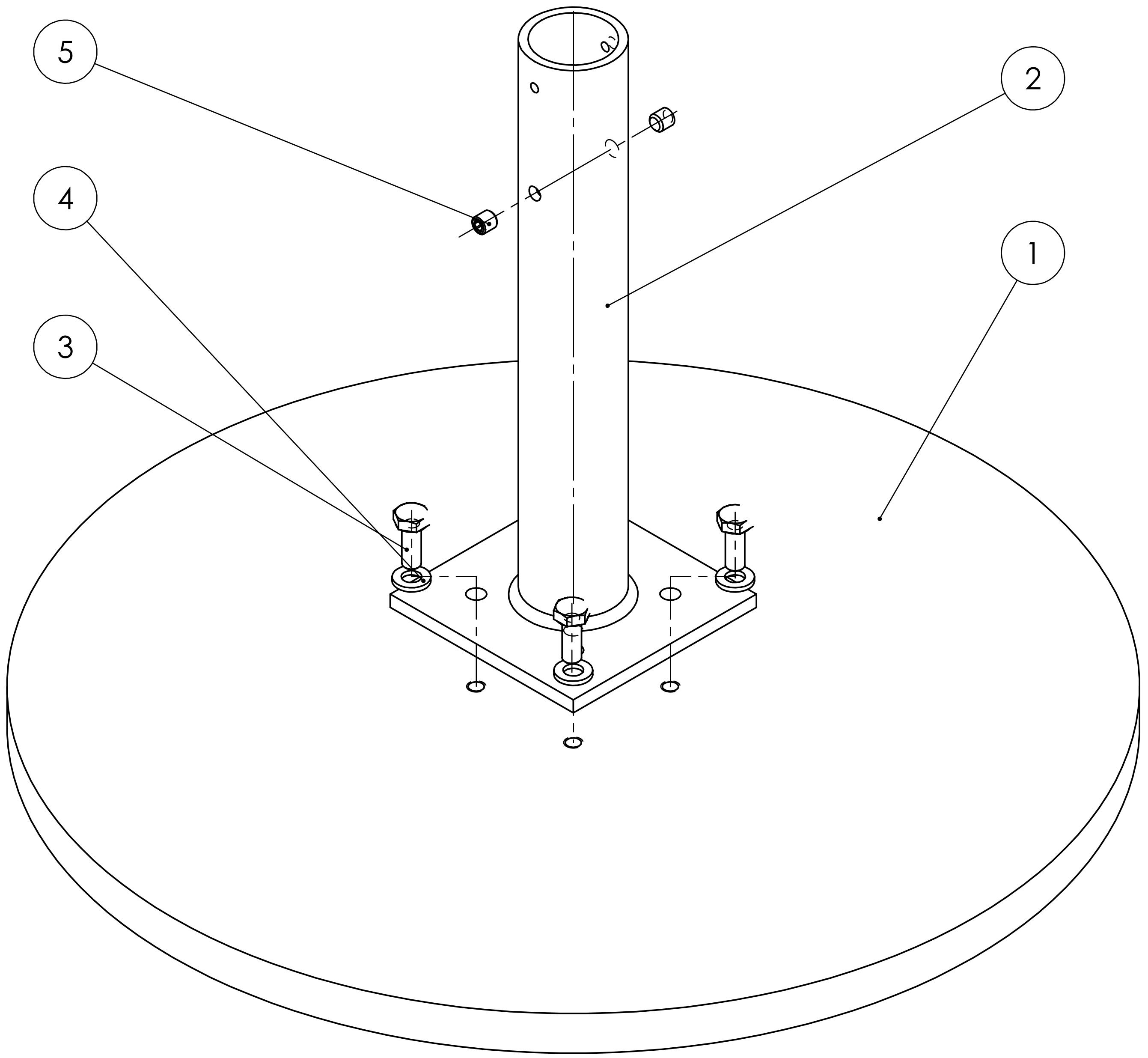

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SUNO

isep Instituto Superior de Engenharia do Porto

Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
Central Structure

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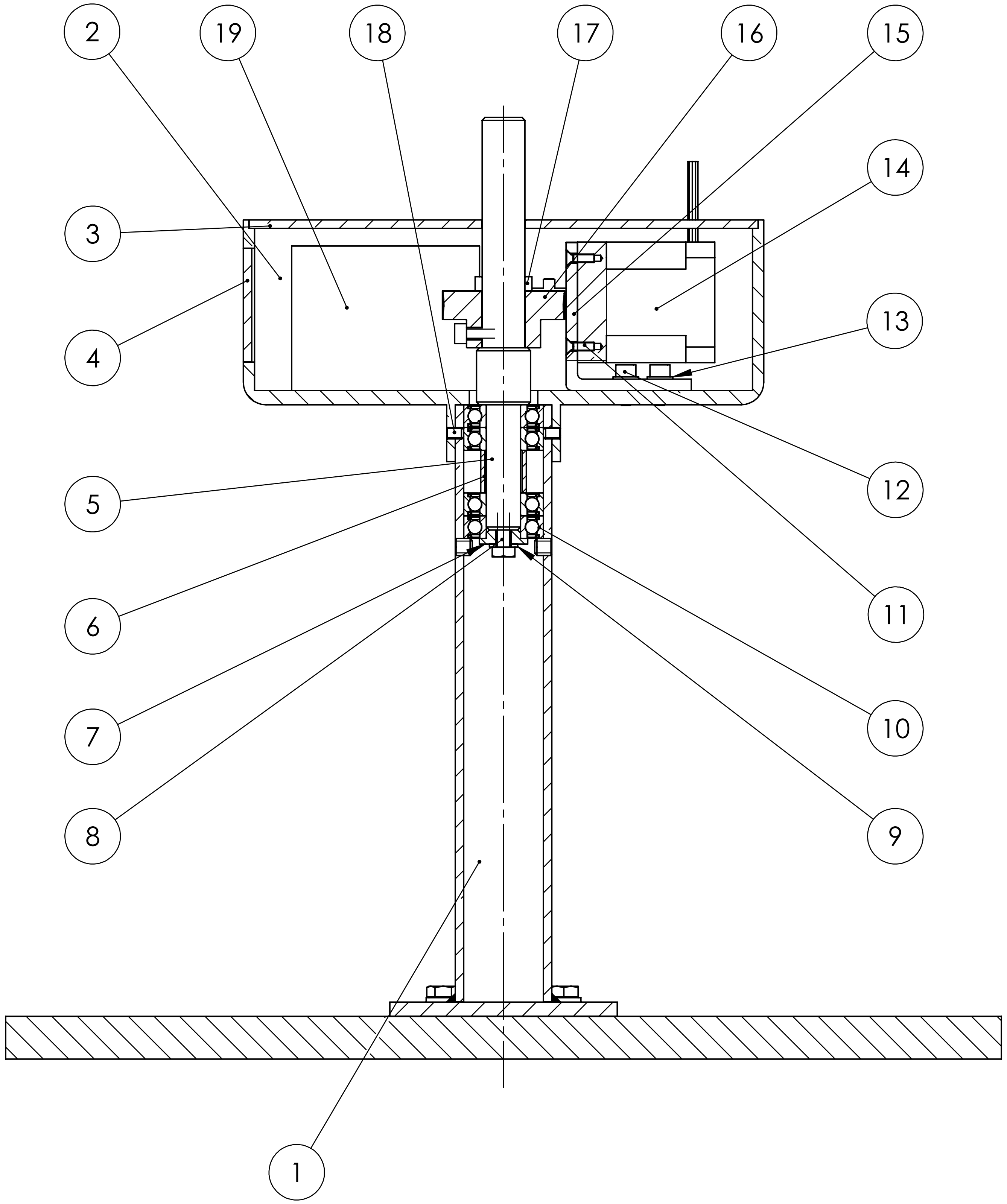

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			Sheet's name: **Central Structure + Central Box**			
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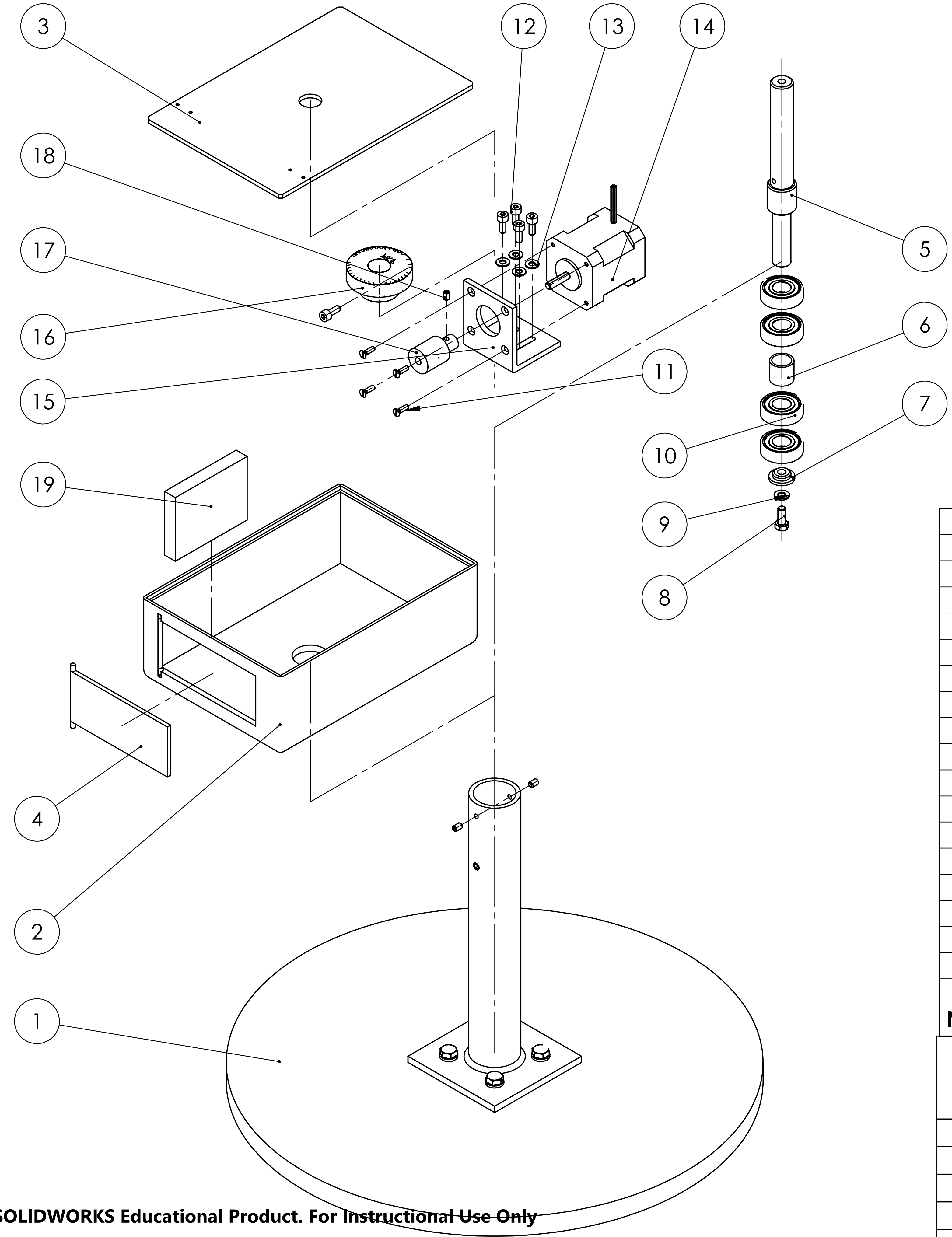

