

# Robotica Minor

## Concept design

### Groep 5

Thijs Boumans	4214854
Anne Brus	4142586
Bob van Haren	4228278
Stephan Neevel	4232623
Hugo Reinbergen	4161173
Ian Zhang	4243943

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# Chapter 1

## Summary

In this report the process of developing the object requesting educational robot Tawi has been documented. A picture of Tawi can be seen in figure 1.1. This robot plays a game with children by shooting twenty balls into the air almost like a volcanic eruption. Numbers are displayed on these balls. The robot then asks and displays a math question similar to: What is three + nine? The child then has to put the balls with numbers one and two on them, making twelve, into the mouth of the robot and the robot asks another question. When the child is done putting all the balls into the robot, the game restarts.



Figure 1.1

This robot idea was developed by completing a design process. First, several robot ideas have been graded on, among others, the ability to be realised, safety and innovation. After this, a field analysis of the chosen object requesting educational robot has been done, to see what important trends there are in the field of robotic toys. The robot needs to be original to compete with competitors, the ultimate price of the robot should be around 100 and the robot needs to be interesting for children to play with.

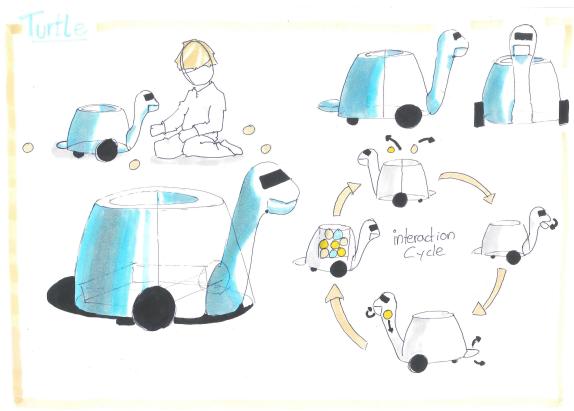


Figure 1.2: Volcanobot

Next, the use cases of the chosen concept have been explained, these include asking the child for objects. Based on the use cases, the functional analysis has been done. Functions like being attractive to children, shooting balls and recognizing the objects have been identified. These function lead to must haves, should haves, could haves and wont haves; concrete design requirements. With the MosCow model and the functional analysis in mind, the morphological map gives a clear overview of design options.

Three initial designs have been made: the volcano bot, the box-bot and the truck teacher. These design can be seen in pictures in this summary.

The volcano bot has already been described above, the box-bot lets children insert the objects in his hands and lifts them into his own shooting mechanism and the truck teacher does the same with a dump truck design. Furthermore, the choice of object form of balls size 50 mm has been chosen for safety reasons and ease of transportation in the robot itself. In addition, the game as described above has been chosen in favour of others, together with the game mode of dancing to music and manual control of robots driving system.

To see whether the initial designs were feasible, they have been further improved by doing initial mechanical calculations, making an initial software design and listing electrical components. Next, the choice for the volcano robot has been made. Per concept, this has been evaluated on difficulty to build, originality and the entertainment value for children. Also Maja Rudinac from the TU Delft, expert on robotic interaction with children, believed that the volcano robot was the best concept, because it was the most original.

The next step was the development prototype design, consisting of mechanical, programming and electrical design. The mechanical design consists of the following parts: the design of the mouth with a rod system, choice of re-using the Pioneer platform and the spring loaded launching mechanism that works with a worm gear motor. Further calculations have been done on the timing belt that transports balls from the lower part of the neck into the shooting pipe. Also, numerous strength calculations have been done. To conclude the mechanical design, a full SolidWorks 3D model of the robot has been made. The software architecture of the robot has been listed, using classes to avoid duplicate code. In the electrical design, a circuit has been designed and the choice for a NiMH battery has been made.

A planning has been made for the next period in which the Tawi prototype will be built and

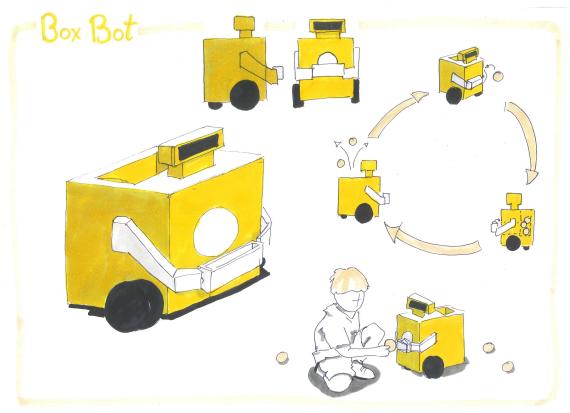


Figure 1.3: Box-bot

tested, finishing it in the week of January 12th 2015.

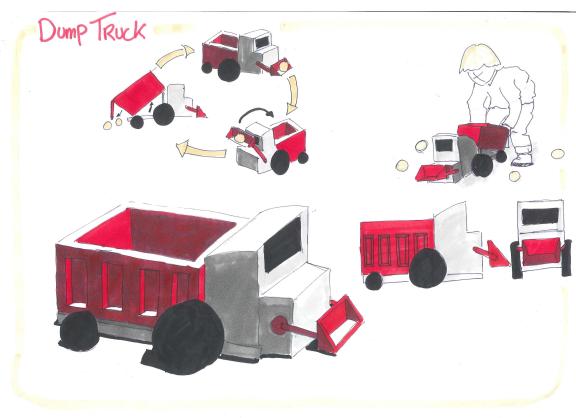


Figure 1.4: Truck Teacher

# **Chapter 2**

## **Introduction**

Currently, there are not many robots on the market, but since recent developments in technology, it will increase to become available for households and on the market. The goal of this report is to display the design steps taken and the decisions made for developing an autonomous educational robot.

The name of the report developed is: Tawi. Tawi will be used in households to help children learn different school subjects. A design process over the course of ten weeks will help develop this robot. This report will explain this design phase and substantiate the decisions made for the robot. The design process is divided in three stages: the idea development stage, the concept stage and the final stage. In the idea development stage several brainstorms will be held to develop an idea for the robot and to come to three different concepts. In the concept stage these concepts will be further improved and developed to full concepts. One concept will be chosen and this robot will be developed into a final blueprint for a prototype in the final stage. At the end of this report a final design for the robot can be seen.

# **Chapter 3**

## **Ideas and choice of the robot**

The first stage of creating a concept is holding a brainstorm for a function of the robot. The following ideas were considered :

- Underwater exploration robot
- Train cleaning robot
- Groceries sorting and storing robot
- Gum-buster robot
- Toy clean-up robot
- Tag robot
- Volcano robot
- Object requesting educational robot

### **3.1 Underwater exploration robot**

The first idea was the Underwater Exploration Robot. It would explore the depths of the North Sea to map it out and discover new species of fish, since a lot of the depths are still unexplored and are currently still being explored by divers.

This idea was considered very difficult. It would require a waterproof shell up to depths of 70m. If the robot would leak even slightly, the entire robot could stop working. On the other hand, it is a very interesting idea.

In the end, it was decided it to be too challenging.

### **3.2 Train cleaning robot**

The next idea that passed the block was a train cleaning robot. This robot would vacuum and scrub the floor of the train carriages, empty garbage bins and maybe even check the seats for contamination. This idea didn't come through because it's not that interesting to work on, the market for it is small and it's not easy to test, since it would require an empty train. It also scored low in terms of innovation, as there are already vacuuming robots on the market.

### **3.3 Groceries sorting robot**

The third idea was a groceries sorting and storing robot. It would be an arm that picks up groceries, scans its barcode to identify it and then puts it away in a cupboard or drawer. An example of usage would be that the supermarket would place the box with shopping items on the counter and the robot would unload this.

This would involve making an arm with at least 5 motors in it, making a program that compares the barcode to one in a database to find out what product it is and a vision system to identify cupboards and drawers. This was considered quite complex, because of the many components and the perfect communication necessary between them. So it was decided to be too difficult for the time given to complete this project.

### **3.4 Gum-buster robot**

Another idea that was mentioned was a “gum-buster” robot. The robot would carry a steam powered device that would clean urban areas. This would be useful, because it is currently a very time-consuming activity, and in the UK, the government currently spends 850 billion per year on cleaning gum. (Gray, 2014)

The robot would have to know where to clean and where not to clean. This could be done with GPS or the robot would clean per block and it would have to be able to stay on the sidewalk. The robot would also have to have a strong body, so that people won’t accidentally knock it over. Finally the robot would have to be safe, so that it does not try to bust someones foot with steam.

Safety and navigation are big issues, so this was also considered difficult.

### **3.5 Toy clean-up robot**

One of the top ideas was a robot that would help kids clean up their toys. It would make cleaning fun by helping the child with cleaning up leftover toys on the floor. Imagine this robot to look like an open dump truck, with a shovel on the front to scoop up the toys. It would then put the toys in the box where they belong and children could make a game of it.

The robot would need to identify toys to clean up, while leaving stuff like extension cords on the floor. This would be done with a vision system.

This robot sounded very fun to build, since it already gave a clear view of how this robot would operate. It helps teach children to clean up their stuff and looks cool doing it. It would have some difficulties in recognizing objects and differentiating them from other objects that should not be cleaned, but it would be possible and not too challenging.

### **3.6 Tag robot**

A growing problem in society is that people are getting heavier and are exercising less. Children are also getting lazier, and resort to playing inside on game consoles, iPads etc. A robot, that plays with children to motivate them to move and to play outdoors more, could be a solution to this problem. The first idea to motivate kids to play outside is the “Tag” robot, that would run or drive away from the person playing with it.

It would need a button or touch sensitive layer to recognize that it has been tapped. This could result in the sensors breaking, because the child operating it might tap it too hard and could

break it. Another point to consider is the fact it would have to drive at a high enough speed to be challenging for a child. This makes for a lot of safety issues and makes it very risky.

### 3.7 Volcano robot

Another idea, inspired by a Dutch game called “buskruit”, came to the table. This game is played with a ball that is kicked away and while one person retrieves the ball, the other people hide. This idea, combined with “Tag”, resulted in the volcano robot. The robot would shoot a light-weight ball (to avoid injury to the person operating it) into the air, and would run away from the person playing with it. The person playing with the robot would retrieve the ball and wins by putting it back into the robot. Part of the attraction in this robot would be a fun-looking shell (think of a turtle-like shell) so that the child likes to play with it. This robot would involve making an object detection function so that it doesn’t drive into objects on the playing field. It would also require the playing field to be predetermined, so it doesn’t randomly drive onto the road. Finally, the same issue of driving at a high speed would create the same safety issues as the “Tag” Robot.

### 3.8 Object requesting educational robot

The last idea is a robot that requests items, for example by voice or an LCD screen, that have a number or some sort of picture on it. The robot requests a specific number or item and a child places the item in the mouth of the robot or in the hands of the robot. The robot recognizes the object, and if it is the correct object, the robot will pass it through to its shooting mechanism magazine and plays a rewarding sound or wiggles or moves in a way that displays positive emotions. If the item is incorrect, the robot spits the object out or returns the object to the child. When there’s a certain amount of objects in the shooting mechanism magazine, the robot will shoot them all away. Then the robot will request the next item and the child searches for them. After finding it, the child will give the correct object to the robot and the game will start over. This robot would require a shooting mechanism, with for example a spring. It would also need to recognize the items, preferably with RFID.

### 3.9 Final decision

For the final decision, every idea was rated, as shown in Table 3.1. The ideas will have several categories with different weights, each of them will be graded. The following categories, are considered:

- Ease of programming
- Ease of mechanics
- Size of potential
- Testability
- Innovation
- Cool-factor
- Safety

To decide which idea will be developed into a robot, the ideas were given grades. First, categories on which the ideas will be graded have been created.

The weight factor goes from one to four depending on the importance of every category, one being not so important and four being very important. Testing also got a four because this will be done at the end of the creation process where time and money are limited and on-the-spot testing would heavily be preferred over requiring a high pressure water tank for example. The “cool-factor” is a small bonus for cooler ideas, since it would be more interesting to make “cooler” ideas, thus motivating the team to work harder.

After grading every idea in every category. The average of the grades of the individual group members was taken per category in every concept. The final score would be the sum of all marks multiplied by their weight. The lowest score has been awarded to the underwater exploration robot and the concept with the highest score is the object requesting educational robot.

Table 3.1: Grading of factors

Idea description/name	Ease of programming	Ease of mechanics	Ease of electronics	Size of potential market	Testability	Innovation	Safety	Cool-factor	Total
Water exploration robot	5	2	1	4	6	8	7	7	119
Train cleaning robot	8	6	7	4	2	5	5	5	123
Grocery robot	3	3	8	6	7	9	4	9	140
Gum-buster robot	8	5	8	5	8	7	4	5	152
Cleaning robot	2	8	7	8	8	7	7	7	163
Volcano Robot	8	7	6	8	7	6	3	8	141
Object requesting robot	9	6	7	8	8	6	8	7	179
Weight factor	3	3	3	3	4	3	4	1	

# **Chapter 4**

## **Field analysis**

This chapter will be about the field of application of the object requesting educational robot. Different aspects of this application field will be addressed. Afterwards the robot concept will be further specified.