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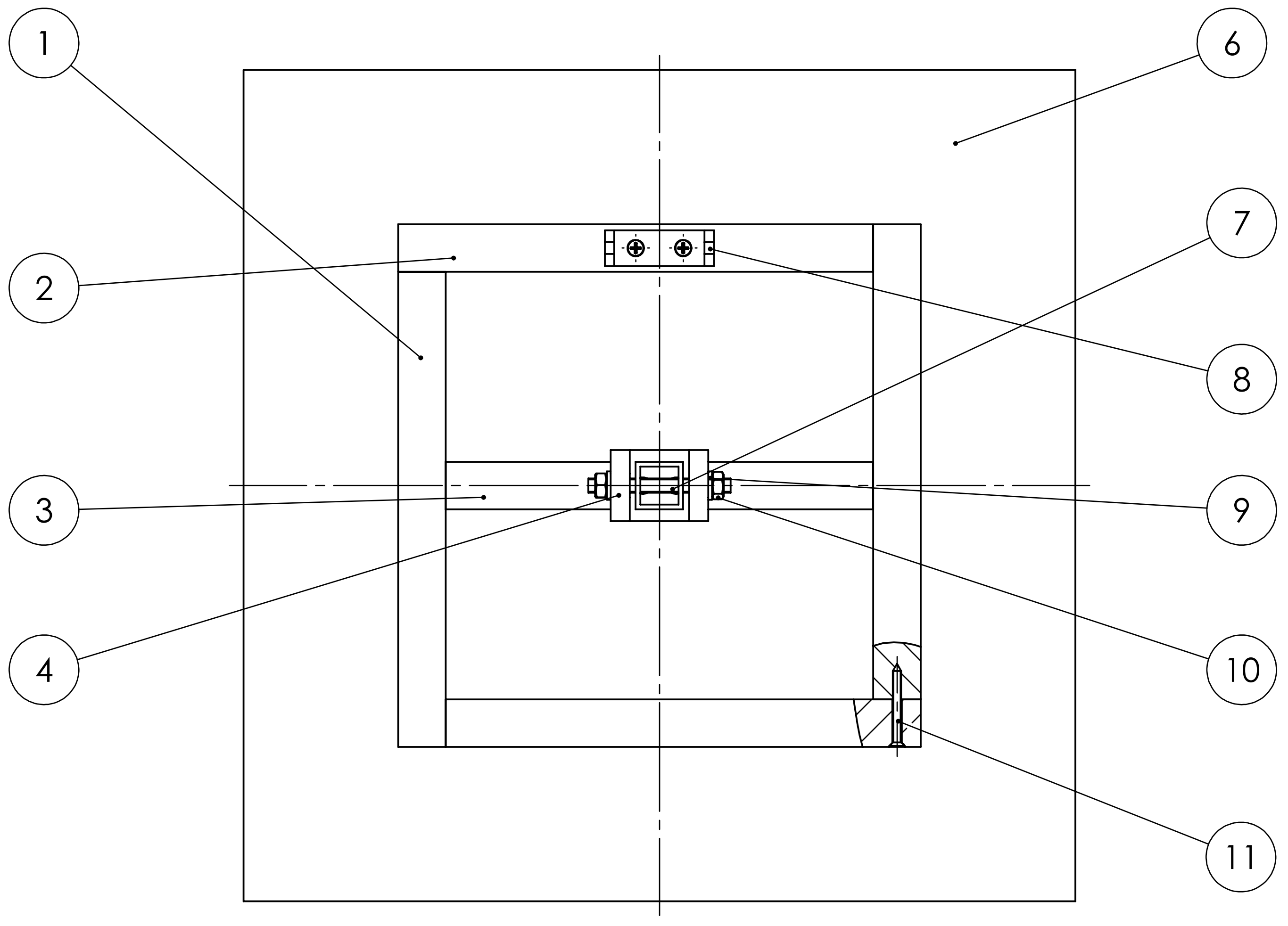
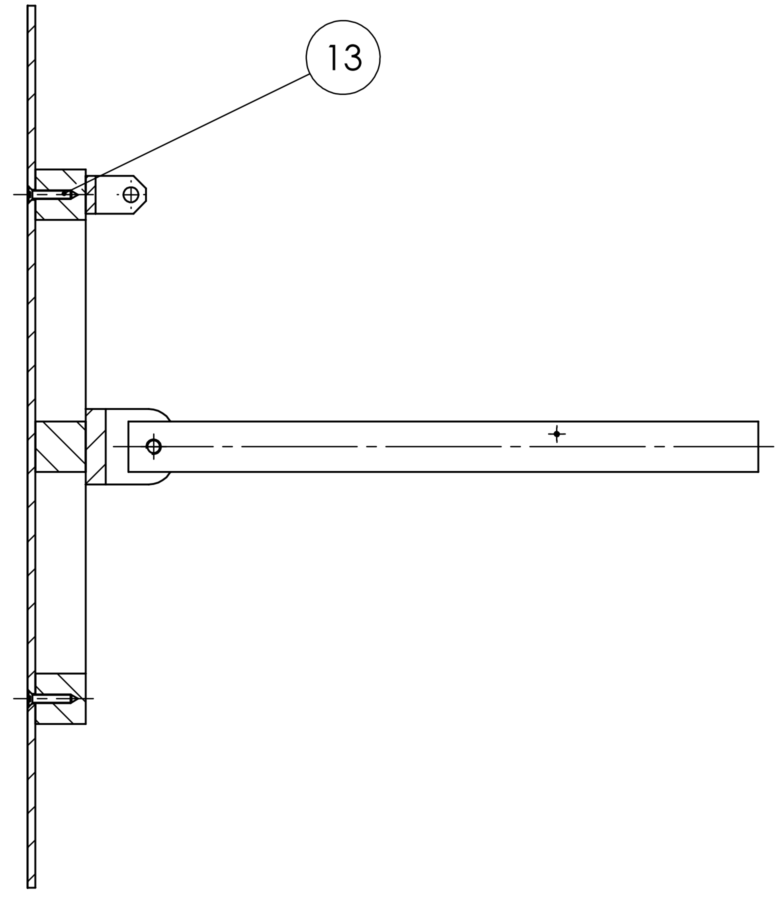
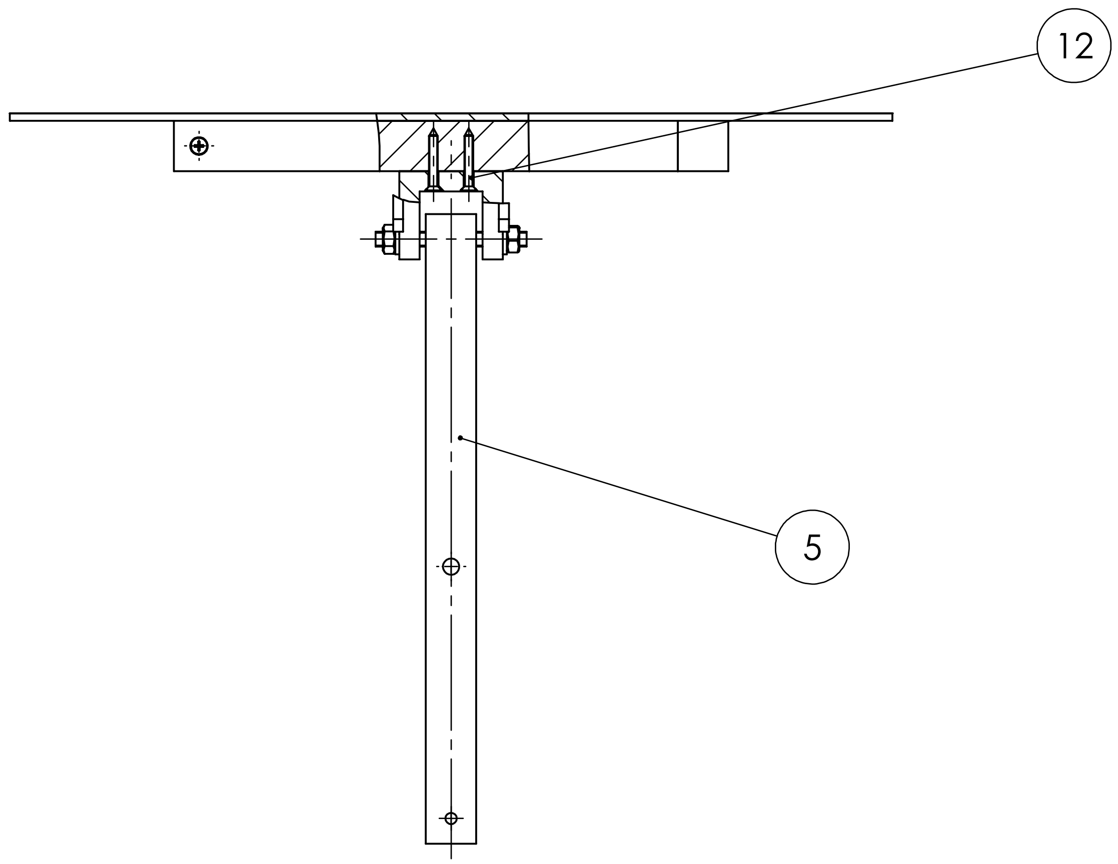
18	T3.99.11	DIN 916	PER0406	3
17	T3.02.09.A	PLA	ISEP@3DPRINT03	1
16	T3.02.08.A	PLA	ISEP@3DPRINT02	1
15	T3.02.07.A	PLA	ISEP@3DPRINT01	1
14	T3.99.10	NEMA 17	MTR-DC17T-275-F	1
13	T3.99.09	DIN 125a	ANC04ZN	4
12	T3.99.08	DIN 933	91280410	5
11	T3.99.07	DIN 963	09630310Z	4
10	T3.99.06	DIN 625	T6001-ZZ	4
9	T3.99.05	DIN 125a	ANC05ZN	1
8	T3.99.04	DIN 933	93380512ZN	1
7	T3.02.06.A	PP	ISEP@WS08	1
6	T3.02.05.A	Aluminium	ISEP@WS07	1
5	T3.02.04.A	AISI 1015	ISEP@WS06	1
4	T3.02.03.A	PP	ISEP@WS05	1
3	T3.02.02.A	PP	ISEP@WS04	1
2	T3.02.01.A	PP	ISEP@WS03	1
1	T3.01.00.A			1

SUNO	isep Instituto Superior de Engenharia do Porto		Project's name: **Self-Oriented Solar Mirror (SUNO)**			
			Sheet's name: **Central Structure + Central Box**			
Nº of sheet	**T3.02.00.B**					
Replace at			Replaced by			
	Name	Date	Weight	Format	Scale	Sheet 6 of 10 sheets
Drawn	**EPS TEAM 3**	**18/06/2017**	**2496.81**	A3	**1:3**	
Checked						







N.º	N.º of sheet	Material (Standard)	Component reference	Qty.
13	T3.99.15	DIN 7982	79823519	4
12	T3.99.14	DIN 7982	79823525	2
11	T3.99.13	DIN 7982	79823535	6
10	T3.99.12	DIN 934	934M06ZN	2
9	T3.99.02	DIN 125a	ANC06ZN	2
8	T3.03.08.A	PLA	ISEP@3DPRINT05	1
7	T3.03.07.A	DIN 975	ISEP@WS14	1
6	T3.03.06.A	LDPE	ISEP@WS13	1
5	T3.03.05.A	AISI 1015	ISEP@WS12	1
4	T3.03.04.A	PLA	ISEP@3DPRINT04	1
3	T3.03.03.A	Pine tree	ISEP@WS11	1
2	T3.03.02.A	Pine tree	ISEP@WS10	2
1	T3.03.01.A	Pine tree	ISEP@WS09	2

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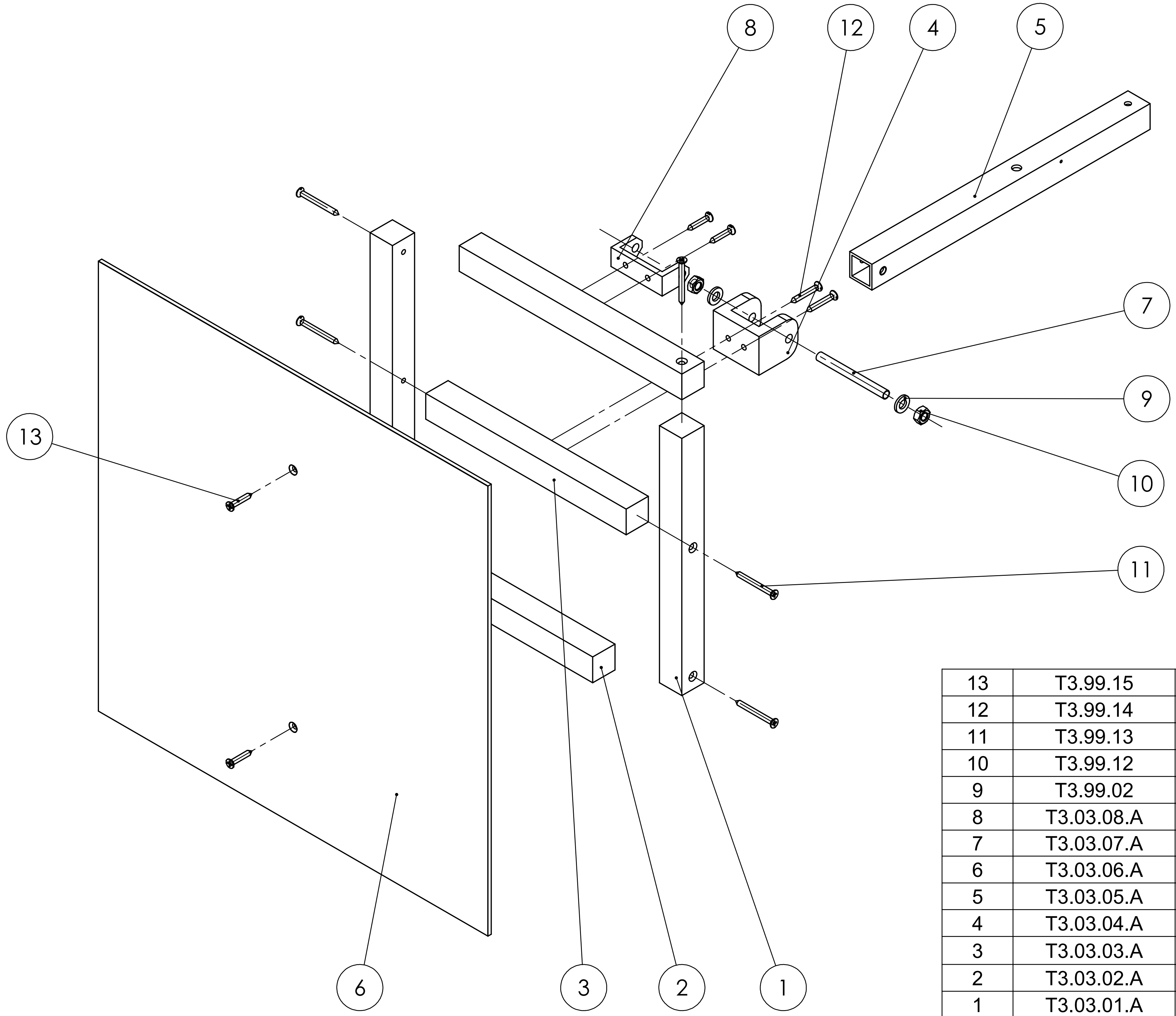
Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
Mirror Assembly

Nº of sheet	**T3.03.00.A**		Replaced by				
Replace at							
	Name	Date	Weight	Format	Scale	Sheet 7 of 10 sheets	
Drawn	**EPS TEAM 3**	**18/06/2017**	**808.74**	A3	**1:3**		
Checked							

SOLIDWORKS Educational Product. For Instructional Use Only



N.º	N.º of sheet	Material (Standard)	Component reference	Qty.
13	T3.99.15	DIN 7982	79823519	4
12	T3.99.14	DIN 7982	79823525	2
11	T3.99.13	DIN 7982	79823535	6
10	T3.99.12	DIN 934	934M06ZN	2
9	T3.99.02	DIN 125a	ANC06ZN	2
8	T3.03.08.A	PLA	ISEP@3DPRINT05	1
7	T3.03.07.A	DIN 975	ISEP@WS14	1
6	T3.03.06.A	LDPE	ISEP@WS13	1
5	T3.03.05.A	AISI 1015	ISEP@WS12	1
4	T3.03.04.A	PLA	ISEP@3DPRINT04	1
3	T3.03.03.A	Pine tree	ISEP@WS11	1
2	T3.03.02.A	Pine tree	ISEP@WS10	2
1	T3.03.01.A	Pine tree	ISEP@WS09	2

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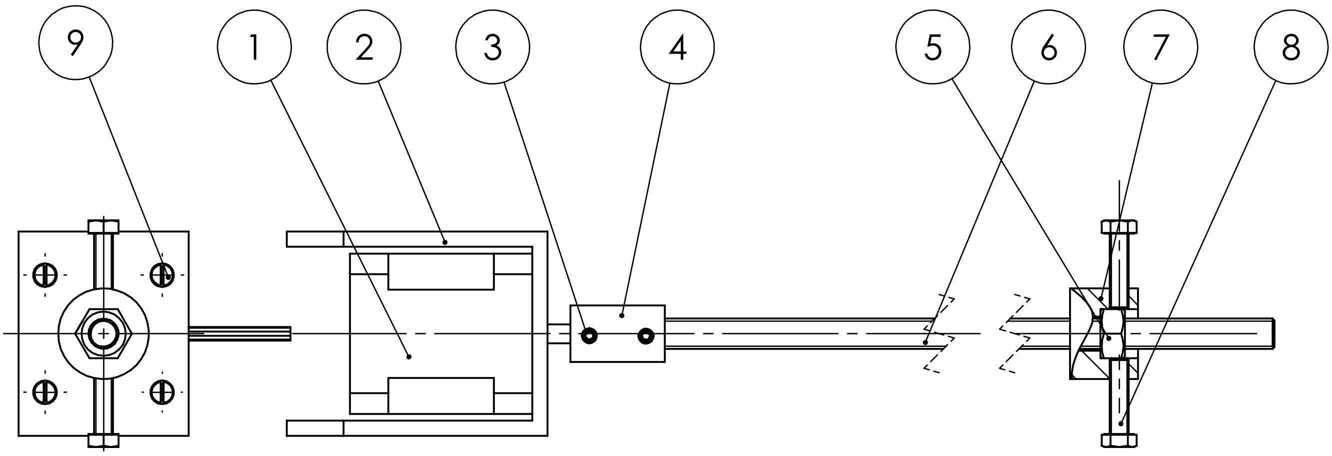
Project's name	Self-Oriented Solar Mirror (SUNO)	
Sheet's name	Mirror Assembly	
Nº of sheet	T3.00.00.B	
Replace at		Replaced by

	Name	Date	Weight	Format	Scale	
Drawn	EPS TEAM 3	18/06/2017	808.74	A3	1:3	Sheet 8 of 10 sheets
Checked						



9	T3.99.07	DIN 963	09630310Z	4
8	T3.99.17	DIN 933	93380520ZN	2
7	T3.04.04.A	PLA	ISEP@3DPRINT07	1
6	T3.04.03.A	DIN 975	14858473	1
5	T3.99.16	DIN 934	934M08ZN	1
4	T3.04.02.A	AISI 1015	ISEP@WS15	1
3	T3.99.11	DIN 916	PER0406	2
2	T3.04.01.A	PLA	ISEP@3DPRINT06	1
1	T3.99.10	NEMA 17	MTR-DC17T-275-F	1
N.º	**N.º of sheet**	**Material (Standard)**	**Component reference**	**Qty.**

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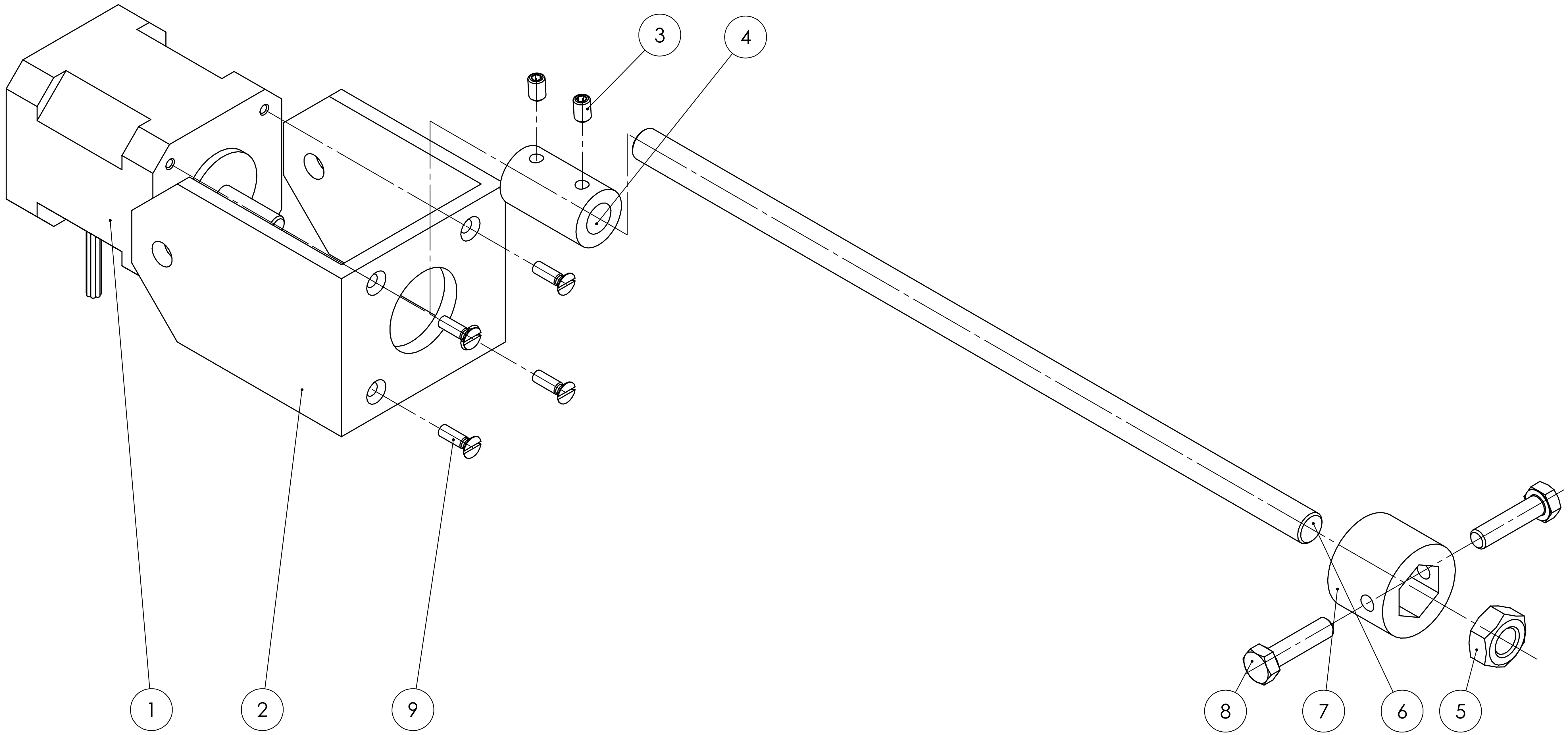
Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
Leadscrew Assembly

Nº of sheet	**T3.04.00.A**						
Replace at			Replaced by				
	Name	Date	Weight	Format	Scale	Sheet 9 of 10 sheets	
Drawn	**EPS TEAM 3**	**18/06/2017**	**372.92**	A4	**1:2**		
Checked							



N.º	N.º of sheet	Material (Standard)	Component reference	Qty.
9	T3.99.07	DIN 963	09630310Z	4
8	T3.99.17	DIN 933	93380520ZN	2
7	T3.04.04.A	PLA	ISEP@3DPRINT07	1
6	T3.04.03.A	DIN 975	14858473	1
5	T3.99.16	DIN 934	934M08ZN	1
4	T3.04.02.A	AISI 1015	ISEP@WS15	1
3	T3.99.11	DIN 916	PER0406	2
2	T3.04.01.A	PLA	ISEP@3DPRINT06	1
1	T3.99.10	NEMA 17	MTR-DC17T-275-F	1

SUNO

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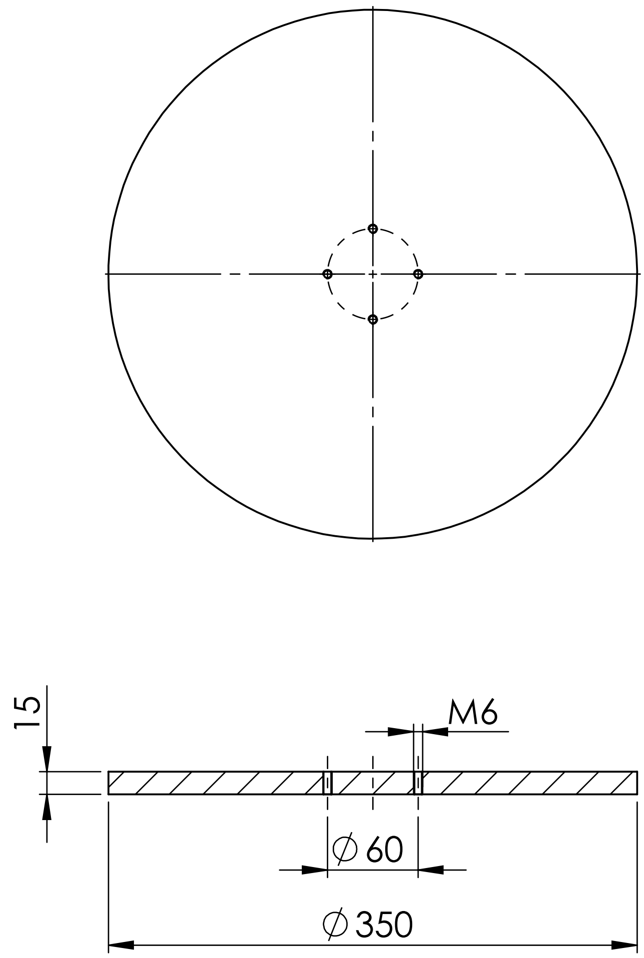
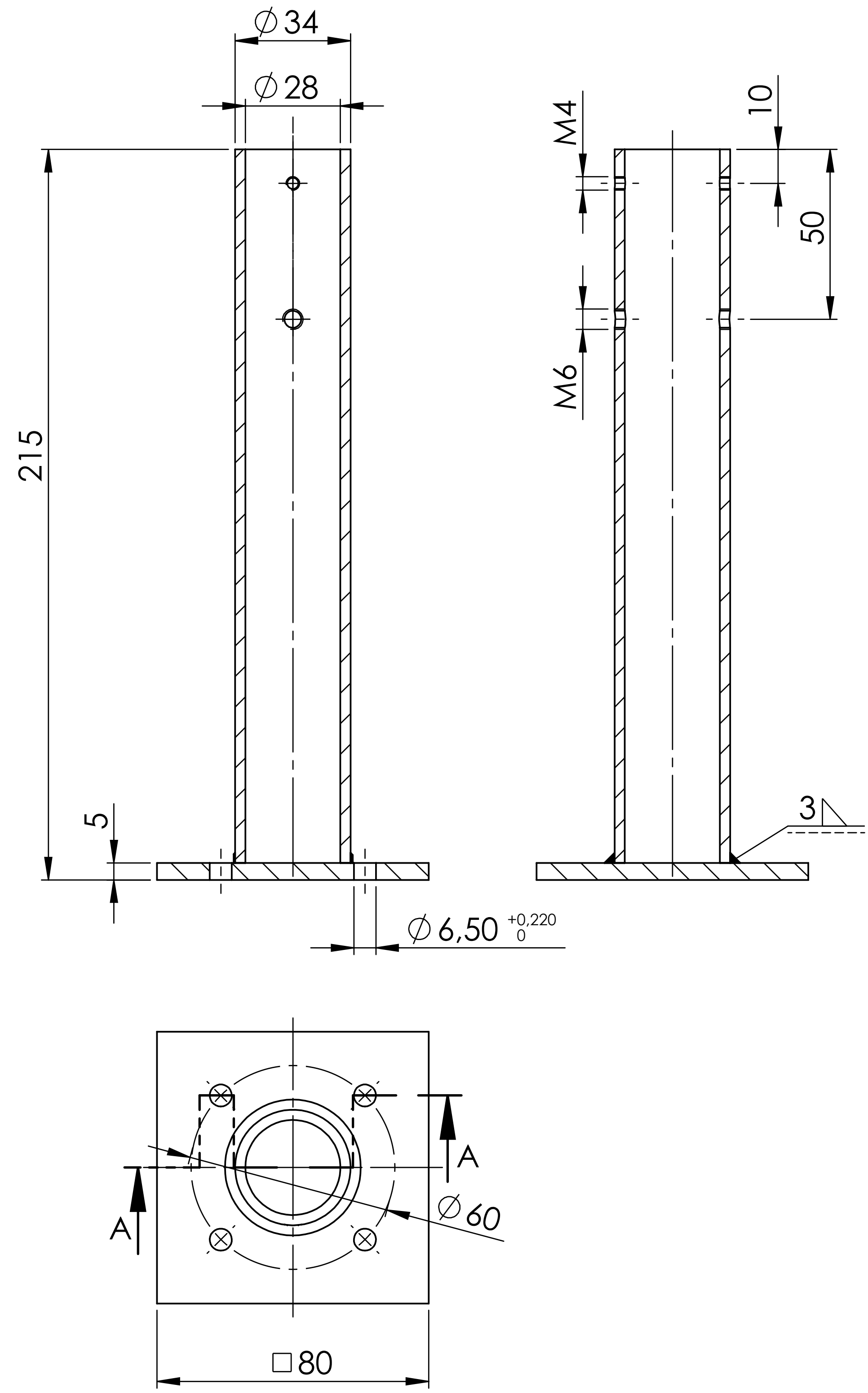
Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
Leadscrew Assembly

Nº of sheet	**T3.04.00.B**						
Replace at			Replaced by				
	Name	Date	Weight	Format	Scale	Sheet 10 of 10 sheets	
Drawn	**EPS TEAM 3**	**18/06/2017**	**372.92**	A3	**1:1**		
Checked							



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m					
	Name		Date			
Drawn	EPS TEAM 3		18/06/2017			
Checked				Project's name: **Self-Oriented Solar Mirror (SUNO)**		
Nº of sheet	T3.01.01.A					
Replace at				Sheet's name: **Circular base**		
Replaced by						
Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 1 of 26 sheets
Pine tree	**Exterior varnish**		**490.28**	A4	1:5	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.01.02.A**	
Replace at		
Replaced by		