### **4.1 Competitors**

The market for autonomous robotic toys is not very big yet. There are some fully autonomous robots being sold for around 100. Most of these robotic toys are focused on older children, and focused on boys in particular, examples can be found in Appendix F. The indirect goal is to get an autonomous robot on the market for about the same amount of money, but it should target a different group of users, this group of users being younger children of both sexes. To compete with these competitors, originality is key.

### **4.2 Technological**

The price of computer calculations (processing power) has dropped a lot over the recent years. CPUs, Central Processing Units, have become so cheap that they are now available in toys. The price will continue to go down in the future. This can be explained by Moore's law: the power of a newly developed processor doubles every two years ("Engineering Laws - Moore's, Rock's, Butter's and others", 2012). And with Rock's law that state that the cost of a given unit computational power will halve every 36 months. This has to do with the ever decreasing chip and component size, which makes it possible to get more components on the same surface. If you look at a chip with a certain processing power, it will become smaller and therefore cheaper every year.

Also, computer vision systems are up and coming because of this increased processing power. Vision systems needed a pretty hefty system a few years back. Now, it's possible do vision processing with a much cheaper system and therefore it becomes more interesting for developers to use vision systems.

### **4.3 Social**

Over the past 20 years, more and more toys have become electrical rather than fully mechanical. This move from mechanical over to electrical has also affected children in the sense that they are getting used to electrical toys.

The target group for the educational robot is children between 4 and 8 years old. Children from

6 to 8 years old create their own rules for games and create new games altogether. Once the children hit the age of 8 or 9, they tend to be playing outside more, without the supervision of their parents. (“Child development: 6-9 years”, n.d.)

#### **4.4 Challenges**

There are several challenges to be faced when developing and producing an autonomous robotic toy.

The first challenge is that robots are expensive to develop and to prototype compared to non-robotic toys. This is because of the high cost of computer components and required level of knowledge of employees.

Another challenge is to keep the robot interesting. Children tend to be bored quite quickly by a toy these days, and then the old toy makes way for a new one. It should have a high amount of options or expansions to make it interesting for a longer period of time, without making it too expensive.

#### **4.5 Conclusion**

In conclusion, the robot needs to be original to compete with competitors, the ultimate price of the robot should be around 100, this will be helped by the fact that computer components become cheaper. Also, the robot needs to be interesting for children to play with.

#### **4.6 Competition**

The toy industry is very large, so it is quite hard to determine which are most closely related to the robot. The key components to the robot are the autonomous operating and the learning aspect for children. An analysis on the competitors can be found in Appendix F: Competitors.

# Chapter 5

## Use Cases

In this chapter, the use cases will be explained. The use cases can be found in Appendix A. Use cases describe a sequence of events and actions that follow upon a certain interaction between the an actor and the product. This actor can be the child or the software. The use cases turn offer a structure for necessary requirements. This is an example of a use case:

---

### Use Case 1 Ask for objects

---

*Actor*              Robot

---

*Trigger*              The robot is switched on

---

*Main Success Scenario:*

1. The software decides what kind of object to ask for.
  2. The robot asks the child for the object through voice or picture.
  3. The child gives the object to the robot.
- 

*Extensions:*

3.a The child cannot find the object:

1. The robot waits a minute and repeats the question
- 

In Use Case, there will be a description on what the Actor needs to do. This Use Case will be triggered by the Trigger. When the Use Case is triggered, it will follow the steps in the main success scenario. Any unsuccessful events are described in the extensions.

# Chapter 6

## Functional analysis

With the use cases layed out, a functional analysis of the robot can be made. All the functions and sub functions of the robot will be given and explained. It will be possible to make the morphologic overview using the contents of this chapter.

To make this functional analysis graphic, a flowchart has been made according to the example of (Viola et al., 2012). This flowchart can be found in figure 6.1.

This has been constructed in the following way, on top the ultimate function has been placed: to entertain and educate the children. In the row beneath will be the sub-functions to reach this goal. In the row beneath that sub-function, will be the sub-functions to reach the goal of the sub-function, etc.

To conclude, the most important functions of the robot are that it is able to recognize an object, to shoot an object and to be attractive to children. The sub-functions of these functions are a base for the contents of the morphologic overview.

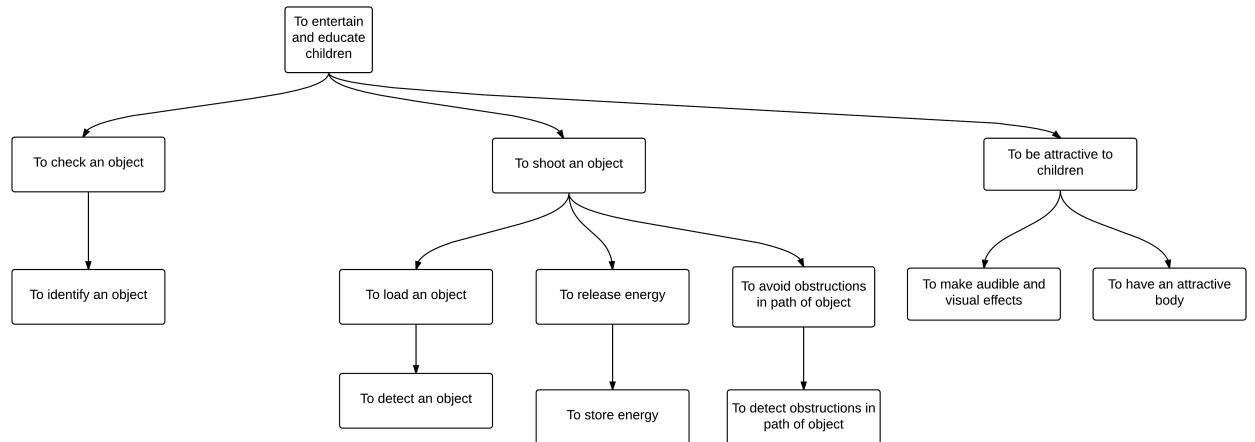


Figure 6.1: Functional Analysis

# Chapter 7

## MoSCoW analysis

The requirements of the robot will be organized using the MoSCoW Analysis. The analysis can be found in Appendix B.

The MoSCoW Analysis will be used to pinpoint the requirements and differentiate the actual requirements from the more luxury objects. This will be useful when there is a time rush or a shortage in money for example.

The results of the MoSCoW Analysis and the Functional Analysis in the previous chapter, will be used to set the Morphological Map, which will be found in the next chapter.

# Chapter 8

## Morphological map

Using the MoSCoW Model and the Functional Analysis of the previous chapters, the Morphological Map for the designs was made. This Morphological Map can be found in Table 8.1.

Subject	Option 1	Option 2	Option 3	Option 4	Option 5
Mechanical Parts					
Movement	3-wheel	Tracks	4-wheel	None	
Release Mechanism	Spring	Flywheel	Air Pressure	Magnetic	Turning + gravity
Shootable Objects	Balls	Cubes	Anything		
Protection	Material	Case	Structure	Frame	Bumper
Design	Turtle	Dragon	Robot	Truck	Whale
Electronical Parts					
Sensor (Shooting)	Ultrasonic	Infrared	Camera	Laser	
Computing	Arduino	Laptop	Raspberry Pi	Mobile phone	
Recognition Object	RFID	Camera	Radio	Magnetic	Infrared
Obstacle avoidance	None	Ultrasonic	Camera	Laser	
Battery	Plugged in	Li-Ion	LiPo	NiMH	
Display	None	LCD			
Speakers	Yes	No			

Table 8.1: Morphological map

The Morphological Map is divided into two parts: the Mechanical parts and the Electronical parts. The Mechanical parts will be varied when making the initial designs, while the Electronical parts will remain constant, as the initial design of the robot will unlikely affect the electronical parts, since the overall electronics design of a small scale robot is usually the same. There are a few little things to note about the Morphological map. The first one being that sensor (shooting) is the sensor that is used to prevent the robot from shooting when the child is right above the shooting mechanism. This will ensure the safety of the child. This map will be used to create a certain amount of initial designs, of which three shall be selected to be improved and turned into full concepts.

# Chapter 9

## Initial designs

The design of the robot will be decided by doing a brainstorm. The brainstorm consists of three stages: first a lot of ideas will be generated, then the ideas will be discussed and to conclude the brainstorm, the ideas will be narrowed down to three concepts. The brainstorm technique and the ideas can be found in Appendix C: Brainstorm initial designs.

The design of the game will not be elaborated here, this can be found in Chapter 11: The game. The following are the three end concepts for the robot:

### 9.1 Volcanobot

The Volcanobot is a robot in the form of a tortoise with a volcano on its back, see figure 9.1. The main idea is to let it shoot the objects from the volcano on its back, ask for a certain object, let the child retrieve that object and put it in the mouth to scan if it is correct. When all the items are retrieved, a new game will start by shooting all the objects out again.

Example: Volcanobot shoots the objects, asks for the answer of  $3 \times 3$ . The child then retrieves the ball with 9 on it and puts it in the mouth. It should scan the ball and swallow it and it will ask a new question. If the child retrieved the ball with 8 on it, the ball should fall out of its mouth or be spat out by the robot.

The robots shooting mechanism is based on a spring and would require a container for the objects with a radius of approximately 160mm and a height of 200 mm, for 20 balls with a 25mm radius. The container would be filled from a high point at a high angle, so that the objects can't be shot back into the filling mechanism or get stuck in the filling mechanism. Because a tortoise neck is generally very low, we will have to use a mechanism similar to a conveyor belt to transport the object to the main container in the middle.

The robot will give feedback to the child when the objective is correctly solved or when it's not. Feedback is given on a screen in the robots eyes and via movement and sound. When the child makes a mistake he or she will be encouraged to try again.

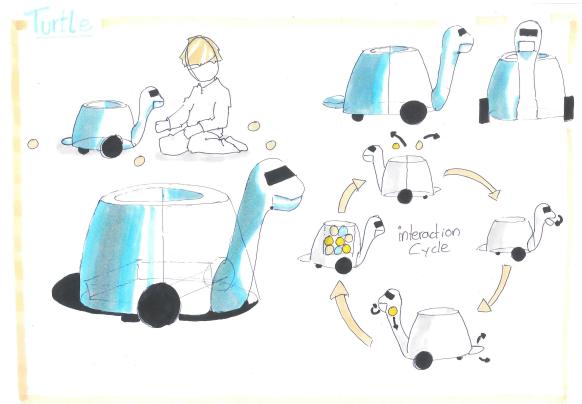


Figure 9.1: Volcanobot

## 9.2 Box-bot



Figure 9.2: Box-bot

The Box-bot is a square formed robot, see Figure 9.2 . The game begins by shooting from the top of the robot and would ask for a certain object via sound and a screen. The child retrieves the object and puts it in a hole on the front side of the robot to scan it. If it's correct, it will be swallowed and kept in its container. If it is not right it would be dropped on the ground in front of the robot.

The shooting mechanism would be similar to the Volcano-bot, using a spring and a container for the objects with a radius of approximately 160mm and a height of 200mm, for balls with a 20mm radius. It would also have to be filled from a high point at a high angle, so the objects can't shoot back into the filling mechanism or get stuck in the filling mecha-

nism. However, the exterior of the Box-bot won't require a low loading point, like the Volcano would, so it's possible to load from a higher point, without needing a conveyor belt mechanism.

## 9.3 Truck Teacher

The Truck Teacher is a robot in the form of a shovel truck, that can be found in figure 9.3. At the beginning of the game, it lets the balls roll off the truck by toppling the container. Then the robot will ask for a certain object. The child should then retrieve the object and scan it on the window or in the bucket of the truck. If it is the correct item, it will load the object into the container of the truck by rotating the arm of the bucket.

This robot would release the balls by toppling the container by using a screw spindle. The container would be the same size as the platform and the objects would have to be balls, since lower friction is needed to let the objects fall of the truck.



Figure 9.3: Truck Teacher

# Chapter 10

## Object design

The objects that can be used in the robots come in different forms and sizes. The form and size of these objects will be decided in the following paragraphs.

### Form

Theoretically, one can consider all kinds of forms for the objects. However, this robot would need to transport the objects and shoot them into the air. This is realized in an easy way by taking spherical objects. Balls are able to roll with low friction and are easily transported through the robot. Square objects for example won't be able to transport as easily as spherical objects would.

For these reasons, we have decided on using spheres as the final form.

### Size

Safety is a big issue regarding the size of the balls. Children under 3 years of age can safely play with balls that are at least 44 mm of diameter ("Choosing Safe Toys", n.d.). The specific age group will be given in chapter 11: The game.

Because of this, the balls will have to be at least 44 mm. Besides this, the readability of the print on the ball, the availability of that certain size of balls and the amount of space used for the loading cylinder, where the balls are stored, should be considered.

Balls should already be readable from 44mm, so this should be fine, but it would of course be more readable when selecting larger balls.

The easiest available balls to get are balls with a diameter of 50 or 60mm. Other balls would probably have to be specifically fabricated.

Finally, the available space for the loading cylinder is 180mm high and has a diameter of 155mm. When selecting 50mm, it would be enough space to store approximately 20-23 balls. Figure 10.1 shows how the balls are stacked.

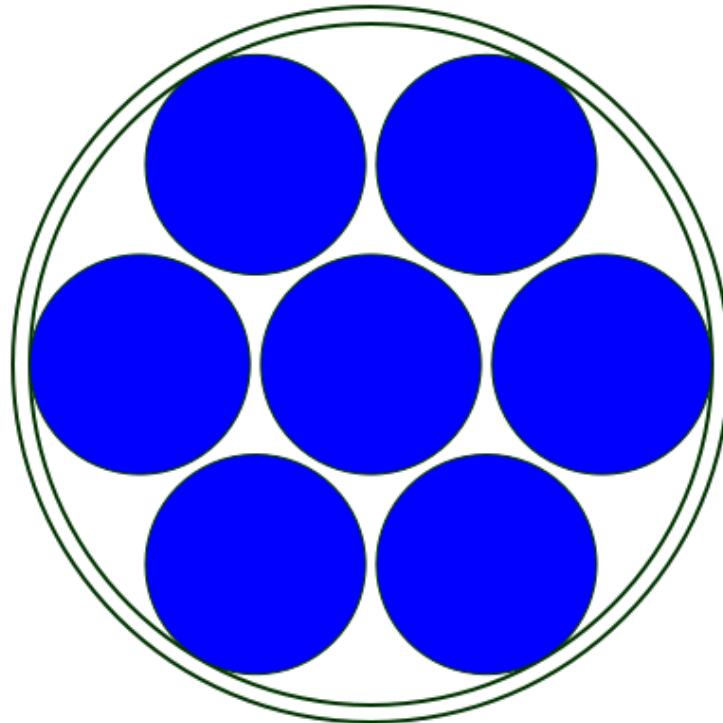


Figure 10.1: This figure shows how the balls will fall in the launching pipe for 50mm balls.

If the 60mm balls would be used though, it would decrease significantly to around 12-15 balls. Since there is also storage space in the neck, the total storage would be around 30 balls. This is enough for the 26 letters of the alphabet and without using the neck it would be enough for 2 sets of the numbers 0-9.

The 50mm balls would be most advantageous and will therefore also be used.

### Material

For the materials, the ball must not be able to hurt the child when it falls on the child's head. For this reason, a material like foam or styrofoam would be ideal.

## Conclusion

The final decision is 50mm foam or styrofoam balls, depending on the availability and price of both. An example is shown in figure 10.2.



Figure 10.2: A 50mm foam ball with RFID sensor inside

# Chapter 11

## The game

### 11.1 Initial Game Choice

The robots main purpose is to play a game or several games with a young child. Several games were designed. The following list consists of all considered games and a conclusion on how feasible and unique they are.

#### 11.1.1 Tag

Playing “Tag” with the child. This consists of the child touching the robot, the child starts to run away, the robot will then try to touch the child, the robot will try to run away and so on. This game would give a lot of difficulties: the robot has to be very fast, the child needs to be detected and very important is that the robot would not be scary for the child, since the robot will run after them. This game was not chosen, since the robot will be quite heavy and fast, so it would be too dangerous for the child to be run over or bumped in to.

#### 11.1.2 Ball shooting game 1

This was a spin-off of the “Tag” game. The robot would shoot a ball and then would drive away from the ball. The child would need to retrieve the ball and put it back in the robot. This gave the same complication as the “Tag” game and this idea was discarded in kind.

#### 11.1.3 Hide and Seek

This game would have two variants, one where the robot seeks the child and one where the child looks for the robot. When the robot needs to hide, it would need excellent detection properties to see if it is hidden. The detection was considered to difficult to build in half a year so the idea was not considered feasible.

#### 11.1.4 Tamagotchi

In this game the child would need to care for the robot, feeding it, playing with it and letting it sleep. This would teach the child caring for something. The robot would have to be excellent in reacting to the child and for this it would need touching sensors and multiple moving parts. A lot of caring robots are already on the market, like for example Pleo (see Appendix F: Competitors), so it would not be new or innovating. Considering this, the Tamagotchi game was not chosen.

### **11.1.5 Dancing**

The design was to include a dancing feature in the Tamagotchi game, but it would also be very fun just to have an extra feature for the robot. The robot will begin to dance when it hears music. The robot would need music detection and would need to have several dance moves. This is quite easy to implement with easy sensors, so this feature is feasible.

### **11.1.6 Manual driving**

Manual play with a controller can also be very fun, but it's not part of the project, since it needs to be an autonomous robot. This feature might be implemented along the development for testing purposes, but is not deemed necessary for a successful product.

### **11.1.7 Ball shooting game 2**

The ball shooting game was slightly adjusted to make it a feasible game. The ball would have a picture on it and the robot would ask for the correct ball. The child would then return the correct ball to the robot and the robot would somehow collect these in his body. When the robot has collected all the balls it will shoot them out of his body again, and the game will start over. This game can have several elements for different ages, for example by using colored balls, balls with letters, balls with numbers etc.

“Ball shooting game 2” is considered feasible since it doesn't involve the difficulties of “ball shooting game 1”, like fast driving and following an object anymore. “Ball shooting game 2” is considered more original and fun for a large span of age groups.

### **11.1.8 Conclusion**

The robot will be used for ball shooting game 2 as explained above and as and dancing to music could be implemented as an extra feature. This is considered a feasible game, which can entertain the child for a long time and keep it entertaining for several years if the robot and the game are designed correctly.

## **11.2 Game options**

The selected ball shooting game is also very expandable. Following is a list of possibilities for the object requesting education robot.

Forms of recognition:

- Colour
- Form
- Animals
- Food

Math:

- Multiplying
- Subtracting

- Adding

- Dividing

Alternate options:

- Driving manually
- Dancing with music
- Tamagotchi
- Walking autonomously
- Sleep
- Dance while playing

# Chapter 12

## Improve 3 initial designs

### 12.1 Proof of concept calculations

For the box-bot and Volcanobot, we were using similar launching systems with springs. Calculations will therefore be largely the same. All of the calculations on the spring launching mechanism can be found in Appendix I. In short, the motor we need would have to deliver a minimum of 1.5Nm. This is quite large, but nothing we cannot work with.

For the Truck Teacher concept, only the tipping mechanism needs some calculations. Again, the calculations can be found in Appendix I, but in short, we only need to have a lifting force of about 3N. This is easily solved with a screw spindle and a small motor.

### 12.2 Sketches of exterior

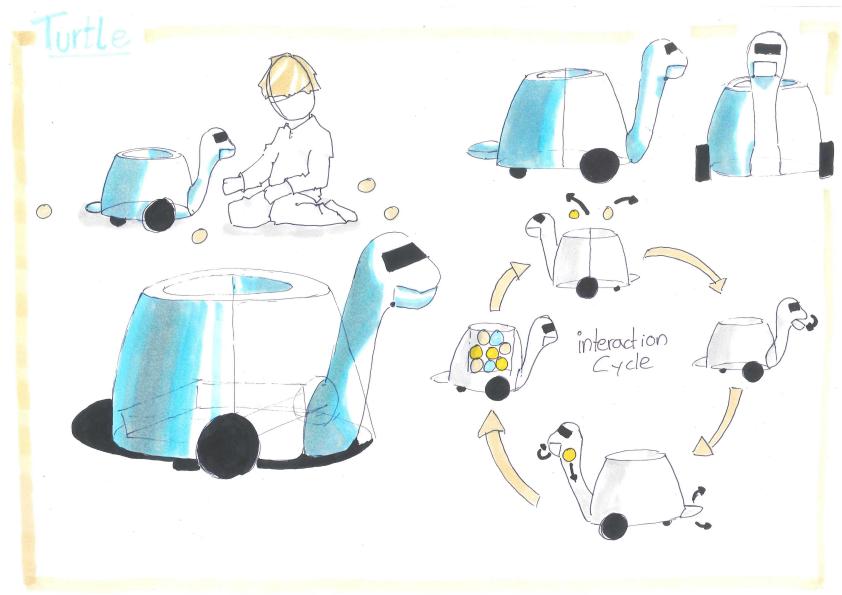


Figure 12.1: Volcanobot

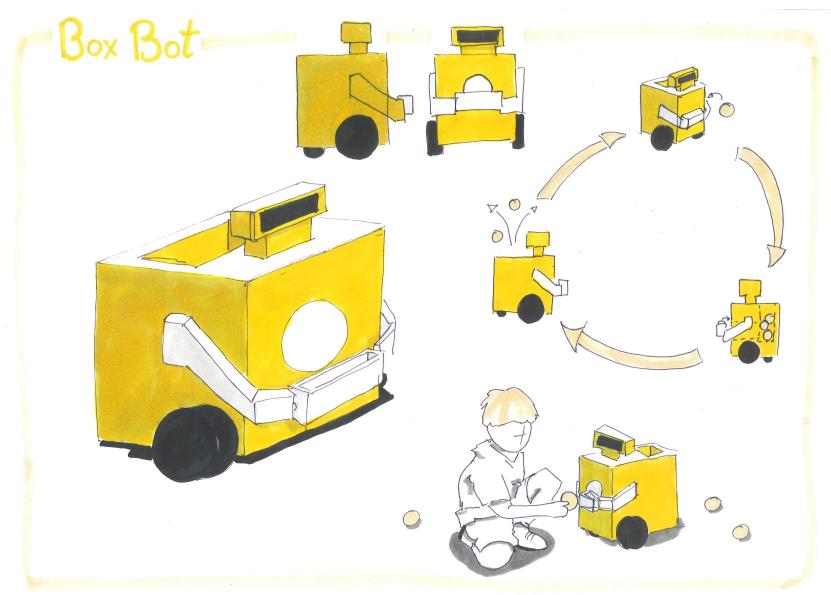


Figure 12.2: Box-bot

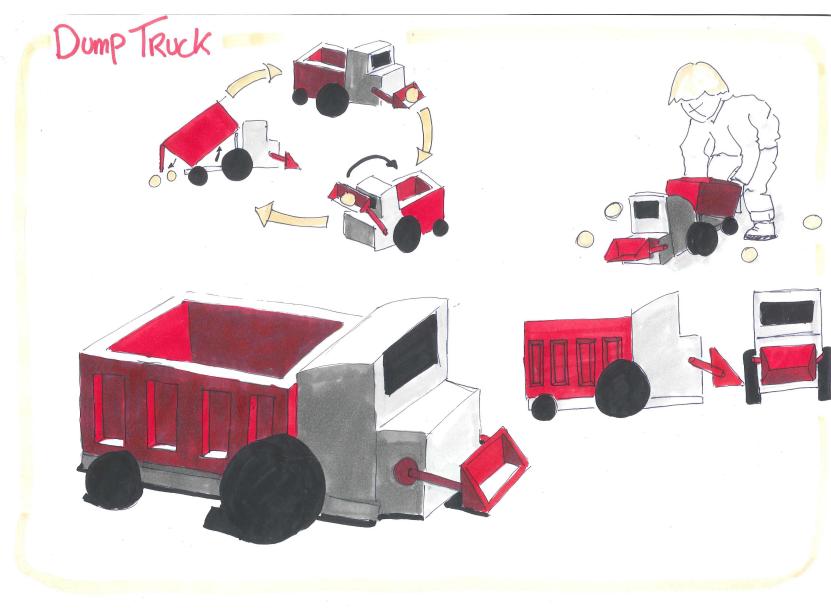


Figure 12.3: Truck Teacher

### 12.3 Sketches of mechanics

Again, the mechanics for the Box-Bot and for Volcanobot are quite similar. The spring launch mechanism applies to both the Box-Bot and Volcanobot.

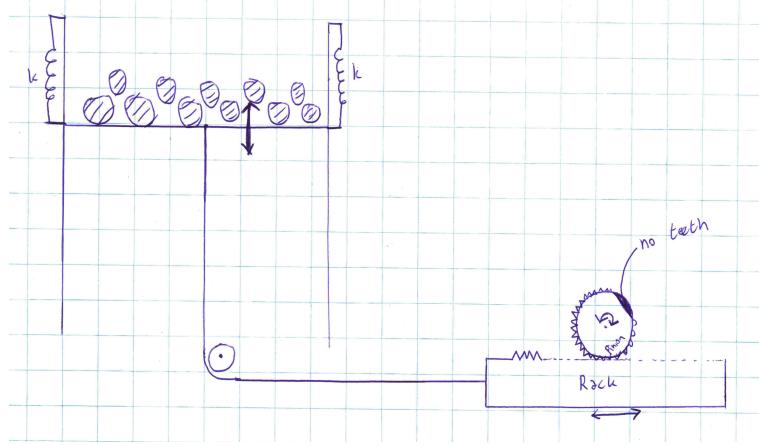


Figure 12.4: Schematics for the launching mechanism of the Box-bot and Volcanobot

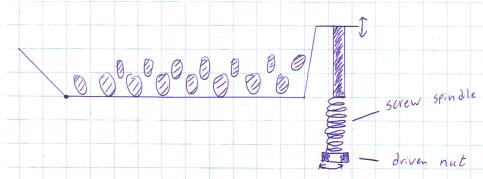


Figure 12.5: Schematics for dumping functionality of the Truck Teacher

### 12.4 Initial software architecture

At large there is little difference between these three designs from a software perspective. The actual difference is just how the motors are controlled and how emotions are expressed by the robots. The software structure diagram in Figure 12.6 shows the different subsystems found in the software on the second row. It further specifies the functionality of these subsystems in the row below. From this diagram we learn what the distribution of classes and namespaces should look like in the software. Each node in a row should implement the nodes it is linked to in the row below it. With the top node bringing everything together into the main operating function. This diagram holds for all three concept since they only differ on the lowest level of implementation, which is not covered in this scope.