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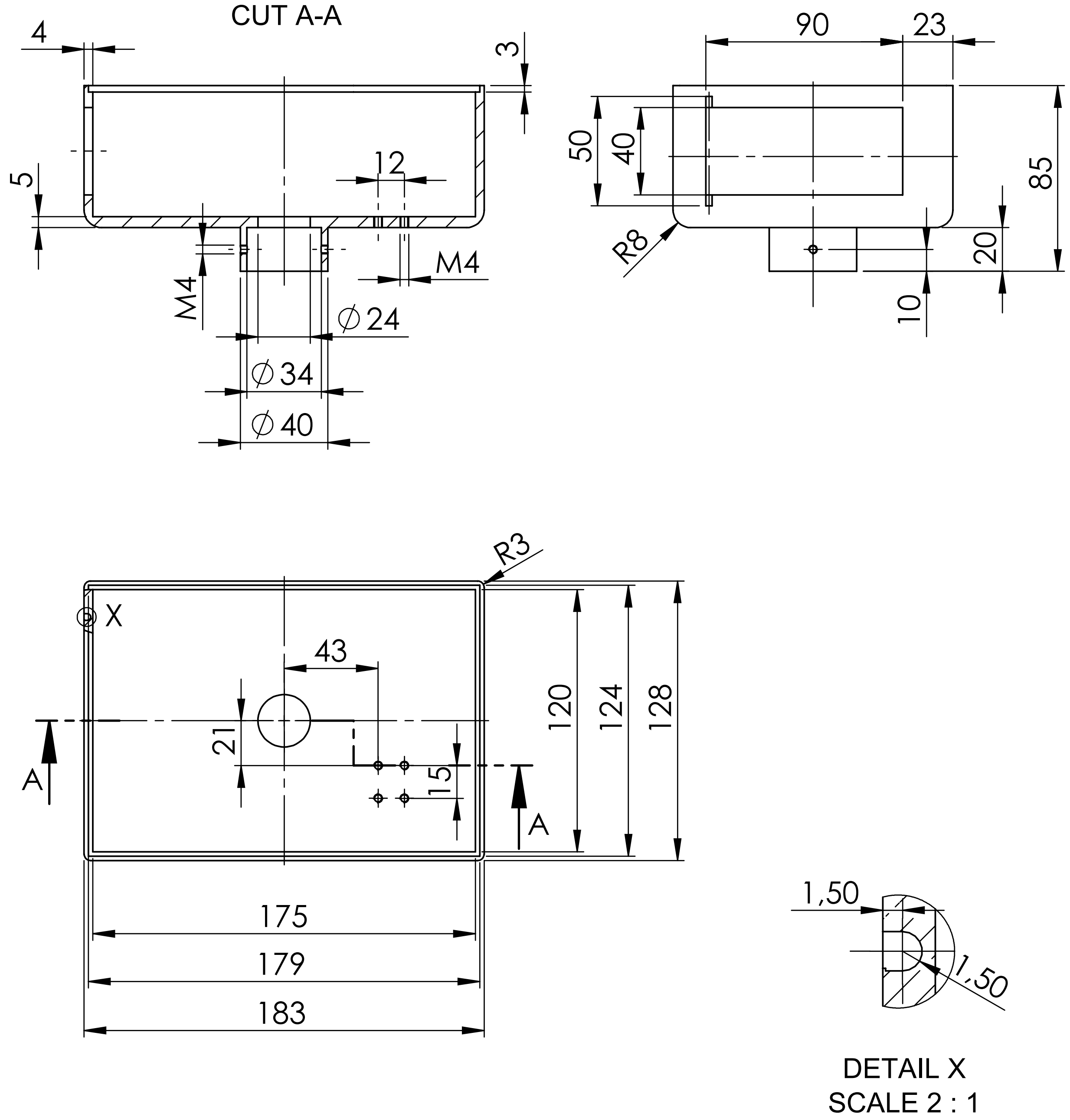
SUNO

Project's name
Self-Oriented Solar Mirror (SUNO)

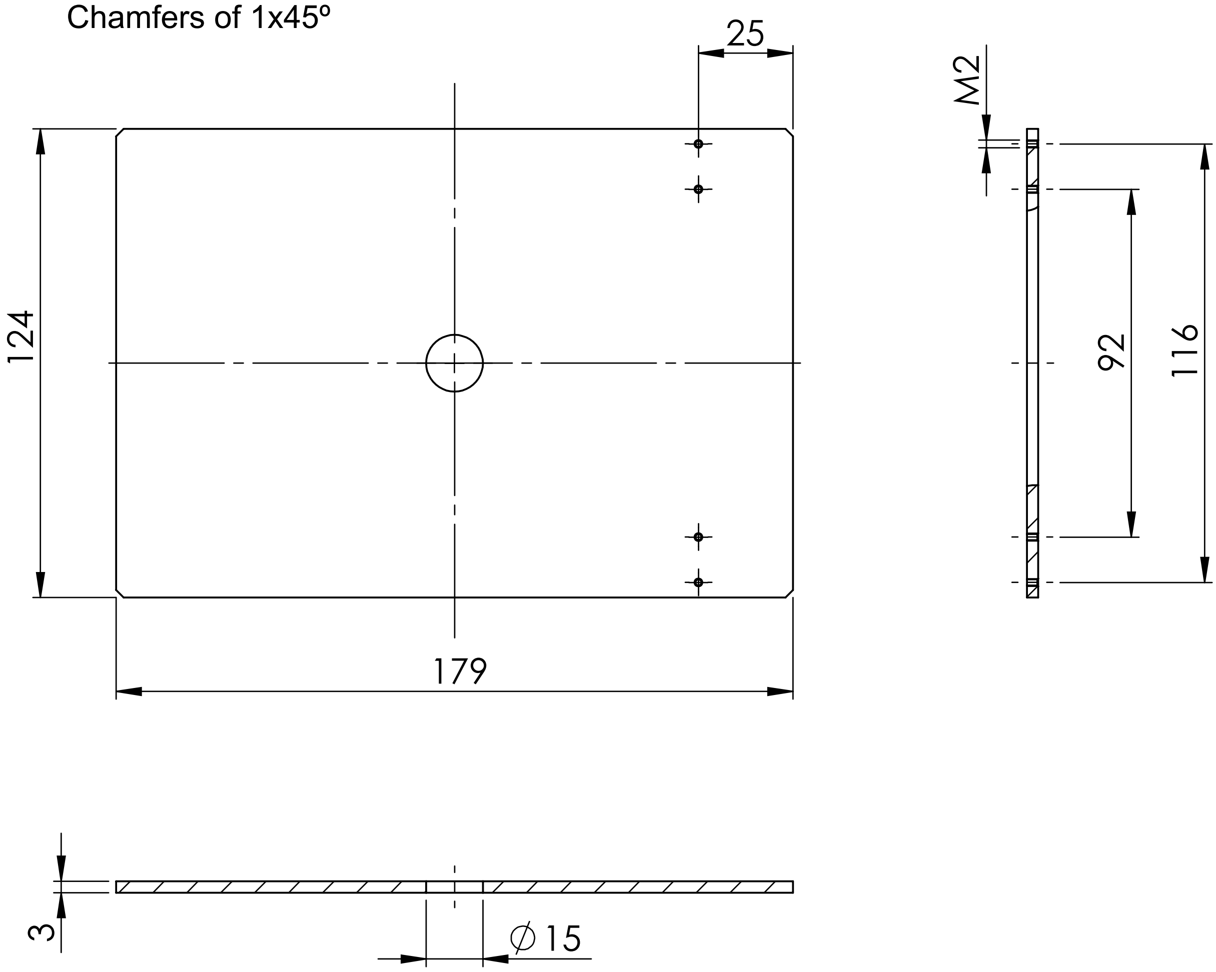
Sheet's name
Central Post

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 2 of 26 sheets
SAE 1015	**Shiny brown paint**		**730.29**	A4	1:2	

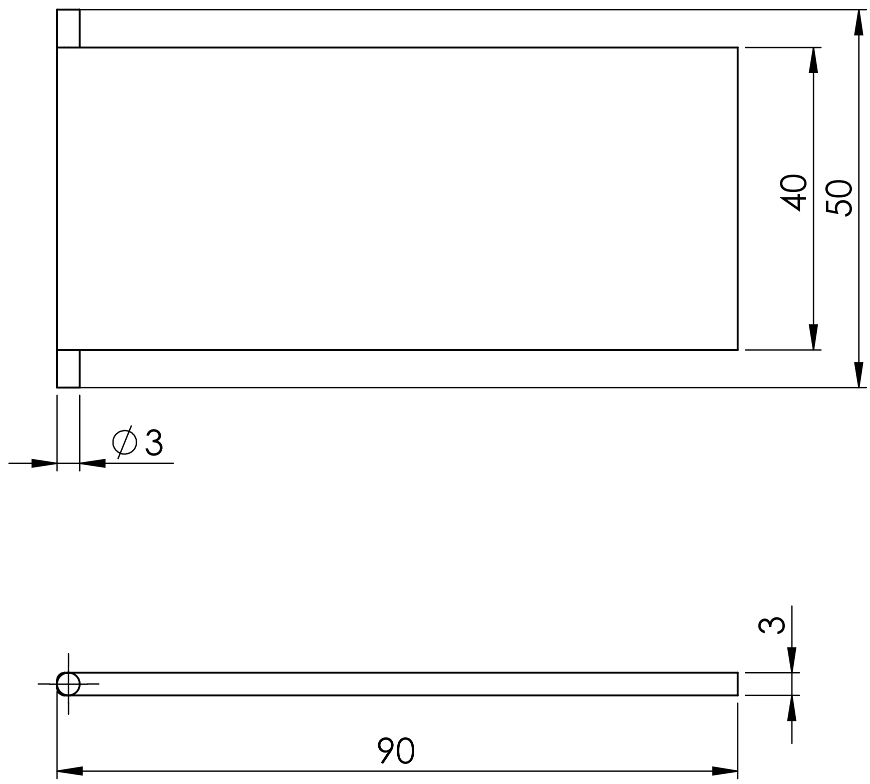


Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		isep Instituto Superior de Engenharia do Porto			
	Name	Date				
Drawn	**EPS TEAM 3**	**18/06/2017**				
Checked			Project's name **Self-Oriented Solar Mirror (SUNO)**			
Nº of sheet	**T3.02.01.A**					
Replace at			Sheet's name **Box**			
Replaced by						
Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 3 of 26 sheets
PP			**213.73**	A4	1:3 2:1	

Chamfers of 1x45º



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m			isep Instituto Superior de Engenharia do Porto
	Name		Date	
Drawn	**EPS TEAM 3**		**18/06/2017**	
Checked				Project's name **Self-Oriented Solar Mirror (SUNO)**
Nº of sheet	**T3.02.02.A**			
Replace at				Sheet's name **Box Cover**
Replaced by				
Material	Treatment	Surface finish		Weight: **61.59** · Format: A4 · Scale: 1:2 · Sheet 4 of 26 sheets
PP	**Shiny brown paint**			



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.02.03.A**	
Replace at		
Replaced by		

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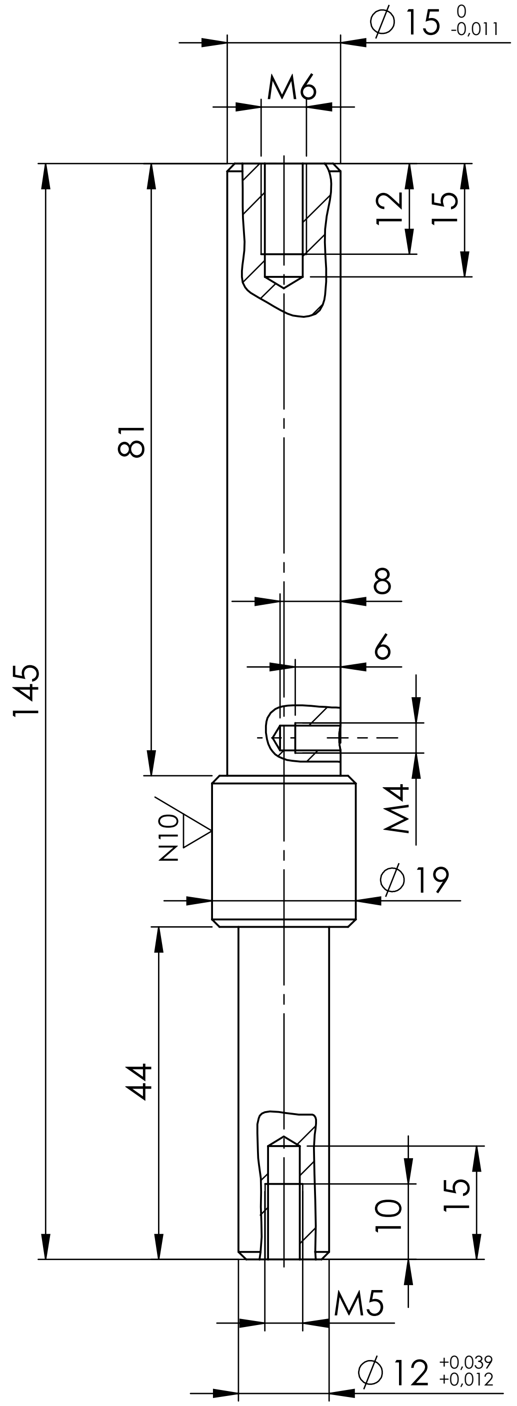
Project's name
Self-Oriented Solar Mirror (SUNO)

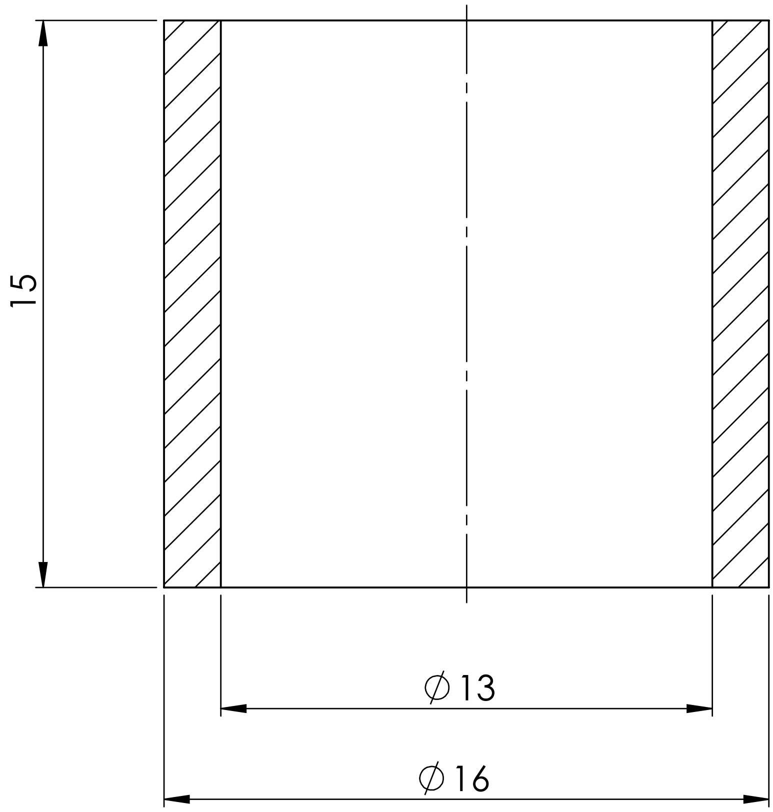
Sheet's name
Box door

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 5 of 26 sheets
PP			**9.66**	A4	1:1	