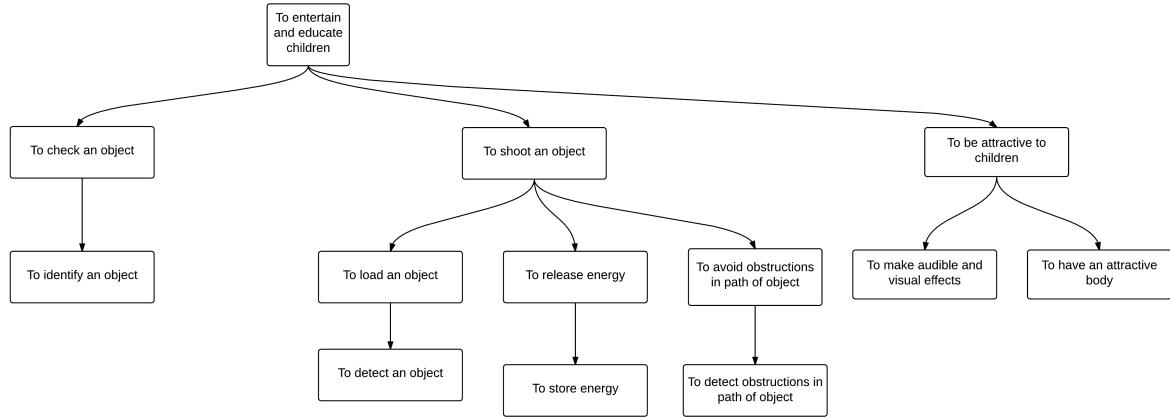


Figure 12.6: The software structure diagram

## 12.5 Initial electronic and electrical design

For the electrical and electronic design, a few things will have to be decided. The following parts will have to be considered:

- Battery – Li-Ion, LiPo and NiMH
- Computing – BeagleBone, Arduino, Laptop, Smartphone, Other
- Lights – LED
- Display – LCD
- Speaker
- Motor
- Sensors – Ultrasonic

The only difference between the three designs is the amount of motors. The final decisions will be made in the final prototype electrical design.

# Chapter 13

## Concept choice

In this chapter, the decision for the final concept design will be made and explained. Recall that there were three concepts: the Truck Teacher, the Box-Bot and the Volcano Robot. The decision was made after careful consideration of the following factors:

- Difficulty to build
- Entertainment value for children
- Originality

### 13.1 Difficulty to build

The final concept should not take half a year to build, because there is only 8 weeks. This is an important factor, but all of the concepts tick the box of “able to be constructed in less than 8 weeks”. The “Truck Teacher” is the easiest to build. There would be only 2 very simple constructions besides the driving features:

- Making the container on the back able to dump balls.
- Making the bucket on the rotate to get the balls into the back container.

The Box-bot and the Volcanobot both require some more construction to be fully functional.

- A launching mechanism with a spring, an air-cannon or something else.
- A conveyor belt to transport the balls, once they have entered the robot, to the launching tube.

For the Volcano Robot, an appealing shell is also required, which requires the making of a jig. The Volcano Robot is therefore the hardest to build, followed shortly by the Box-Bot and the Truck Teacher. The Truck Teacher being the easiest to build.

### 13.2 Entertainment value for children

After meeting with Maja Rudinac, expert on robots and their interaction with children, it became clear that the Truck Teacher concept would not be very interesting because there is already a high number toys in the form of a truck on the market. A toy can be entertaining if they already know it, but a toy like they have never seen before is likely to be more entertaining, engaging.

The Box Bot is very simple and whilst it may look like it is from the future, it's not a very attractive concept for children. Adding a lot of lighting and sound effects might increase this, but not in the way that a different body shape would affect it.

Miss Rudinac also mentioned that she had never before seen a robot shaped like a turtle with a volcano on its back. After some research, this turned out to be true. There is however a character from the Pok  mon (Nintendo, 2014) named Torkoal, that looks very similar to the concept of Volcano Robot.

The entertainment value of Volcano Robot is the highest, followed by the Truck Teacher and the least attractive robot is the Box Bot.

### 13.3 Originality

Making a robot that is original is not very important, but it makes for that “never seen before” experience with children. An original and new concept that does not exist yet adds to the entertaining value for children. You could therefore call originality a sub-category of the entertainment value.

As mentioned in the previous paragraph, Volcano Robot scores high when it comes to originality. Both the Box-Bot and the Truck Teacher score low, but the Truck Teacher scores the lowest. This is because a truck like toy has been seen numerous times before.

### 13.4 Final concept choice

After weighing the pros and cons of all the concepts against each other, the Volcano Robot concept comes out as the best. Volcano Robot scores high on originality and entertainment value. Even though Volcano Robot might be a bit harder to design and build, it will be more interesting and is probably more fun for children. Therefore the Volcano Robot was chosen to be further developed.

# Chapter 14

## Name and logo

Several options were considered for the name of the turtle. First of all the name needs to appeal to children and their parents. It would be best to have a short name, which is easy to pronounce. Furthermore the name needs to relate to the robot, so it has to do something with volcanoes, turtles, robots or child education.

After searching for names the island group Tawi Tawi was found in the Philippines. This island group has several volcanoes and an island called Turtle Island. It was decided that Tawi Tawi sounded nice but was a little bit too long, so the name would be shortened to Tawi. Tawi the Turtle has a nice ring to it and is a unique name for the robot.

After deciding on the name a logo was designed. The logo (see figure 14.1) is very simple so it is easy to recognize for children and their parents.

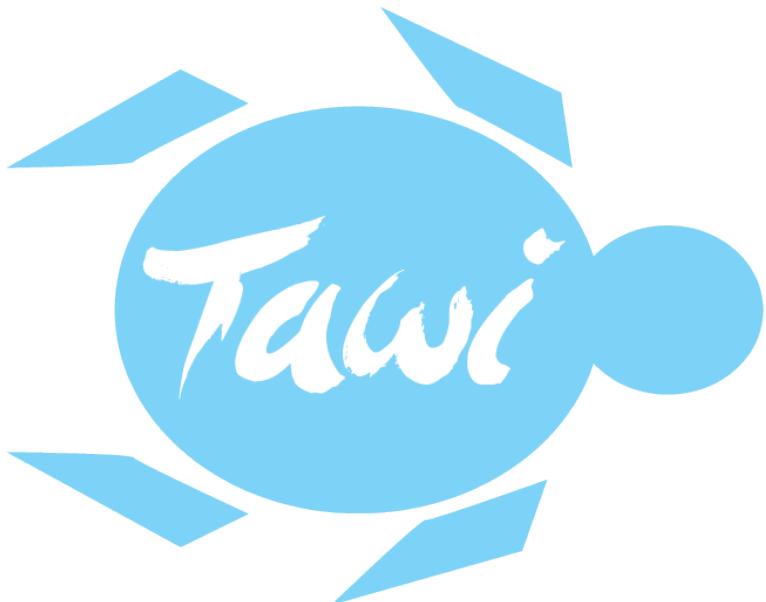


Figure 14.1: The logo for Tawi

# Chapter 15

## Development prototype design

### 15.1 Analysis of required parts

All parts that will need to be made can be found in Appendix K: Drawings.

### 15.2 Mechanical design

#### 15.2.1 The mouth

Opening the mouth is an operation for a servo. The servo would not fit directly next to the mouth though, so we needed to use some sort of transmission for the movement.

Lucky for us, the mouth is not very heavy. We're using the smallest servo we can find, which delivers 0.15Nm at 5V.

According to our calculations, which were done with an exaggerated weight of the mouth and can be found in Appendix I, we could use an arm attached to the mouth axle that is two-thirds the length of the servo arm. If it is bigger, this only gives us more advantage. Since the servo arm has several attachment points, we are using an arm that has the length of half the servo arm. We can then adjust the servo arm when needed.

An overview of the mechanisms can be found in Figure 15.1.

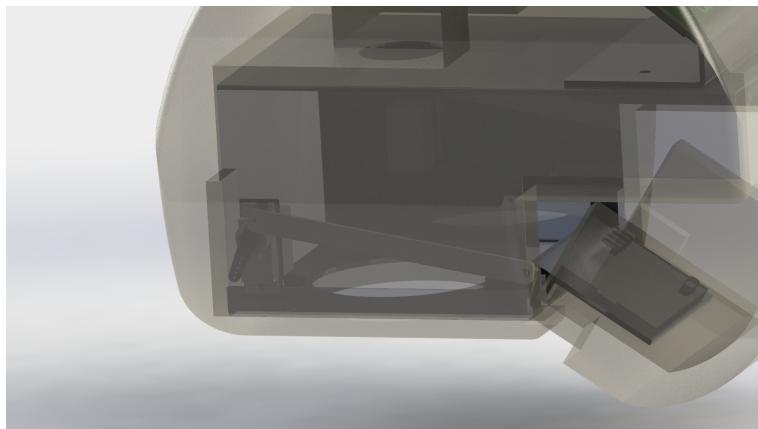


Figure 15.1: The mechanism to open the mouth

### 15.2.2 Platform

For the platform we had a good look at what we would need and what the requirements for it are. From this, we quickly realized that the DPR4 platform as would be supplied to us would be too big and too heavy for our use. We were looking for a platform in the range of 300x300 [mm], and the DPR4 is more than 500mm long and wide. The platform itself should also be quite light, since we're building a toy, and toys have to be lifted and moved once in a while. The stiffness of the frame was of little concern, as we're not planning on putting any heavy constructions on top of it.

We now had two options left:

- Produce a platform ourselves (this would include getting motors and wheels to drive it)
- Try and source a different platform with wheels and motors attached

We thought we'd have a look in the robotics basement for any old platform. This was done mostly because producing a platform ourselves costs a lot of time and probably also money. Turns out that they had a platform that fit our bill quite good: the pioneer platform. This was a robot when we got it, but 2 hours later was stripped down to just a chassis, motors and wheels. The platform measures about 300mm wide and long so it fits our wishes perfectly. We made a model of the platform, motors and wheels and it is found in 15.2.

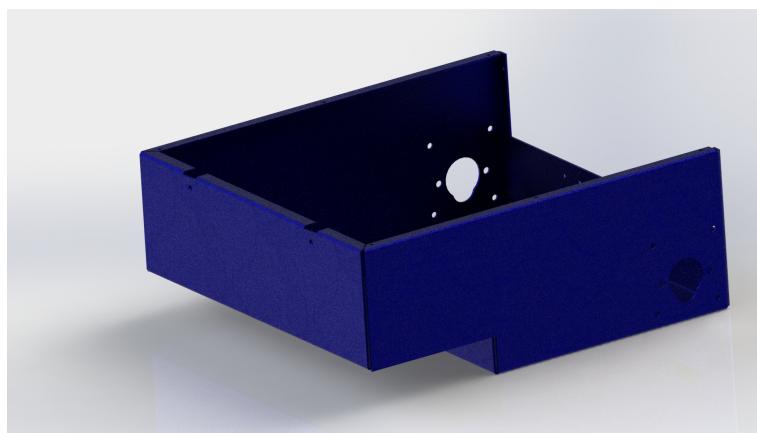


Figure 15.2: The Pioneer Platform

The fact that the platform is already made saves us probably about half a week or so in production. Seeing that time is and will always be an issue, we really struck platform gold here.

### 15.2.3 Motor Choice for Launching

We need a motor to drive a pinion, which in turn pulls a rack backward and that stores energy in our springs. The motor (with attached gearbox) for this application needs:

- Enough power, about 1.5Nm is required so a stall torque of 3Nm or more is desirable
- A relatively small size (it needs to fit in the platform with all the other components)
- A locking mechanism (when we remove electric power from the motor, we want the rack to stay where it is as to not consume more power)

With all this in mind, we thought about building a gearbox and locking mechanism ourselves, which is perfectly fine but just takes time. The idea came forward to use a worm gear as a locking mechanism and a gearbox. This suits our wishes perfectly, since it's a self-locking mechanism, has a huge gear ratio (the worm gear is basically a gear with 1 tooth) and can be relatively small in size.

Further investigation of this revealed that motors are being sold with an attached worm wheel gearbox. Perfect! There was however one problem: most of the motors we could find were sold from China. If you have months of time to wait for parts this is probably fine, but since we don't have months to wait for our motor, we had to find a solution closer to home.

We found a company near Delft that sells these motors for all sorts of purposes. Most of these purposes were automotive, such as windscreen wiper motors or adjustable seat motors. A sheet with specifications is attached as an Appendix J.