Chamfers of 1x45º



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m			isep Instituto Superior de Engenharia do Porto			SUNO
	Name		Date				
Drawn	EPS TEAM 3		18/06/2017				
Checked				Project's name **Self-Oriented Solar Mirror (SUNO)**			
Nº of sheet	T3.02.04.A						
Replace at				Sheet's name **Azimuth Shaft**			
Replaced by							
Material	Treatment	Surface finish		Weight	Format	Scale	Sheet 6 of 26 sheets
AISI 1015		(N8, N10)		191.04	A4	1:1	Sheet 6 of 26 sheets



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m					
	Name	Date				
Drawn	EPS TEAM 3	18/06/2017				
Checked			Project's name: **Self-Oriented Solar Mirror (SUNO)**			
Nº of sheet	T3.02.05.A					
Replace at			Sheet's name: **Shaft Spacer**			
Replaced by						
Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 7 of 26 sheets
Aluminium			**7.58**	A4	5:1	

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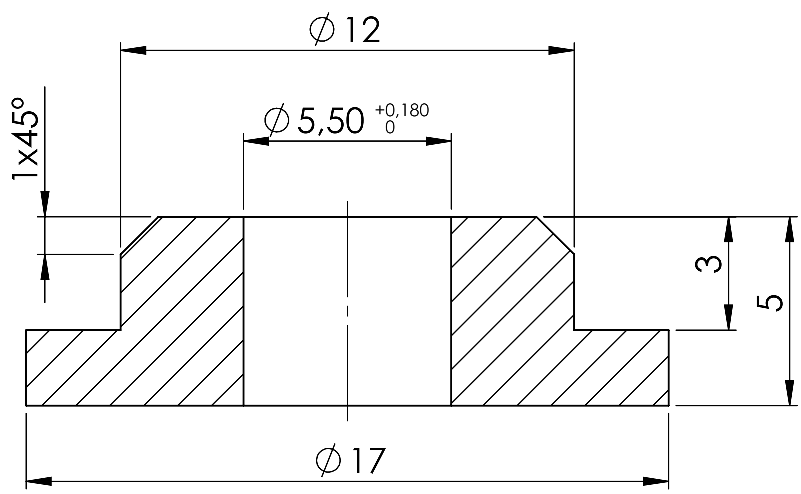

Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		
	Name	Date	
Drawn	**EPS TEAM 3**	**18/06/2017**	
Checked			Project's name **Self-Oriented Solar Mirror (SUNO)**
Nº of sheet	**T3.02.06.A**		
Replace at			Sheet's name **Shaft Holder**
Replaced by			

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 8 of 26 sheets
PP			**4.73**	A4	5:1	

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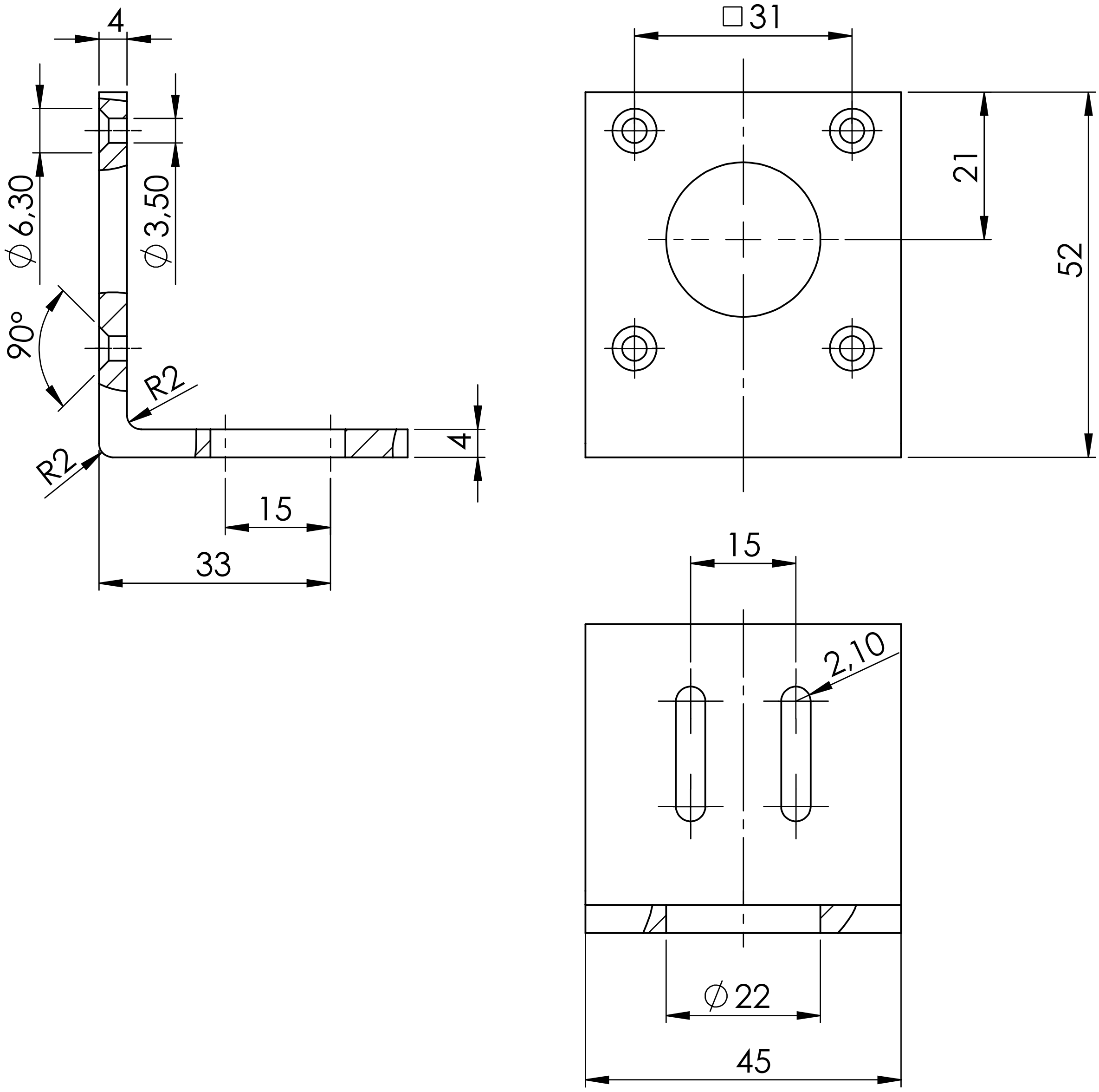
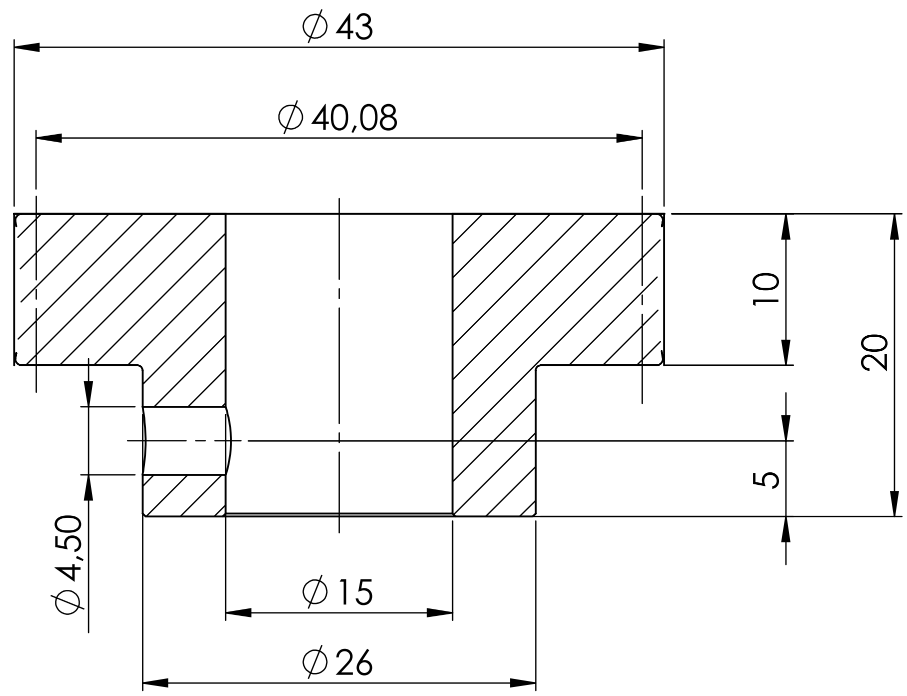


Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m			isep Instituto Superior de Engenharia do Porto			SUNO
	Name		Date				
Drawn	EPS TEAM 3		18/06/2017				
Checked				Project's name **Self-Oriented Solar Mirror (SUNO)**			
Nº of sheet	T3.02.07.A						
Replace at				Sheet's name **Azimuth Motor Bracket**			
Replaced by							
Material	Treatment	Surface finish		Weight	Format	Scale	Sheet 9 of 26 sheets
PLA				**20.19**	A4	1:1	

Worm wheel information	
Normal module	1
Nº. of teeth	40
Helix angle	3º35'
Helix direction	Right
Pitch diameter	40.08
Outside diameter	43



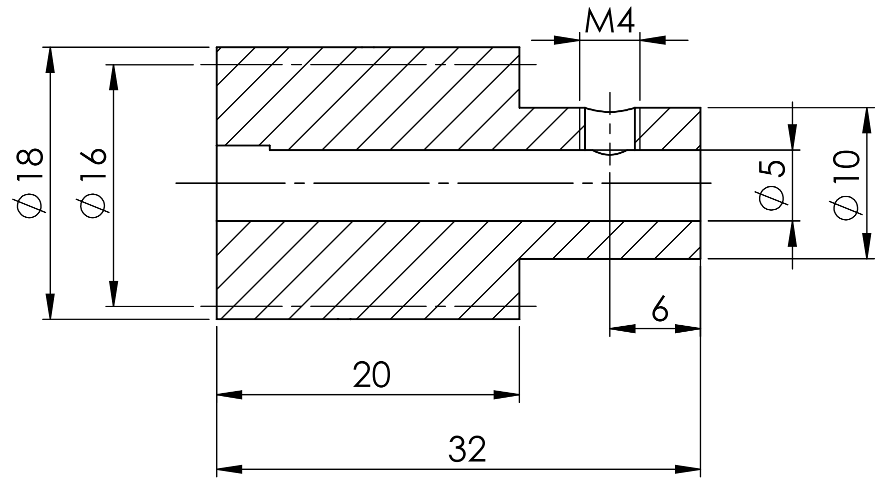
Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		
	Name	Date	
Drawn	**EPS TEAM 3**	**18/06/2017**	
Checked			
Nº of sheet	**T3.02.08.A**		
Replace at			
Replaced by			

Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
Worm Wheel

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 10 of 26 sheets
PLA			**29.40**	A4	2:1	

Worm gear information	
Normal module	1
Nº. of teeth	1
Helix angle	3º35'
Helix direction	Right
Pitch diameter	16
Outside diameter	18



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.02.09.A**	
Replace at		
Replaced by		

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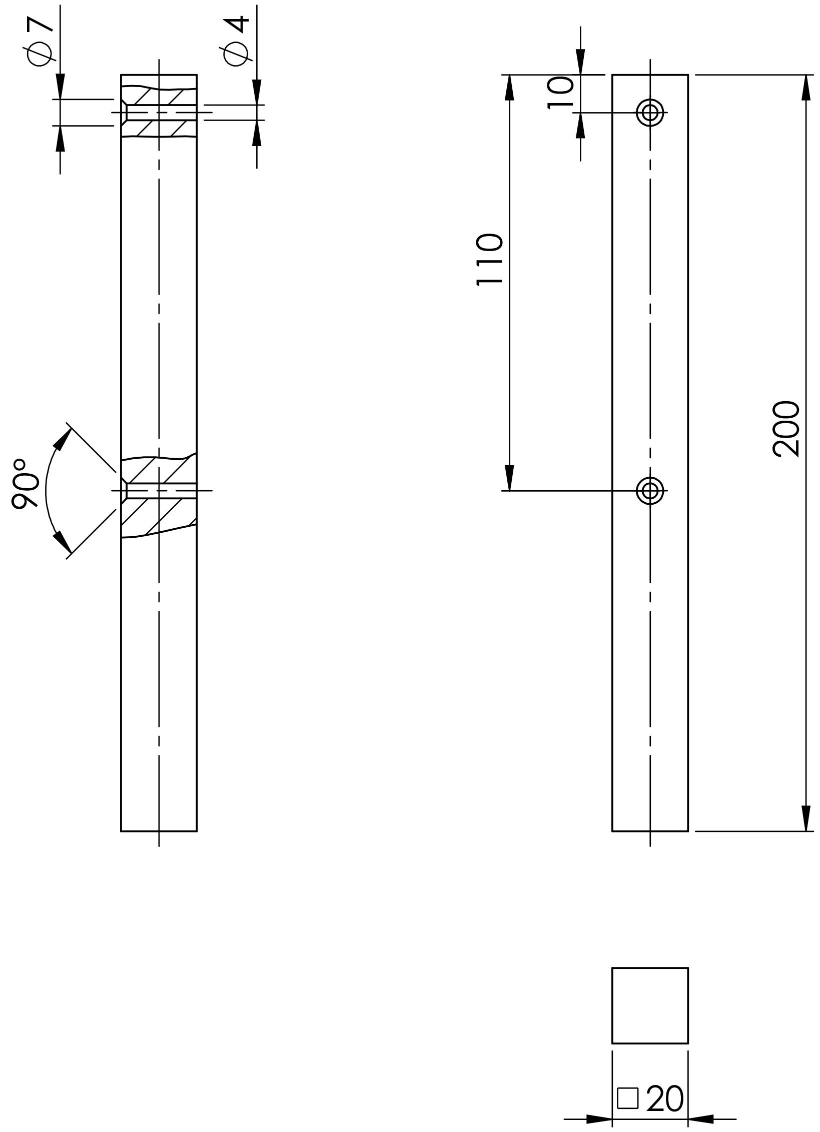
Project's name
Self-Oriented solar Mirror (SUNO)

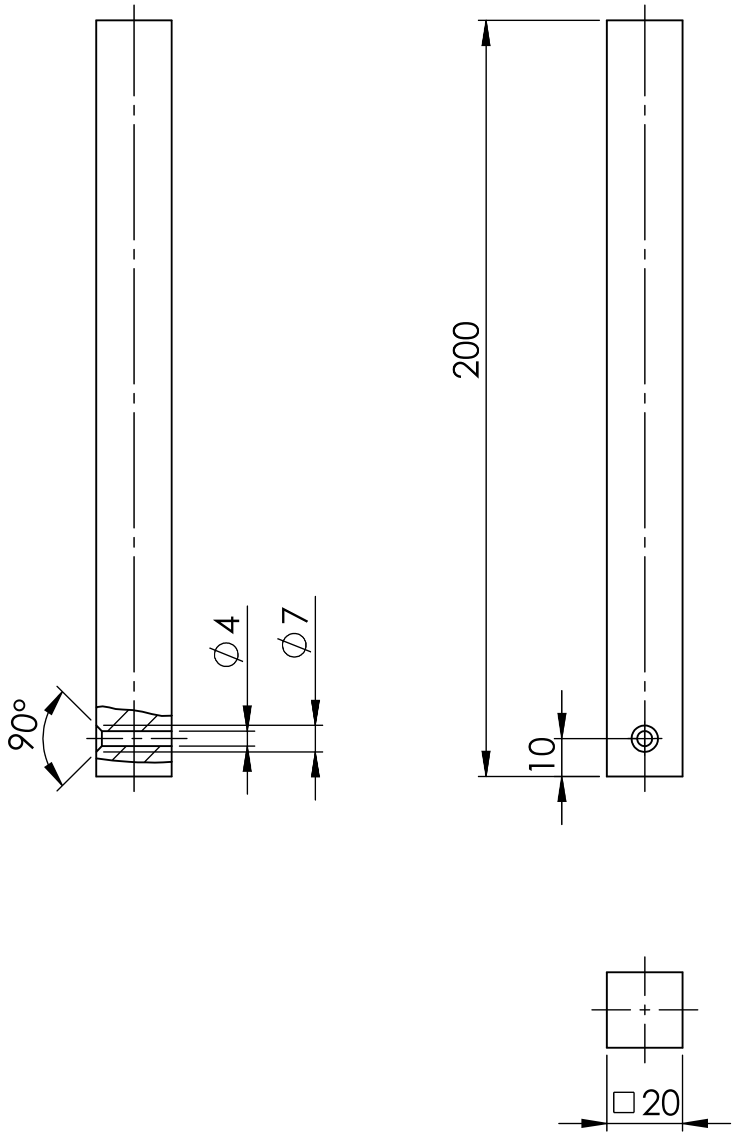
Sheet's name
Worm Gear

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 11 of 26 sheets
PLA			**5.51**	A4	2:1	

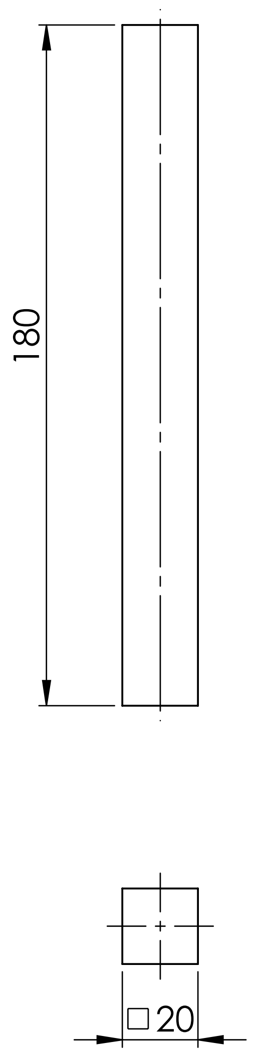


Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		isep Instituto Superior de Engenharia do Porto	SUNO
	Name	Date		
Drawn	**EPS TEAM 3**	**18/06/2017**		
Checked			Project's name **Self-Oriented Solar Mirror (SUNO)**	
Nº of sheet	**T3.03.01.A**			
Replace at			Sheet's name **Lateral Square Profile**	
Replaced by				

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 12 of 26 sheets
Pine tree	**Exterior varnish**		**27.02**	A4	1:2	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m			isep Instituto Superior de Engenharia do Porto				SUNO
	Name		Date					
Drawn	**EPS TEAM 3**		**18/06/2017**					
Checked				Project's name **Self-Oriented Solar Mirror (SUNO)**				
Nº of sheet	**T3.03.02.A**							
Replace at				Sheet's name **Frontal Square Profile**				
Replaced by								
Material	Treatment	Surface finish		Weight	Format	Scale	Sheet 13 of 26 sheets	
Pine tree	**Exterior varnish**			**27.11**	A4	1:2		



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		
	Name	Date	
Drawn	**EPS TEAM 3**	**18/06/2017**	
Checked			Project's name **Self-Oriented Solar Mirror (SUNO)**
Nº of sheet	**T3.03.03.A**		
Replace at			Sheet's name **Central Square Profile**
Replaced by			

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 14 of 26 sheets
Pine tree	**Exterior Varnish**		**24.48**	A4	1:2	

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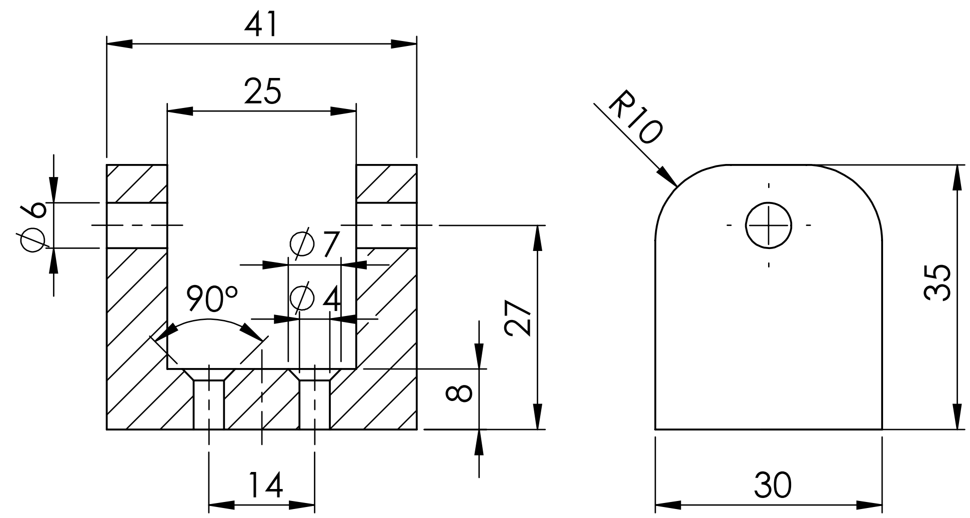
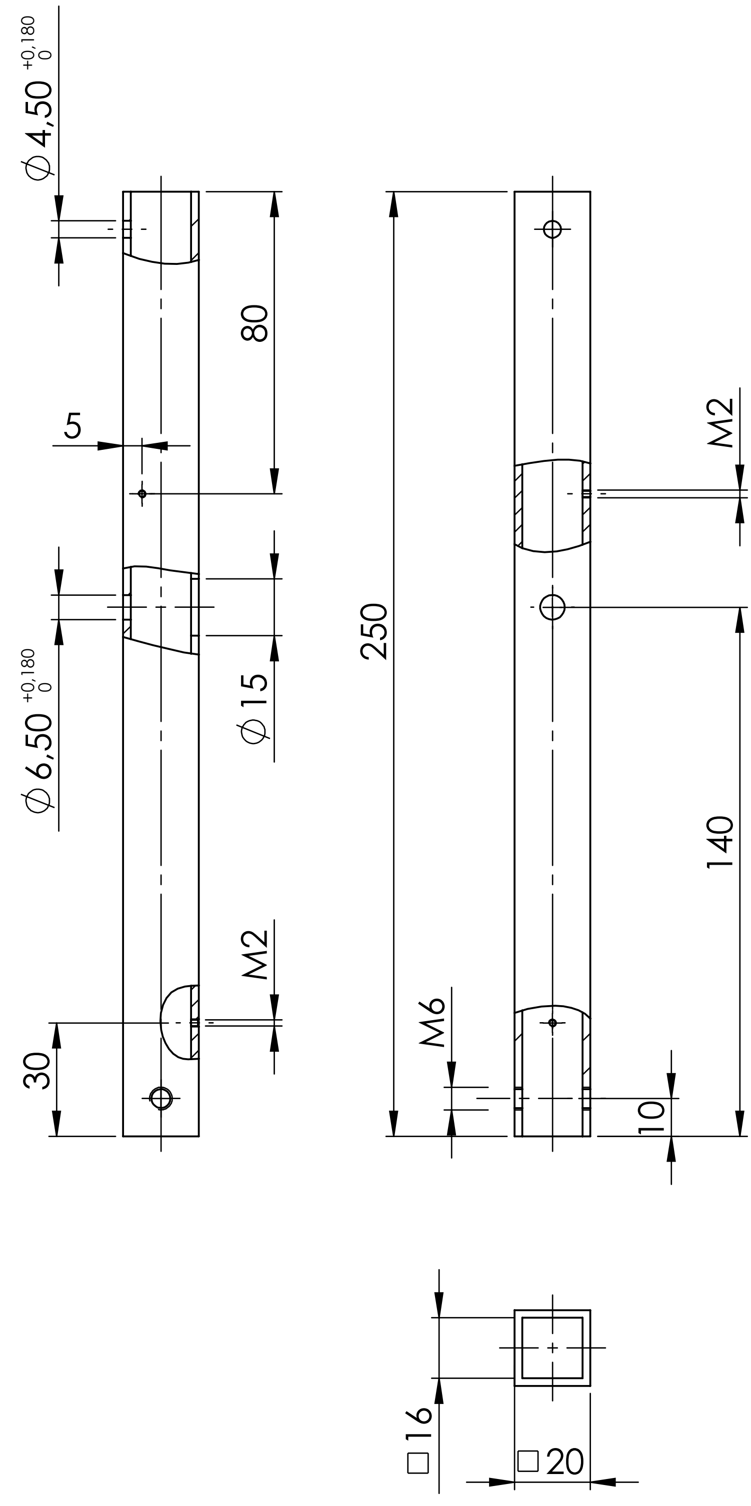
SUNO

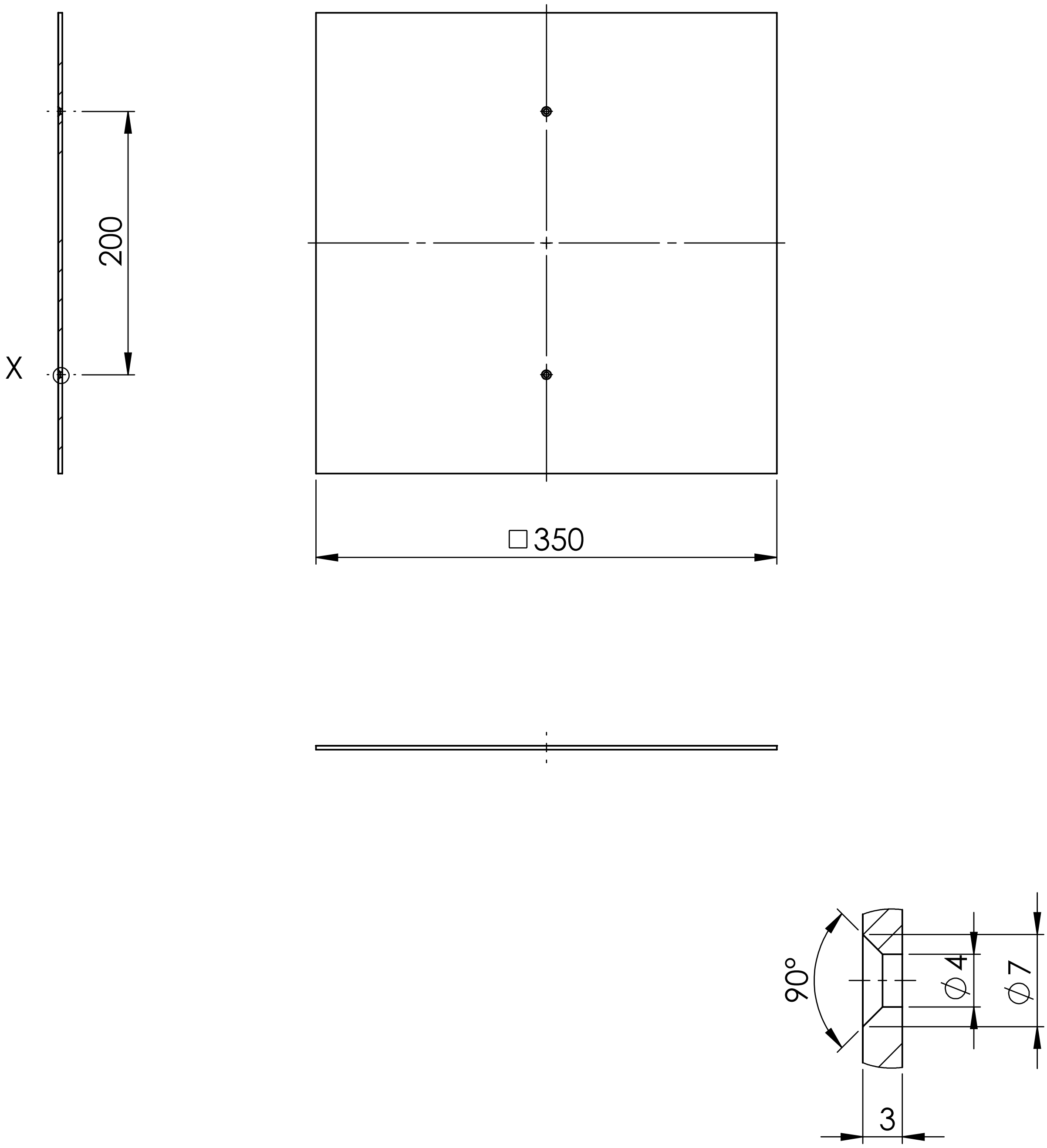


Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		isep Instituto Superior de Engenharia do Porto			SUNO
	Name	Date				
Drawn	**EPS TEAM 3**	**18/06/2017**				
Checked			Project's name **Self-Oriented Solar Mirror (SUNO)**			
Nº of sheet	**T3.03.04.A**					
Replace at			Sheet's name **Mirror Joint**			
Replaced by						
Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 15 of 26 sheets
PLA			**21.85**	A4	1:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		isep Instituto Superior de Engenharia do Porto	SUNO
	Name	Date		
Drawn	EPS TEAM 3	18/06/2017		
Checked			Project's name **Self-Oriented Solar Mirror (SUNO)**	
Nº of sheet	T3.03.05.A			
Replace at			Sheet's name **Cross Connector Square Profile**	
Replaced by				