#### 15.2.4 Launching mechanism

Choosing a mechanism to tension and then release energy to launch our balls up into the air was a tough process. We considered several things:

- A mechanism that works with air pressure and a set of valves
- A mechanism that works with spinning wheels (like those used in tennis ball launchers)
- A mechanism that works with springs and has a release of some sort

All of these seemed to have potential. We decided to find the ones with most cons and cross it off the list.

First off, the air cannon would need some sort of compressor or a storage tank with compressed air in the platform. This is certainly possible but would cost us a little bit of room in the interior of the platform. Also, making the launch tube completely airtight so the launch goes according to the calculations is quite a difficult process and it's susceptible to wear too as rubber rings wear out from rubbing the walls of the launching tube. The option with compressed air was therefore crossed off the list.

Spinning wheels is a good option, as it would send balls flying up quite high. There's a couple problems with this option though. First off, it can only launch one ball at a time. We want to launch about 20 and this could be done by firing all the balls quickly after one another, but doesn't look as good as one big 'explosion' of balls coming from a volcano.

Also, it takes up quite a lot of room since it needs two spinning wheels with a diameter of twice the ball diameter each. This would equate to about 250mm in length for the total launch mechanism, which is almost the entire platform length.

And last but not least, spinning up wheels with a considerable mass costs quite a bit of energy, not all of which is going to go into the launch but some of it will also remain in the wheels.

Finally, a spring mechanism was chosen. The release however we were not sure of. We could make some sort of finger to hold the carriage as it travels, and make the finger release at the bottom. This is quite an intricate process with quite a lot of parts, and is therefore not ideal. Another option is to extend the springs with a rack and pinion. We would take off a couple of teeth of the gear to make the release. When the gear rotates and the rack gets to a point where there are no more teeth, it automatically shoots forward. It consists of little parts and is relatively easy to build. It needed some simple calculations to figure out the travel of the springs and the diameter of the gear, but this was not a problem.

A picture of the final construction can be found in Figure 15.3. Detailed part drawings can be found in Appendix K.

We used some plastic (POM) guiding rails to guide the rack as it's being pulled back. POM is good for this use as it is a little bit wear resistant and has a low coefficient of friction on metal.

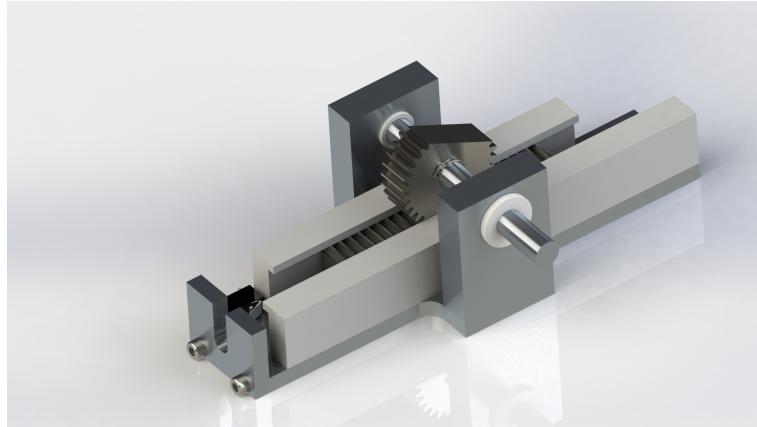


Figure 15.3: Launching mechanism

#### 15.2.5 Calculating the glue bond

Calculations have been done on the glue bond that holds the ring on to the launching tube. These calculations have been performed because a combined force of 100N is exerted on to the ring and we want it to not slide on the launching tube.

The shear stress on the glue bond is calculated as shown in Figure 15.4

$$\tau = \frac{F}{A} = \frac{100[N]}{0.004[m^2]} = 25000[Pa] = 25[kPa]$$

Figure 15.4: Formula for calculating the glue bonds

Most glues have a shear yield stress larger than 10MPa, so there is nothing to worry about here.

#### 15.2.6 The ball transport system

In the robot, spherical objects need to be transported from the lower part of the neck to the upper part of the launching pipe. There are multiple solutions to this problem. First let's start with the requirements for this problem. The objects that needs to be transported are styrofoam balls with a weight that is one or two grams. The solution must also be small in height to make sure that the robot is as low as possible.

It was considered to use a shooting system that shoots the balls through a pipe into the launching pipe. This would involve a similar system as used in the launching pipe itself; a spring that stores the energy and a rack and pinion construction. A system like this is complex and it would not be easy to calculate the friction between the spherical objects and the walls of the pipe.

Another solution was a conveyor belt to transport the spherical objects. This belt could be a V belt or a timing belt. V belt pulleys are bigger in diameter than timing belt pulleys, and

the whole solution would also be more expensive than a timing belt setup. So the solution comes to a timing belt with pulley.

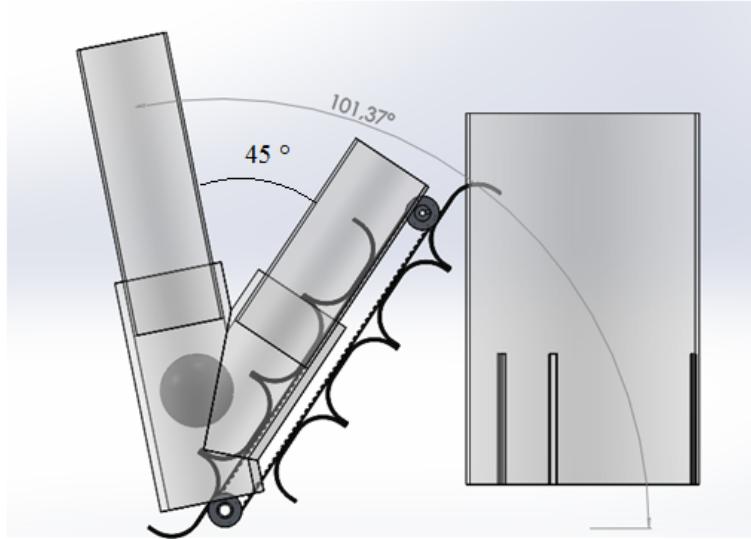


Figure 15.5: The timing belt pulley setup for the transport of the ball

In Figure 15.5, a drawing is displayed which shows the timing belt pulley setup. Now, a calculation of the torque of the motor to transport the balls is made.

The torque that needs to be transmitted to the driving pulley (the upper pulley in Figure 15.5) is equal to:

$$M = \frac{T_e * d_p}{2c}$$

The effective tension is equal to:

$$T_e = F_a + F_g + F_{ab} + F_{ai}$$

$F_a$  is the resulting force from acceleration of the balls.  $F_g$  is the resulting force of the weight of the balls.  $F_{ab}$  is the force resulting from acceleration of the belt and  $F_{ai}$  the force required to accelerate the pulley. There is also friction from the fact that the rubber strips that hold the balls are colliding with the launching pipe.

It is now stated that the acceleration is almost zero and only the steady state situation is regarded. Then, only the weight of the balls is important. There is room for five balls at once, so the total weight is 10 grams.

With the angle included (56.37 degrees) this results in a tension force of 0.1 N. The total moment the motor will have to deliver, with a pitch diameter of 0.02 meter is 1 Nmm. The friction from the flaps is hard to calculate. We will assume that the total moment to be delivered is 10 ten times this, so 1 Ncm.

It is accepted that the balls will travel the 0.25 meter along the belt in 10 seconds. With the pitch diameter of the pulley, this results in axle speed 24 rpm. The selected motor which is properly available has a no load speed of 25 rpm, and a rated torque of 8 Ncm. This motor will operate at near no load speed, because the moment required is much lower than the rated

torque, so the 24 rpm will most likely be reached and the ball will be transported in just over 10 seconds.

### 15.2.7 Neck strength calculations

To check whether the neck is strong enough to support a child pulling on it, a strength calculation is necessary. The material used is pvc, with yield strength of 35 MPa (DYNA, 2003). The maximum moment which the pipe can hold is:

$$M = W * \sigma$$

With

$$\frac{\Pi}{32} * \frac{(D^4 - d^4)}{D}$$

The outer diameter  $D$  is 63 mm, and the inner diameter  $d$  is 59 mm. So  $W$  is 5665 mm<sup>3</sup>. The maximum moment that can be imposed is  $35 * 5665 = 2.0 * 10^5$  Nmm. The free neck length is 112mm, so the maximum force to be imposed  $2.0 * 10^5 / 112 = 1770$  N. This equals a pull force of 180kg in perpendicular direction of the neck. To further investigate whether the link between the neck and the rest of the robot is strong enough to support a child pulling on it, a simulation of this part of this has been done in section 15.5. Conclusion: this is enough to support a child pulling it. How much force the robot can sustain before it tips over will be calculated in the next section.

## 15.3 Calculation of stability and tip-over effect

As you can see in figure 15.6, the robot has a design that is possibly vulnerable to tip over, when a child pulls on the neck of the robot. A calculation will be done see the severity of this problem. From the Solidworks model, the centre of mass can easily be calculated. The distances to the axes of rotation have also been displayed in figure 15.6. The weight of the robot is 12,2 kg so the force of the kid required to let the robot tip over is equal to:

$$F_{pull} = 63/400 * 12.2 * 9,81 = 19N$$

This translates to a mass of 1.9 kg. This is very low, even for a child, so the robot will easily be pulled over. To compensate for this, it is necessary to add weight to back (the left end in figure 15.6) of the robot. Here, there is already a battery installed, but a second battery could give the pulling force needed a multiplication of 2. A last resort could be the installation of extra dead weight like scrap metal or brick at the back of the robot. This would of course lead to an increase in energy consumption by the driving motors, slow the robot down and would give no other benefit than stability, in comparison to the battery which would provide extra power. Concluding, adding extra batteries to the back of the robot would be best to prevent the robot from tipping over.

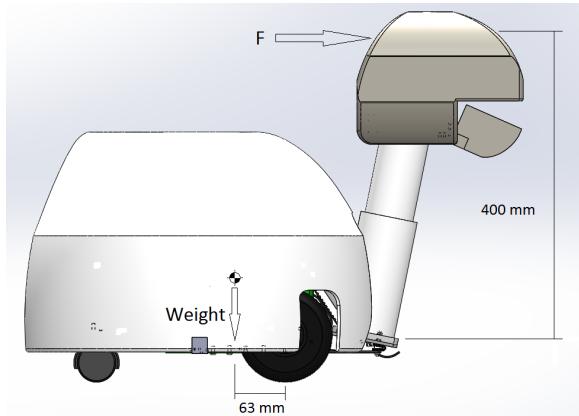


Figure 15.6

## 15.4 Calculating the mouth

The mouth needs a servo to operate, and servos have a limited torque. Therefore, some calculations need to be performed to see if it will close after opening. The full calculations can be seen in Appendix I. In short though, we need the arm on the axle of the mouth to be larger than two-thirds of the length of the servo arm. We chose to go with a ratio of 1:1, as to not load the servo to its maximum.

## 15.5 Simulating the neck

We did a simulation on the neck of the robot to see if it would hold under some stress. The chosen stress is a small child pulling on the neck of the robot. The neck of the robot is weakest like this, because its held in place on the bottom with only an 8mm thick mounting plate. Results of this simulation are below (Figure 15.7). The simulation shows us that the neck can withstand a child hanging on it if the robot is tipped over, the worst situation imaginable because of the length of the neck. The chosen weight of the child is 30kg. The neck will yield when loaded with more than about 40kg, but then again, its not really designed to be able to suspend a child in the air.

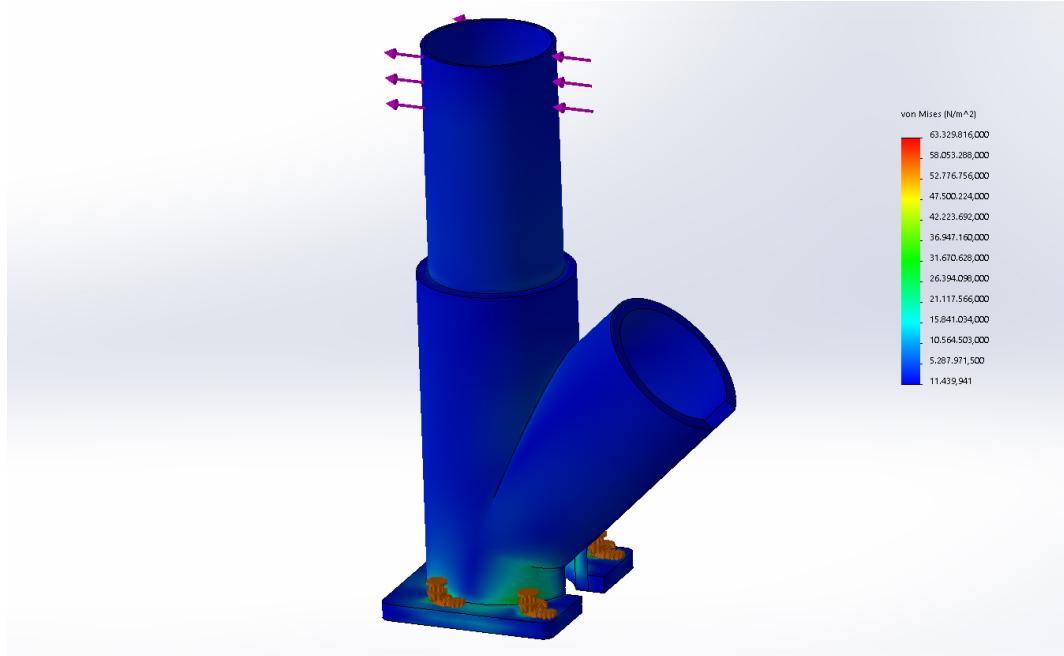


Figure 15.7

## 15.6 SolidWorks model

The whole prototype was put into Solidworks. In figure 15.9 to 15.11 several renders of the model can be seen. In the next stage of this project this whole model will be build. The drawings of the parts, which will be produced, can be found in appendix K. An overview of all parts, which will be bought, can be found in the bill of materials in appendix H.



Figure 15.8: Render of the exterior

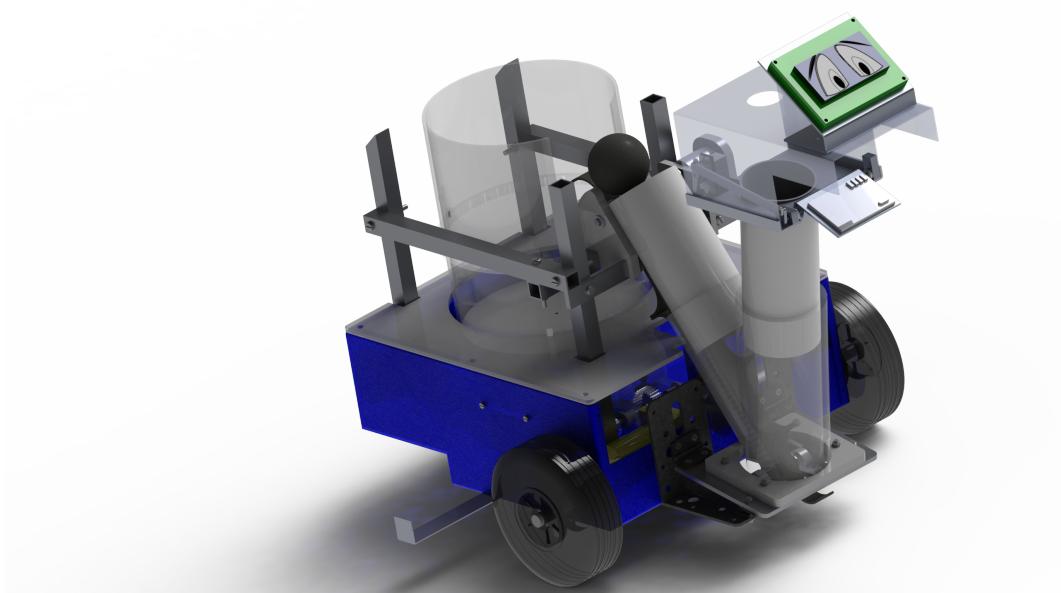


Figure 15.9: The outside structure without the shell

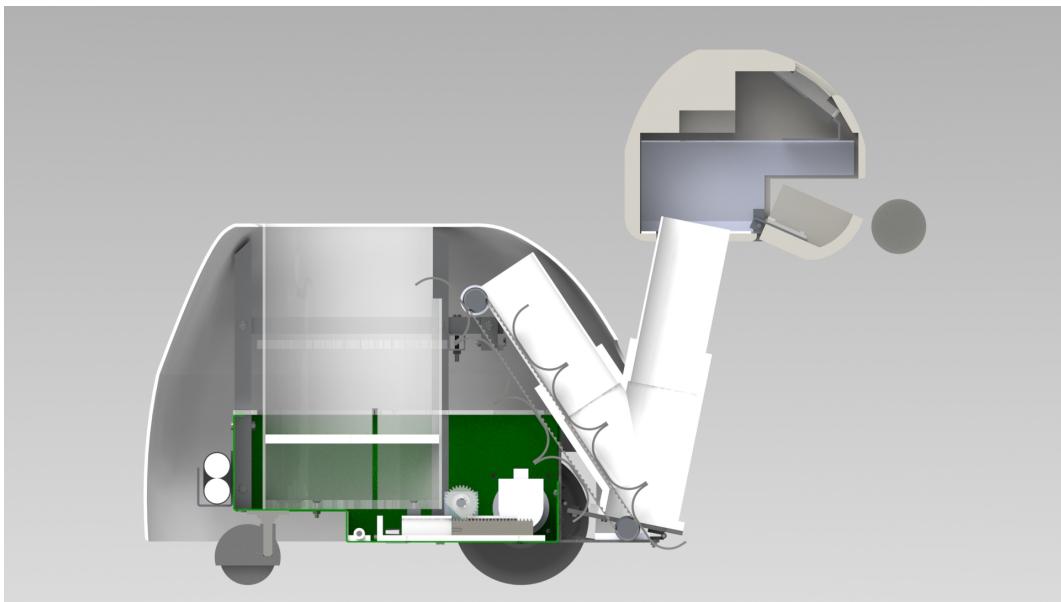


Figure 15.10: Section view of the interior



Figure 15.11: Tawi placed in the user environment

## 15.7 Software architecture

With requirements and concepts worked out in previous chapters. A clear design for the software can now be constructed. The most important scenario for the robot is that the robot can ask for a ball, then wait for the correct ball to be inserted and give positive or negative feedback

depending on whether the given ball was correct. After repeating this process until the volcano fills up, the robot erupts, spreading the balls around himself again.

The overall architecture of the robot is one central node (robot), that delegates work towards several lower level nodes, that in turn each listen to an even lower level node, which either repeats to process or directly controls a device.

With this structure in mind the classes can be defined. Figures 15.12 through 15.15 show the implementation. The first subsystem is the overarching group that contains the handlers for the lower level functions. Figure 15.12 shows the handlers for each node in the first two rows of Figure 6.1. The Audio and Video are separated into their own classes to create a distinction of responsibility for each class.

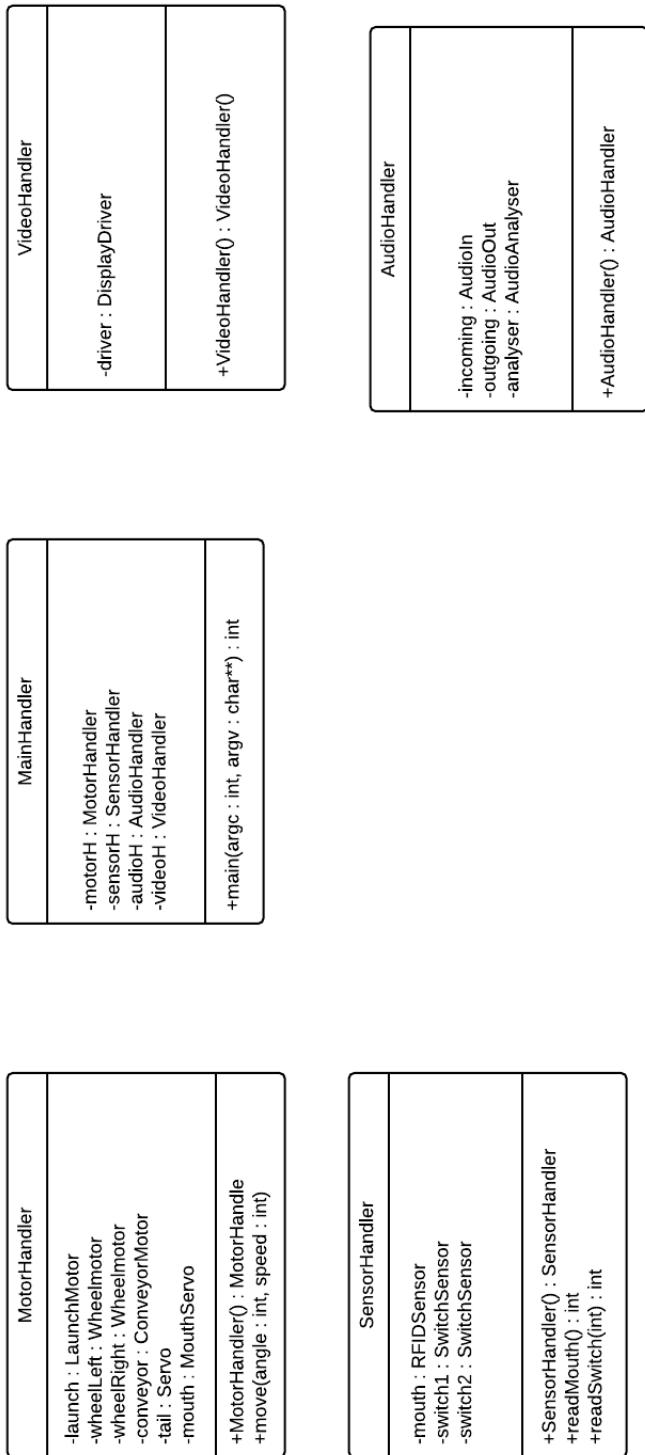


Figure 15.12: The first subsystem is the overarching group that contains the handlers for the lower level functions. These are The Audio and Video are separated into their own classes to create a distinction of responsibility for each class.

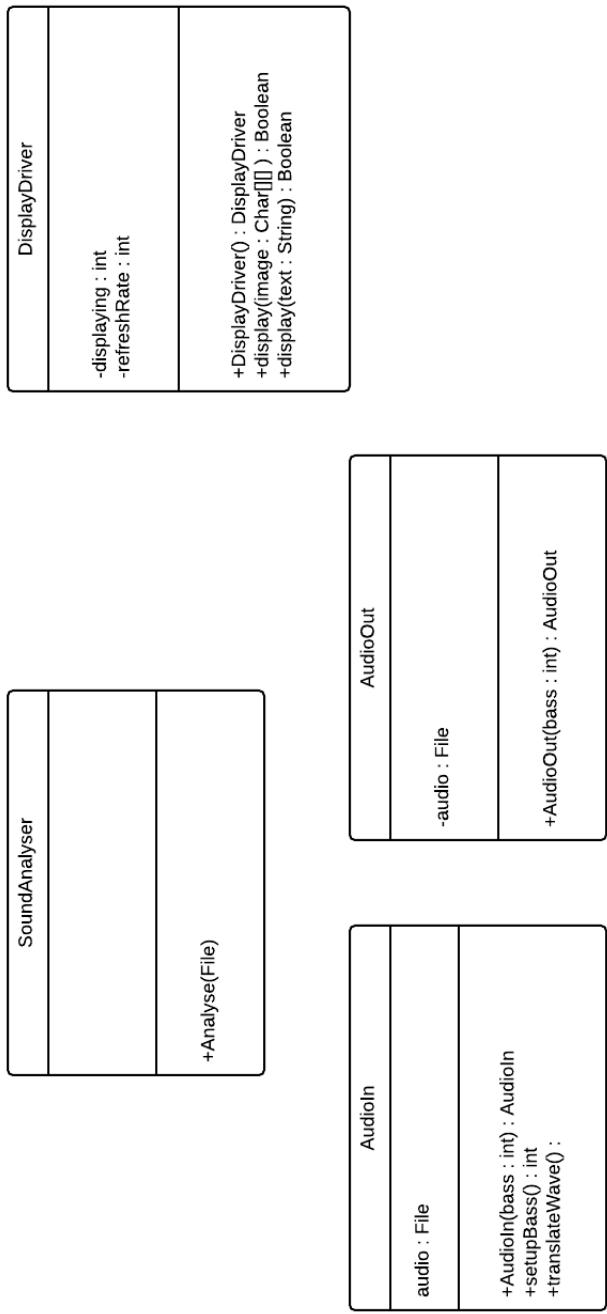


Figure 15.13: depicts the general idea for handling audio input and output. This has to stay ambiguous, since the actual functions and variables are highly dependent on what audio framework is compatible with the hardware of the robot, as well as the algorithm used to analyze and process the signal to and from the audio hardware.