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 16 of 26 sheets
AISI 1015	Shiny brown paint		279.08	A4	1:2	



DETAIL X
SCALE 2 : 1

Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.03.06.A**	
Replace at		
Replaced by		

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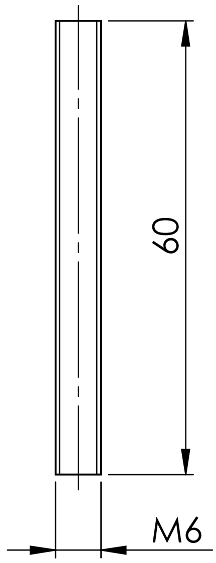
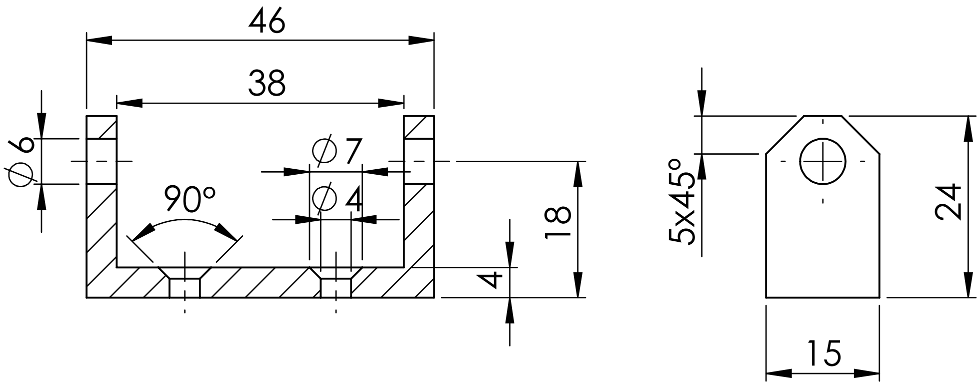
SUNO

Project's name	**Self-Oriented Solar Mirror (SUNO)**
Sheet's name	**Mirror's Surface**

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 17 of 26 sheets
LDPE			**338.39**	A4	1:5 2:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m			isep Instituto Superior de Engenharia do Porto			SUNO
	Name		Date				
Drawn	**EPS TEAM 3**		**18/06/2017**				
Checked				Project's name **Self-Oriented Solar Mirror (SUNO)**			
Nº of sheet	**T3.03.07.A**						
Replace at				Sheet's name **Mirror Joint's Articulating Shaft**			
Replaced by							
Material	Treatment	Surface finish		Weight	Format	Scale	Sheet 18 of 26 sheets
DIN 975				**13.33**	A4	1:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.03.08.A**	
Replace at		
Replaced by		

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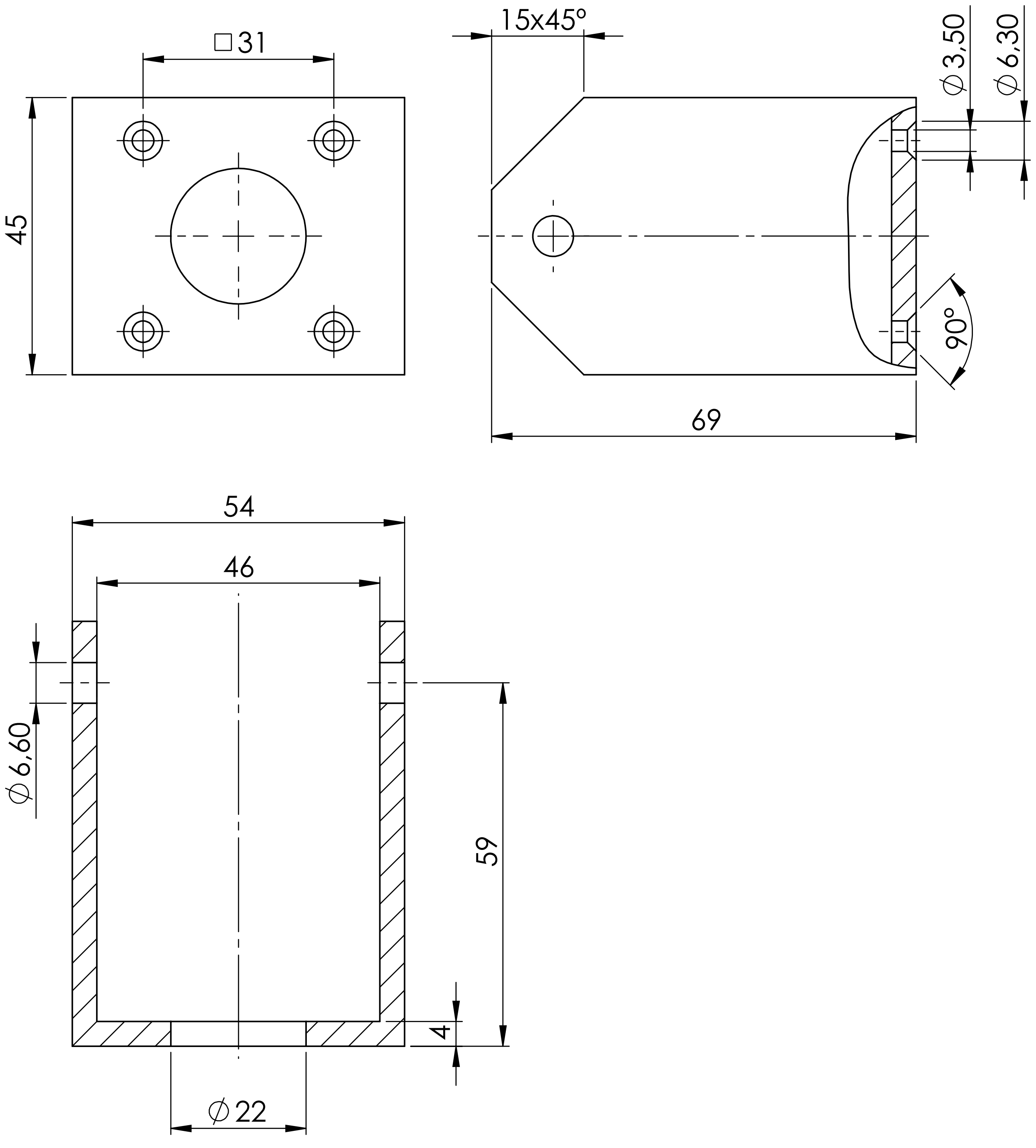
Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
Leadscrew Joint

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 19 of 26 sheets
PLA			**4.69**	A4	1:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m		
	Name	Date	
Drawn	**EPS TEAM 3**	**18/06/2017**	
Checked			Project's name: **Self-Oriented Solar Mirror (SUNO)**
Nº of sheet	**T3.04.01.A**		
Replace at			Sheet's name: **Leadscrew Motor Bracket**
Replaced by			

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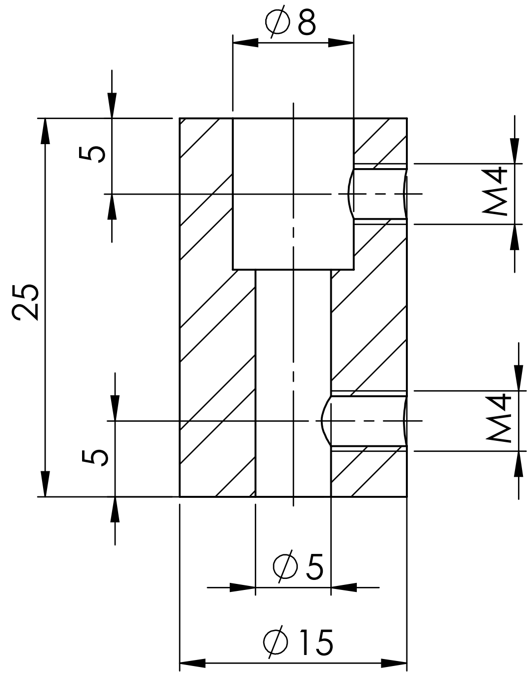
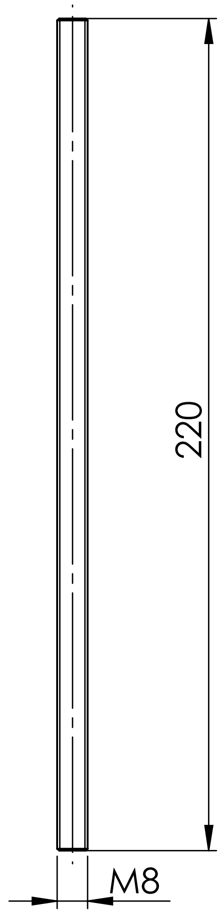
Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 20 of 26 sheets
PLA			**29.90**	A4	1:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m			isep Instituto Superior de Engenharia do Porto			SUNO
	Name		Date				
Drawn	**EPS TEAM 3**		**18/06/2017**				
Checked				Project's name **Self-Oriented Solar Mirror (SUNO)**			
Nº of sheet	**T3.04.02.A**						
Replace at				Sheet's name **Motor Coupling**			
Replaced by							
Material	Treatment	Surface finish		Weight	Format	Scale	Sheet 21 of 26 sheets
AISI 1015				**27.91**	A4	2:1	

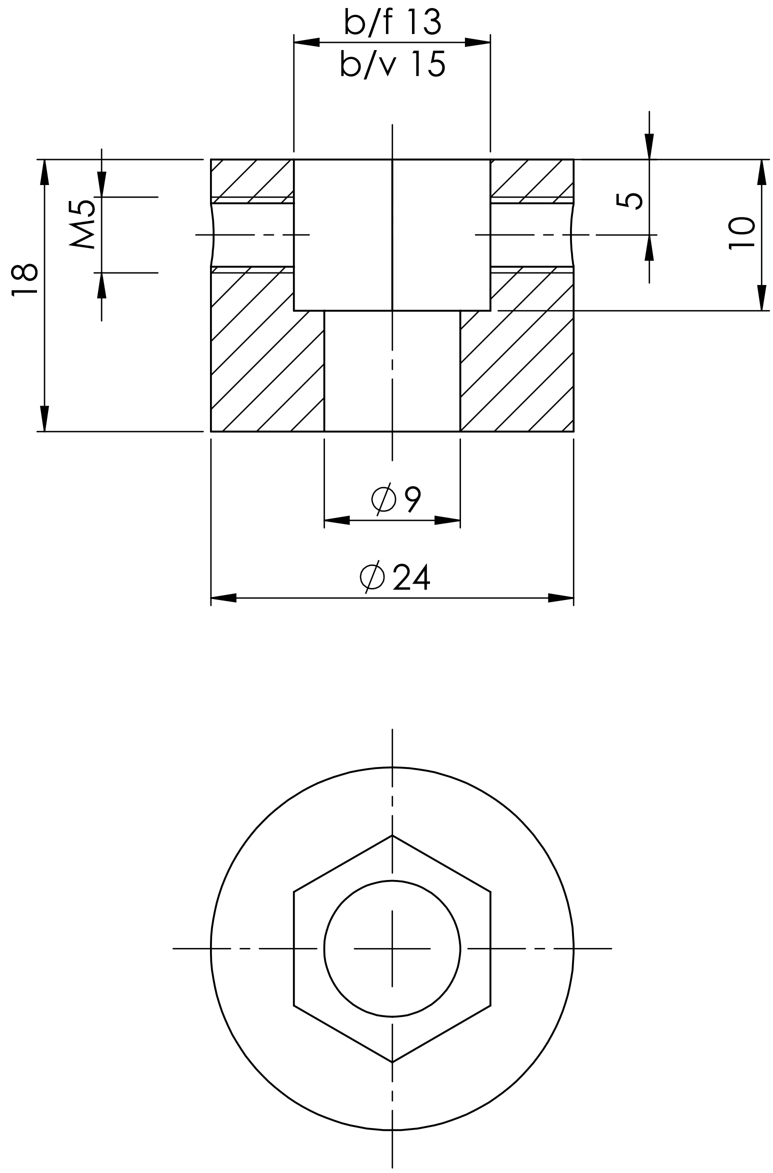


Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.04.03.A**	
Replace at		
Replaced by		

Project's name
Self-Oriented Solar Mirror (SUNO)