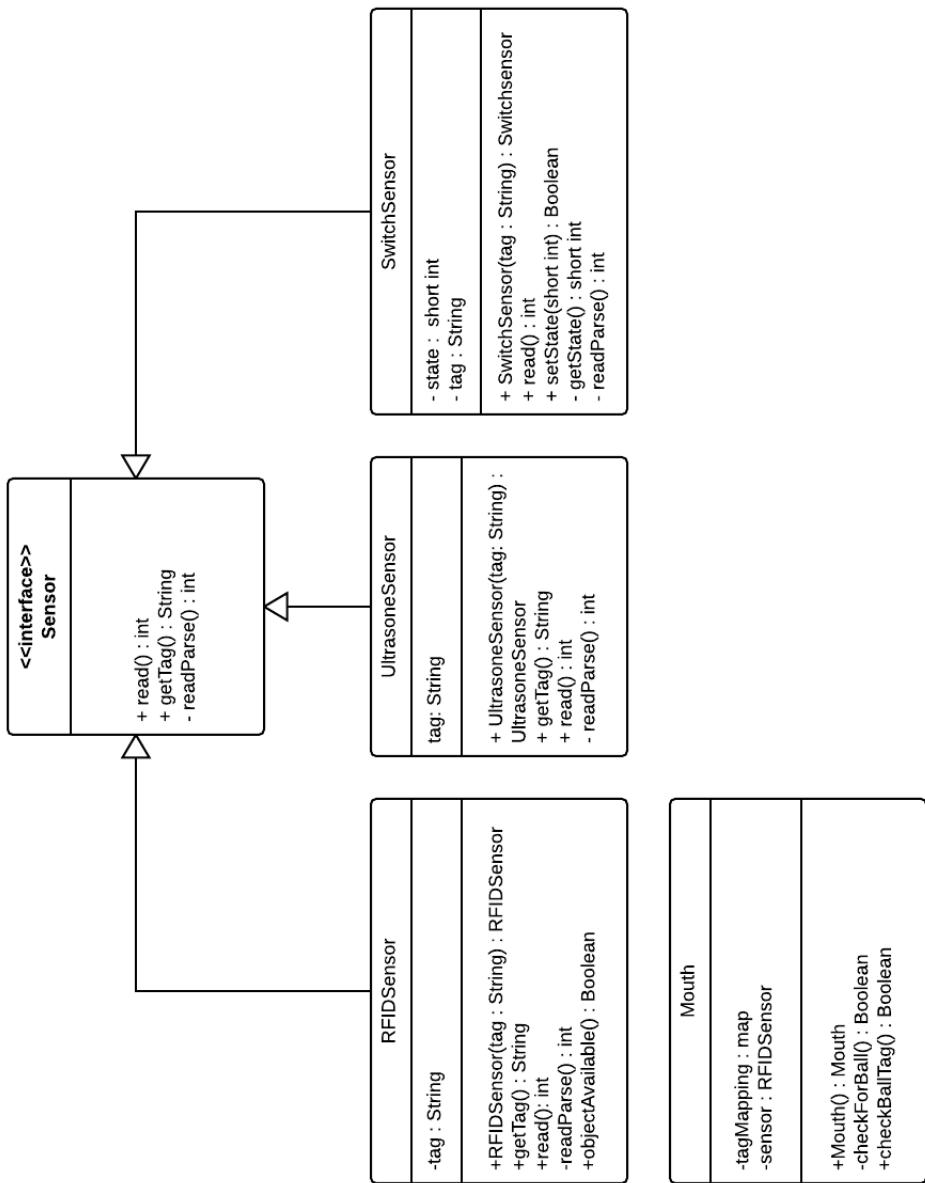


Figure 15.14: This figure shows the handling of balls given to the robot, in addition to other sensors used in the robot. The sensors make use of the interface Sensor to force consistent code patterns in every sensor implementation

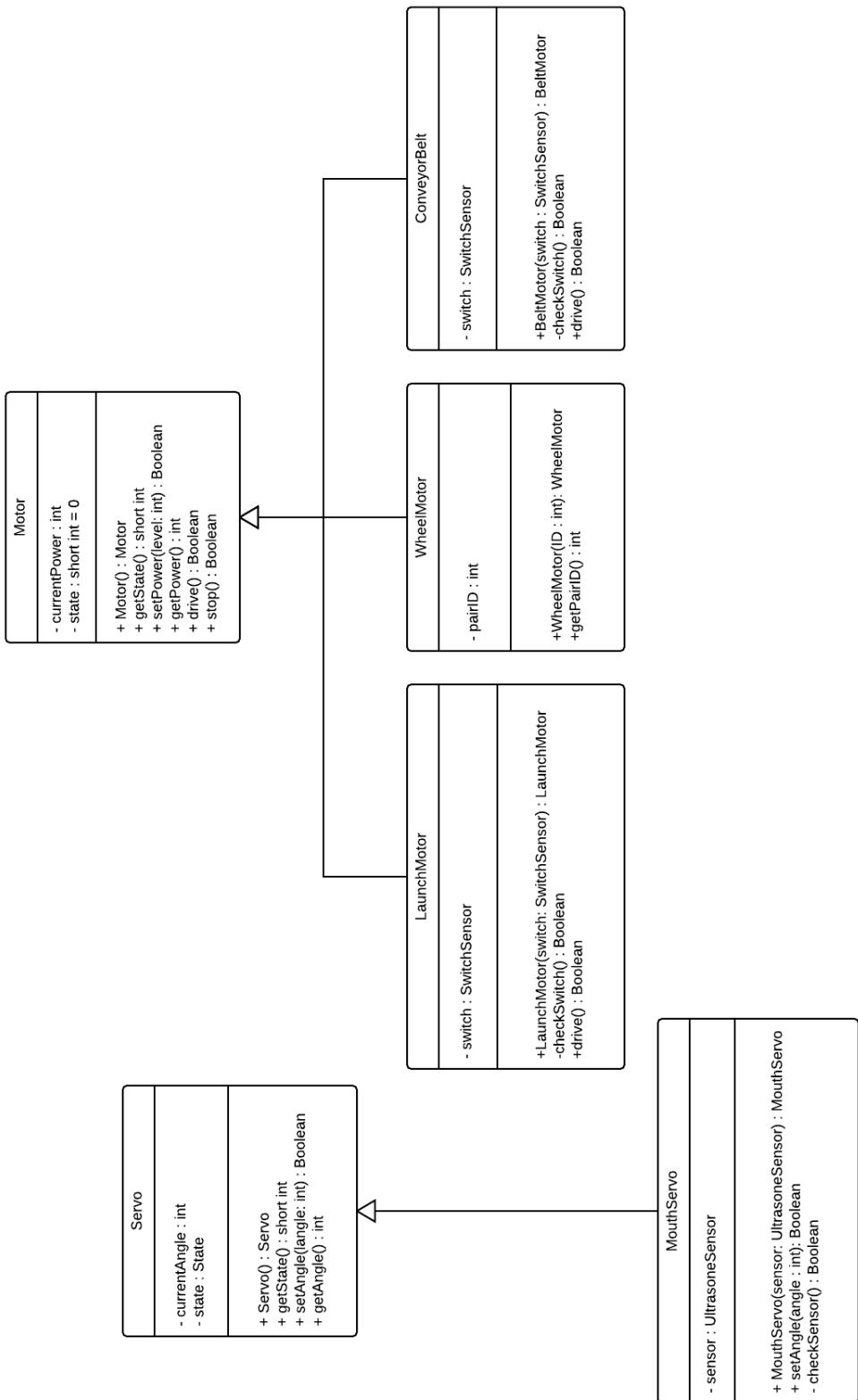


Figure 15.15: The last figure of this segment shows the regulations of the motors and servo. Again classes that handle a motor extend a parent class Motor to reduce duplicate code.

## 15.8 Electrical and electronic design

### 15.8.1 Battery choice

#### Type of battery

When choosing the battery, three types will be considered: Lithium-Ion, Nickel Metal Hydride and Lead batteries. To start off, Lead batteries are not considered viable, because of the low energy density and the size of the batteries (“Lead Based Batteries”, n.d.). The low energy density makes it heavy, while Li-Ion and NiMH can have the same capacity while they are lighter and smaller. Since the robot is supposed to be small, the lead batteries will not be used.

#### Li-Ion vs NiMH

The advantages of Lithium Ion batteries (“Lithium Based Batteries”, n.d.) opposed to NiMH batteries (“Nickel Based Batteries”, n.d.) will be summed up here: Advantages Li-ion over NiMH

- No memory effect like NiMH.
- Higher power-density
- No maintenance required
- NiMH loses capacity when overcharged. Requires a special charging circuit to prevent this.
- NiMH has a higher self-discharge rate than Li-Ion

Advantages NiMH over Li-ion:

- Faster charging
- Li-ion can burst into fire when overcharged or overheated. Requires a special protection circuit.
- Li-ion starts losing capacity from the day it's fabricated

The memory effect means that Nickel based batteries, when constantly discharged until a certain point, can “forget” it can discharge even further than that. This can be cured by fully discharging the battery once in a while. It's the NiCd battery that mainly suffers from this though and the NiMH batteries don't suffer from it that much anymore. Also, it mainly occurs when the batteries are always discharged until the same point, which is usually not the case for consumer technology.

Lithium Ion batteries are quite similar to NiMH batteries, but Li-ion has a slight edge. The main decision will be made by availability and price.

#### Required battery capacity

The required capacity of the battery, is based on one of the requirements stated in the MoSCoW Model in Appendix B. The robot must be able to run for 30 minutes at least. For this reason, Figure G.2 in Appendix G is based on 30 minutes runtime. There's a few things to note about the figure. The capacity of a battery is not equal to the actual capacity that can be used. Service life of batteries are higher when the Depth of Discharge is lower than 80% (“Battery Discharge Methods”, n.d.). Besides this, there is also the self-discharge of the battery. This will

make the effective capacity of the battery approximately 70% of the total capacity. The Time Type indicates when that part receives the current. This is important, since for example the Shooting motor uses 4A, which is a lot more than the other parts, but it only uses it for a short time period. Therefore there is a Maximum Capacity, in which the Shooting motor, the Wheel motors and the Speakers are always on, the Minimum Capacity, in which those objects are always off, and the Average Capacity, which is the average of those two. The Average Capacity is a slightly more realistic indication of how much capacity it will require.

### 15.8.2 Battery decision

The options are lined up in Figure G.1. According to the Required capacity paragraph, the robot would require at least 2633 mAh for half an hour. Also, the required voltage for the motors is 12V. Therefore, at least 3 of Option 1 would have to be bought for 11.1V. To reach the required capacity for Option 2, 2 of those would need to be bought. The other two options already fulfill the requirements. In the end, Option 4 was the cheapest, also fulfills the 12V requirements, while the Li-Ion ones are only 11.1V. Option 3 would have been viable, but it was simply too expensive for a battery for a robot that doesn't actually need that much capacity. For these reasons, Option 4 was selected.

### 15.8.3 Computational options

Several options were considered considering the kind of computer, which is going to control the robot. The following options were considered.

#### Arduino

The Arduino is lightweight and needs less power in comparison to the rest of the option. It is also an easy option because there is one available. Another plus side to Arduino is that shipping data between in- and output is easier.

Negative sides to using an Arduino are that it has very little computational power and has very little memory. Arduino also needs low level programming for almost everything.

#### Arduino + desktop or laptop in base station

Using an Arduino in combination with a desktop or laptop gives a lot more computational power and more memory. But of course this requires a base station, which needs to communicate wirelessly with the robot.

#### Arduino + smartphone (Android)

This combination has more computational power than an Arduino alone but less than an Arduino in combination with a desktop. It has decent memory and it is quite easy to connect an Arduino with a smartphone. The smartphone does need a power supply of its own and it adds an extra device to the whole construction, which will take up space.

#### Arduino + Smartphone + laptop in base station

This fixes the problem of the communication between the Arduino and the base station, because it can make use of the smartphones connection. It keeps all the plus sides of a base station like a lot of memory space and computational power. It also allows data pre-processing before sending it. The use of a lot of devices does make it more confusing and it is hard to keep track of everything, plus all the devices need their own power supply.

#### Arduino + computer parts

The Arduino is given more part to make up for its less optimal qualities, like more memory space and more computational power. This construction has a higher power consumption and probably needs cooling. This also requires a computer to deconstruct or ordering a lot of separate parts. This can be very expensive.

### Raspberry Pi

A Raspberry Pi is easier to program but has little computational power. It has less IO then an Arduino and it requires more steps to interact with peripherals. The Raspberry Pi is more library-oriented than an Arduino.

### Raspberry Pi + Arduino

This makes it easier to control the Arduino and makes it easier to control screens. The computational power remains small and it requires interfacing between Arduino and the Raspberry Pi, this will be more work.

### BeagleBone

It is possible to replace the Raspberry Pi with a BeagleBone. The BeagleBone has a more powerful processor and better connectors. The Raspberry Pi can handle more powerful graphics and has better audio capabilities. The Raspberry also has a bigger community, which can be a higher supply when help is needed.

### Multiple Arduinos or Arduino alternatives

The Intelligence is distributed via more devices this makes it easier to track, since there is one device per task, but of course needs more electronic components.

### Final descision

Because of the computational power required for a few functions and the usage of multimedia, the Arduino showed not powerful enough. The Arduino also does not have enough GPIO pins required for the robot. This means that we need more than just the Arduino. Because of the large number of GPIO pins and the better audio support on a single BeagleBone Black board, we decided to take the BeagleBone rather than multiple arduinos or a Rasberry Pi.

#### 15.8.4 Circuit design

The schematic of the final circuit can be found in Figure 15.16. The LM7805 Circuit is used to transform the 12V of the battery to the 5V that the BeagleBone needs. MOSFETs are used to switch the Transport Motor and the Shoot Motor on and off when needed. The LED streams might also require MOSFETs.