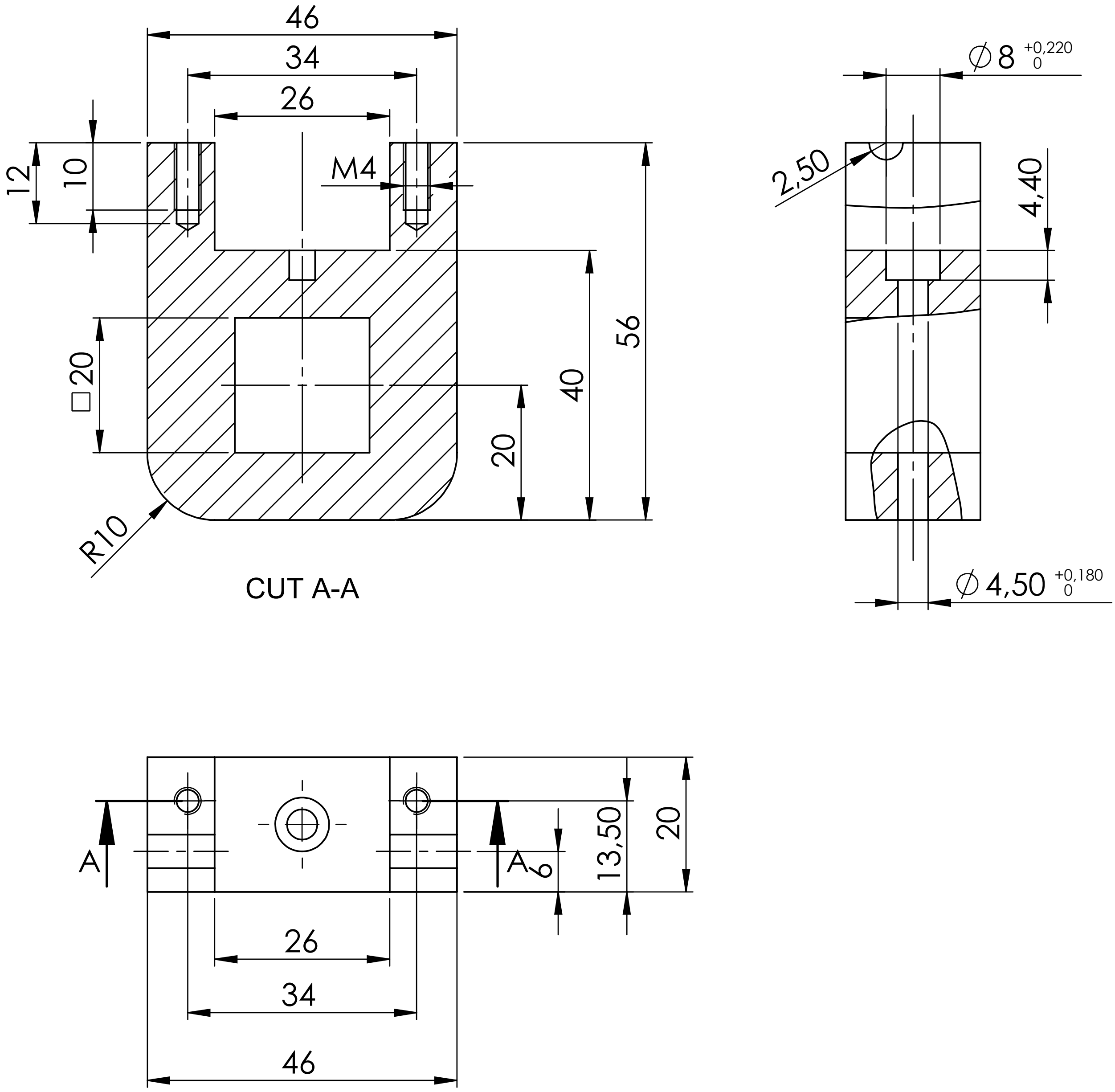
Sheet's name
M8 Threaded Rod

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 22 of 26 sheets
DIN 975			**86.87**	A4	1:2	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m			Instituto Superior de Engenharia do Porto
	Name		Date	
Drawn	EPS TEAM 3		18/06/2017	
Checked				Project's name: **Self-Oriented Solar Mirror (SUNO)**
Nº of sheet	T3.04.04.A			
Replace at				Sheet's name: **M8 Nut Housing**
Replaced by				

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 23 of 26 sheets
PLA			**6.14**	A4	2:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.00.01.A**	
Replace at		
Replaced by		
Material	Treatment	Surface finish
PLA		

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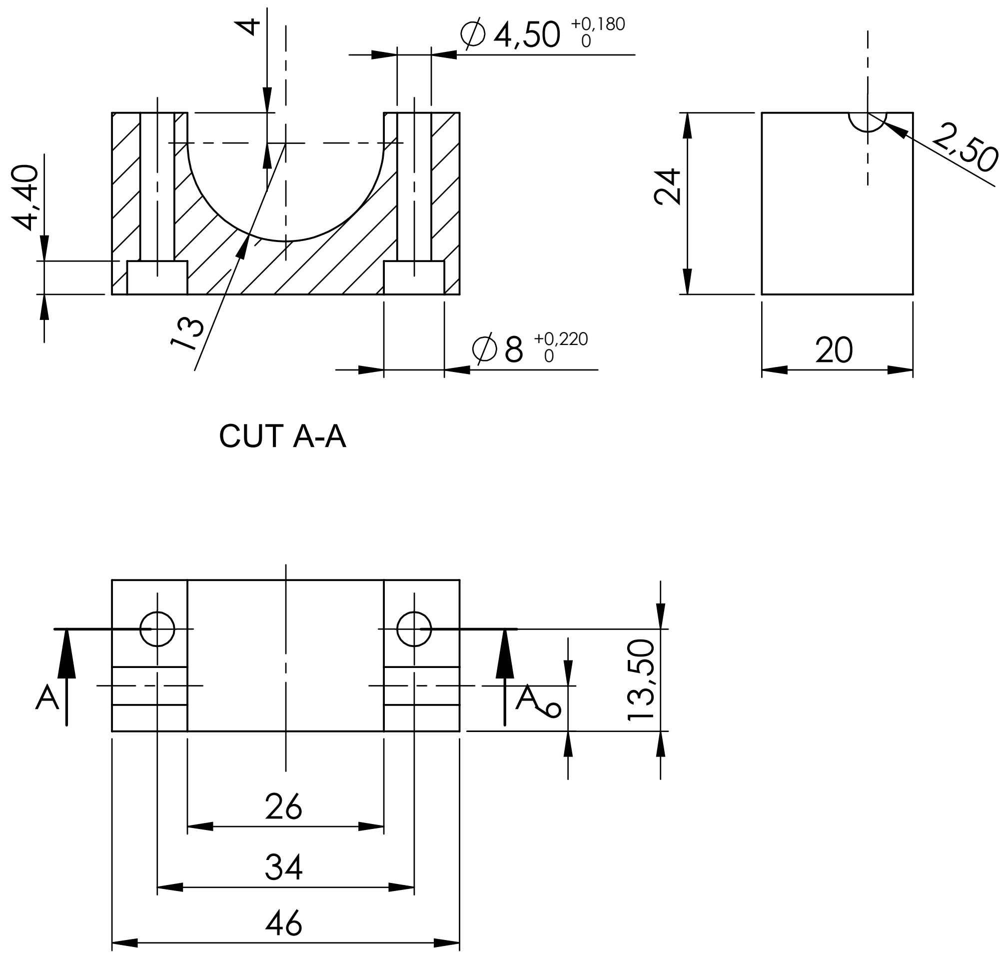
SUNO

Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
M8 Housing Lower Support

Weight	Format	Scale	Sheet 24 of 26 sheets
33.47	A4	1:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.00.02.A**	
Replace at		
Replaced by		

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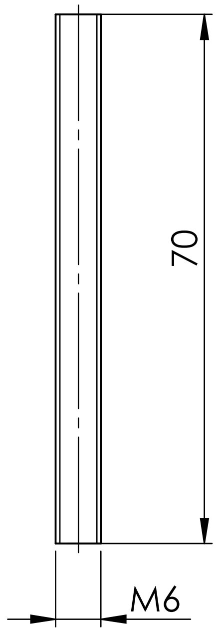
Project's name
Self-Oriented Solar Mirror (SUNO)

Sheet's name
M8 Housing Upper Support

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 25 of 26 sheets
PLA			**13.70**	A4	1:1	



Tolerances	Est.sup.UNE 1037/Tol.gral.ISO 2778-K/Tol.geom.ISO 2778-m	
	Name	Date
Drawn	**EPS TEAM 3**	**18/06/2017**
Checked		
Nº of sheet	**T3.00.03.A**	
Replace at		
Replaced by		

Instituto Superior de Engenharia do Porto

Project's name

Self-Oriented Solar Mirror (SUNO)

Sheet's name

Motor Joint's Articulating Shaft

Material	Treatment	Surface finish	Weight	Format	Scale	Sheet 26 of 26 sheets
DIN 975			**15.56**	A4	1:1	

10. BIBLIOGRAPHY

[1], [2] instructables, 2017. *Quick`n`Dirty Heliostat - Get Some Sun Into Your Home.*

[3], [84], [87], [105] Ibrahim Reda, Afshin Andreas, 2003. *Solar Position Algorithm for Solar Radiation Applications.*

[4], [85] Zafrullah Jagoo, 2003. TRACKING SOLAR CONCENTRATORS: A LOW BUDGET SOLUTION. Springer, ISBN 978-94-007-6104-9.

[5], [86] Di Lu, June 2012. *The Heart of a Phone Camera: The CMOS Active Pixel Image Sensor.*

[6], [103] Mouser Electronics, 2017. *Mouser Electronics.*

[7], [8] Wikoda, 2017. *The Sunflower heliostat.*

[9], [10] Light Manufacturing, 2017. *Heliostat.*

[12], [15] Solar Cooker at CantinaWest, 2017. *The Haines Solar Cooker.*

[13], [14] Pinterest, 2017. *Solar Ovens.*

[16] Solar Cooker at CantinaWest, 2017. *Buy a Solar Cooker.*

[17] article, 2017. *This World-First Farm Grows Vegetables in the Desert With Nothing but Sun and Seawater.*

[18], [19] Youtube, 2017. *Garden Mirror invention.*

[20] NCBI, 2017. *Solar Energy in Food Processing.*

[21] Global Compost Project, 2017. *Desert farm grows 180,000 tomato plants using only sun and seawater.*

[22] Tom Parise, 2011. Water Desalination. STANFORD UNIVERSITY.

[23] Freedonia, 2017. *World Water Desalination.*

[24] Los Angeles Times, 2017. *A battle is brewing over a proposal for a new source of water in the South Bay.*

[25] Goodnet, 2017. *7 Water organizations you should know.*

[26] Royal Solar Shop, 2017. *Solar water heater.*

[27] Energy, 2017. *Solar water heaters.*

[28] Electronics Companies; Delta's Solar Tracking Solution Contributes to Crescent Dunes Solar Energy Project. ENERGY WEEKLY NEWS, Mar 18 2016, pp.163, ISBN 19456980.

[29] British Broadcasting Company, 2008. JAMES MAY'S BIG IDEAS.

[30] R. Vidu D. Barlev, P Stroeve, 2011. Innovation in concentrated solar power. SOLAR ENERGY MATERIALS AND SOLAR CELLS, pp.2703-2725.

[31] The renewable energy website, 2017. *First European Solar Power Tower.*

[32], [33], [34], [35], [36], [40], [41] Project Management Institute, 2000. A GUIDE TO THE PROJECT MANAGEMENT BODY OF KNOWLEDGE. 2000. Project Management Institute Inc., ISBN 1-880410-23-0.

[37] Project Management Tips, 2017. *3 Types of essential resources for your project.*

[38], [39] Project Management Skills, 2017. *Project Quality Manager.*

[42] Belbin Associates, 2017. *Belbin main page.*

[43] Technische Universiteit Eindhoven, 2017. *Belbin team roles specifications.*

[44] Tutorials management, 2017. *Communications Management.*

[46] Association for project management, 2017. *What is stakeholder management.*

[47], [48], [54] key differences.com, 2017. *Difference Between Micro and Macro Environment.*

[49], [50], [51], [52], [53], [59], [61], [63], [65] oxford college of marketing, 2017. *The Impact Of Micro and Macro Environment Factors on Marketing.*

[55], [56], [58], [60], [62], [64] oxford learning lab, 2017. *PESTLE - Macro Environmental Analysis.*

[66] Management Mania, 2017. *Strategic objectives strategic goals.*

[67] Andreia Gama, 01 January 2017. *Marketing.*

[68] Marketing teacher, 2017. *Measuring and monitoring the marketing planning process.*

[69] Earth Observatory, 2017. *Global warming.*

[70] Rochester Institute of technology, 2017. *Sustainability.*

[71] Green Living tips, 2017. *PVC.*

[72], [73] PVC, 2017. *Sustainability.*

[74] Green Living tips, 2017. *MDF.*

[75] Tata steel Europe, 2017. *The sustainable material.*

[76] timber.net, 2017. *Carbon Footprint.*

[77] Shrink that footprint, 2017. *Shrink your product footprint.*

[78] Harvard business review, 2017. *The sustainable Economy.*

[79] Integrated Network for Social sustainability, 2017. *Defining Social Sustainability.*

[80] Sustainable Solutions, 2017. *Life Cycle Analysis.*

[81] R. Anderson, 2011. ETHICS. 1. Hodder Education, pp.7, ISBN 2191-5520.

[82] European Union, 2017. *Low Voltage Directive.*

[83] European Union, 2017. *Machinery Directive.*

[88] InvenSense, 2017. *MPU-9250.*

[89] Charlotte Treffers, Luc van Wietmarschen, June 2016. *Position and orientation determination of a probe with use of the IMU MPU9250 and a ATmega328 microcontroller.*

[90], [91] Electrical engineering Community, 2014. *Difference between open loop and closed loop systems.*

[92] United States Army Material Command, 2000. Introduction. ENGINEERING DESIGN HANDBOOK: HYDRAULIC FLUIDS, University Press of Hawaii, pp.1-1, ISBN 0898750849.

[93] Josep E. Shigley & Charles R. Mischke, 1996. Spurs Gears. STANDARD HANDBOOK OF MACHINE DESIGN, McGraw-Hill, pp.33.1, ISBN 0-07-056958-4.

[94] KHK Stock Gears, 2017. *Spur Gears.*

[95] Josep E. Shigley & Charles R. Mischke, 1996. Worm Gearing. STANDARD HANDBOOK OF MACHINE DESIGN, McGraw-Hill, pp.36.1, ISBN 0-07-056958-4.

[96] KHK Stock Gears, 2017. *Worm Gears.*

[97] Wikipedia, 2017. *Rack and pinion.*

[98] KHK Stock Gears, 2017. *Rack and Pinions.*

[99] DC Comics, 2017. *Batman.*

[100] *On-off switch.*

[101] *Vector arrows keyboard.*

[102] *Tweety.*

[104] Fritzing, 2017. *Fritzing.*

[106] The European Union, 2004. EUROCODE 1: ACTIONS ON STRUCTURES- 1-4: GENERAL ACTIONS- WIND ACTIONS. 1.

[107] IPMA. *Critérios de Emissão dos Avisos Meteorológicos.*