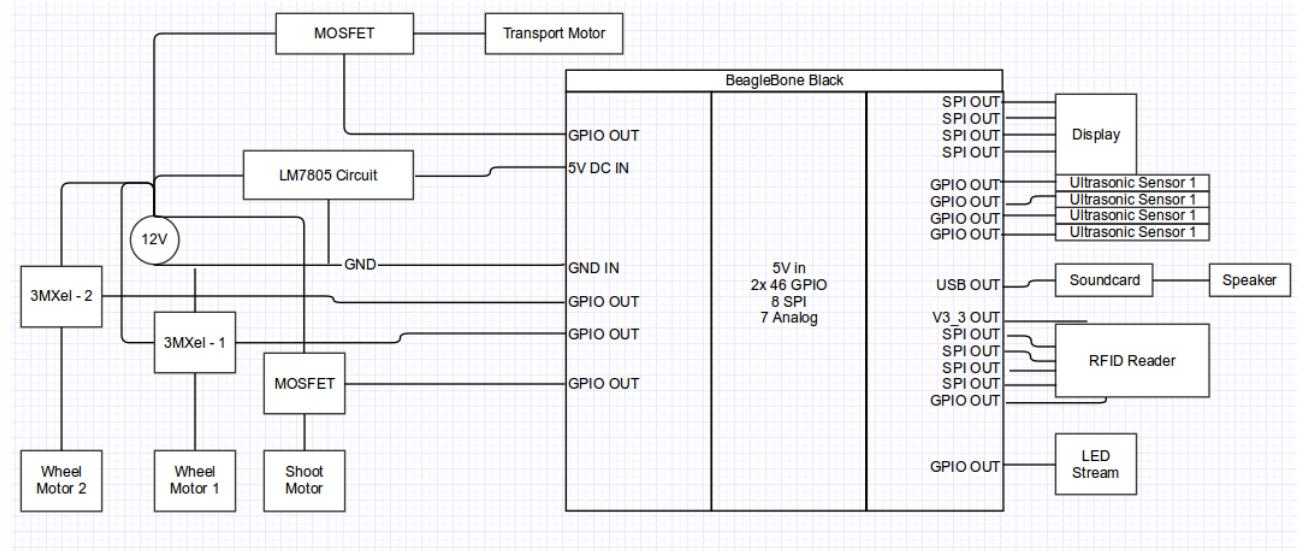


Figure 15.16: The circuit design

#### 15.9 Part list

# Chapter 16

## Planning November to January

Week 1 (10 November)

Ordering Parts

Building Parts

Programming

Week 2 (17 November)

Building Parts

Programming

Week 3 (24 November)

Assembling robot

Mechanics

Electronics Exterior design

Programming

Week 4 (1 December) Assembling robot

Adjustments in prototype for safe test with user

Week 5 (8 December)

Testing with user

Week 6 (15 December)

Adjustments based on test with user

Christmas break from the 22nd of December to 4th of January

Week 7 (5 January)

Report

Prepare presentation and poster

Week 8 (12 January)

Report

Prepare presentation and poster

Week 9 (19 January) Tentamenweek

Week 10 (26 January) Tentamenweek

## 16.1 Software planning

For software development the SCRUM methodology is used. With tasks rather than user stories, tasks are sorted by which order we will execute them(most important first). This gives us the following backlog:

- Task: robot must be able to request items by audio.  
Estimated effort: 2
- Task: robot must be able to process food (open mouth and launch).  
Estimated effort: 7
- Task: robot must be able to identify food items by RFID.  
Estimated effort: 3
- Task: robot must be able to reject incorrect food.  
Estimated effort: 2
- Task: robot must be able to request items by display.  
Estimated effort: 1
- Task: robot must be able to recognize music and dance to the beat  
Estimated effort: 7
- Task: robot must have suitable idle animations.  
Estimated effort: 5
- Task: robot must have animations for “waking up” after boot.  
Estimated effort: 3
- Task: robot must be able to complain about its “needs” (for example low power).  
Estimated effort: 2
- Task: robot must be able to react to voice commands.  
Estimated effort: 7

# **Chapter 17**

## **Conclusion**

This report explained the design phase of this project. In the first phase of the design process several brainstorms were held. The first decision was to make a toy robot for a child. This would be an interesting branch to explore, since children find it fun to engage with a robot and this way it can be made fun to exercise or learn with a robot.

Next, a brainstorm was held to come up with ideas for the design and purpose of the robot. It was decided that the robot would be used to help children learn several subjects from school at home. Three concepts were chosen to be further improved so a choice could be made between the concepts. After considering the three concepts, the turtle robot was chosen, since this robot was more unique and would be more interesting for the user. The concept design is the next phase in the designing process. The turtle robot was further improved and all the parts were designed and chosen. A model was put together for the prototype from these parts, which was used to design the robot and to get a good idea of how the prototype would look. Furthermore all aspects of the robot were further improved and enhanced to make a base for the prototype. Finally a name was chosen for the robot: Tawi.

In the next part of this project the prototype of the robot will be build and tested.

# Chapter 18

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# Appendices

## Appendix A

# Use Cases

---

### Use Case 2 Give the object

---

*Actor* Child

---

*Trigger* The child has found the requested object

---

*Main Success Scenario:*

1. The child offers the object to the robot.
  2. The robot accepts the object and stores it.
  3. The robot makes a satisfied sound and displays pleased emotions.
- 

*Extensions:*

2.a The child gives the wrong object:

1. The robot gives the object back or drops it.
  2. The robot shows displeased emotions and repeats his request.
- 

---

### Use Case 3 Scan the object.

---

*Actor* Robot

---

*Trigger* The child gives an object to the robot.

---

*Main Success Scenario:*

1. The child moves the object near the sensor.
  2. The sensor checks whether the object corresponds with what was requested.
  3. The robot accepts it and stores it.
- 

*Extensions:*

2.a The child has given the wrong object:

1. Return the object to the child.
- 

---

#### **Use Case 4 Scatter the objects.**

---

*Actor*              Robot

---

*Trigger*            The container is full or the robot has just been started

---

*Main Success Scenario:*

1. Check if it is safe to launch or throw objects.
  2. Scatter the objects around the room.
- 

---

#### **Use Case 5 Gather the objects.**

---

*Actor*              Child

---

*Trigger*            The robot scatters the objects.

---

*Main Success Scenario:*

1. The child sees objects fall around the room.
  2. The child gathers the objects.
  3. The child tries to find the object request by the robot.
- 

---

#### **Use Case 6 Child has lost or broken an object.**

---

*Actor*              Child

---

---

<i>Trigger</i>	The robot asks for an object that cannot be scanned anymore.
----------------	--

---

*Main Success Scenario:*

1. The robot notices that it is not receiving the correct object.
  2. After waiting a while, the robot gives an option for skipping this object.
-

## **Appendix B**

### **MoSCoW model**

#### **Musts**

- Safety – Must not be able to hurt a child
- Price – Prototype must have a budget of maximum 1000 euro
- Battery life – Must be able to run for 30 minutes at least
- Design – Must not be scary for children
- Measurements – Must easily move through an open door (Width maximum 70 cm)
- Identification – Robot must be able to identify objects
- Design – Robot must be able to display approval/disapproval of object
- Shooting – Robot must be able to shoot objects
- Energy – Robot must be able to store and release energy for shooting objects
- Safety – Robot must be able to detect if the child is not in the shooting path before shooting
- Design – Robot must look attractive to children

#### **Shoulds**

- Sturdiness– Robot should not be easily damaged when interacting with children
- Interface– Should be easy to understand for children
- Difficulty– Should have different levels for different ages
- Storage – The robot should be able to store objects inside
- Cleanable – Should be easy to clean the robot

## **Coulds**

- Movement– The robot could be able to move around
- Interface– Could have an application for smartphone
- Fun– The robot could be able to dance

## **Won'ts**

- Won't be able to fly
- Won't be able to make underwater explorations
- Won't be able to be used as a vehicle
- Won't be able to battle
- Won't be able to move at great speed
- Won't be able to retrieve the blocks himself

## Appendix C

### Brainstorm initial designs

The brainstorm was held with post-its to give everybody the opportunity to generate ideas without having to wait for the person writing them down. This helped to generate a lot of ideas and helped the group to come to the best design. The ideas could be categorized in different groups.

The brainstorm for the main robot design could be categorized in archetype robotic shapes, animal shapes and motorized vehicle shapes. Some examples are: Wall-E for robotic shapes, a whale or turtle for animal shapes and dump truck or tank for vehicle shapes.

The brainstorm for the balls the robot shoots in the air mostly consisted of ideas for the design or material used. The design ideas consisted from shapes, what they can do and appearance. A couple examples are: poke balls, balls with light or noise, balls with lightning drawn on them or with extra attached material to make it look like for example a fish.

The mechanical brainstorm was a little more difficult. They were categorized in different aspects, which can be found in the morphological chart, see chapter 8.

## **Appendix D**

# **Different games**

### **Colour recognition, age 3 to 4**

The child can practice naming colours with a very young child. The robot would ask for the blue ball and the child would need to represent the correct ball. This game would only be interesting for very young children, but the balls are quite small to fit in the robot so it needs to be age 3 and up.

### **Form recognition, age 3 to 4**

The balls would have different forms and shapes on it. The robot could then ask for the shape “square” and the child would need to give the ball with a square on it to the robot. This game was considered confusing, since the pictures are printed on balls and it would be difficult for them to recognize a shape of a ball. This game was considered to difficult, because of this and will not be used.

### **Food recognition, age 3 to 5**

The child could play a feeding game with the robot. For example, the robot would ask for ice cream and the child would need to give the ice cream ball to the robot. Intuitively the child would try to give real food to the robot. There would need to be a plan for when this happens.

### **Math, age 4 to 9**

The child could practice math exercises with the robot with different difficulty settings. For very young children the robot would for example ask “What is 2 plus 2?” and the child would need to give the ball “4” to the robot. The robot would scan it and take it. For older children it could ask multiplying and even dividing questions.

### **Animal recognition, age 3 to 5**

The balls would have different picture of animals on it and the robot would ask for the correct animal. This could be in different forms like making the noise of the animal or asking for a specific type.

## **Alphabet, age 4 to 9**

The robot can practice words and letters with the child. The robot would have balls with letters on them and can ask for the word “dog” for example. The child would need to give the “d”, the “o” and the “g” to the robot to make the word “dog”. For younger children the robot could just practice individual letters. Older children could maybe even learn a foreign language with the robot by practicing words.

## Appendix E

# Details software design

### E.1 Non-functional requirements

- **Ball-scanning:** Offered balls should be recognized within 3 seconds
- **Launchtime:** Launching has to be able to happen at least once every minute
- **Extensions:** The system should be able to be expanded for new sets of balls
- **Turning Speed:** The robot cannot turn with a speed higher than 0.5 m/s
- **Boottime:** The boot of the whole robot from off to functional should not exceed 20 seconds

### E.2 Use Cases

---

#### Use Case 1 Child offers object to robot.

---

*Actor*            Child, Robot

---

*Trigger*        The child has found a ball.

---

*Main Success Scenario:*

1. The child offers the ball to the robot
2. The robot scans the ball
3. The robot swallows the ball
4. The robot shows positive emotions

---

*Extensions:*

3.a The child has given the wrong object:

1. The robot drops the ball
2. The robot shows negative emotions

### **Use Case 2 Ask for ball.**

<i>Actor</i>	Robot
<i>Trigger</i>	The robot just finished launching or just received a correct object

#### *Main Success Scenario:*

1. The Robot decides what ball to ask for
  2. The robot asks the child for the object through voice or picture
  3. The robot waits for the ball

*Extensions:*

3.a The ball is not given within 2 minutes:

1. Return to step 2

### Use Case 3 Launch balls

<i>Actor</i>	Robot
<i>Trigger</i>	The robot is filled up with balls

#### *Main Success Scenario:*

1. The robot makes sounds indicating it is about to launch
  2. The robot checks if it safe to launch
  3. The robot erupts and launches the balls upwards

## **Appendix F**

# **Competitors**

### **Innvo Labs**

Innvo Labs (Innvo Labs Corporation, 2010) makes a robot dinosaur Pleo, which motivates a child to care for it. This teaches them to care for an animal in a playful way. Pleo operates autonomously and interacts with a child. It has several touch sensors and has different moods. It also needs to sleep and eat. Innvo Labs' target group is children from the age of 12.

### **Zoomer**

Zoomer (Spin Masters, 2014) makes a dinosaur robot, Boomer, but unlike Innvo Labs' dinosaur, this one has a wild character. It moves fast on two legs and he can show emotions. It has several features like biting and roaring, which can make it exciting, but maybe a bit scary toy for children. It will react to several interactions like pulling his tail and following a moving object.

Zoomer also makes a robot puppy (Spin Masters, 2014), that can do several tricks and shows puppy behaviour. This robot is for children of 5 years and above and is easy to operate. The company Zoomer is part of a bigger company SpinMasters. SpinMasters has several brands for different age groups and gender, but most are not related to robotics.

### **Orbotix**

Orbotix (Sphero, 2014) makes two very simple looking robots: the Sphero and the Ollie. The robots are controlled with a smartphone or tablet.

The Sphero changes colour, does challenges and learns tricks. Children can make it go through obstacle courses and can even use it to play videogames with. For older children there is an option to learn to program the robot.

The robot Ollie is programmed to do more spectacular tricks like flips and drifting. It is much faster than the Sphero and more suited for navigating outside.

### **Anki**

Anki (Anki, 2014) makes racing robots, each having their own tricks. The robots are operated by a smartphone and can race each other. The track is a foldable mat, which can be placed on any flat surface.

Anki's vision for their company is to use scientific research of the last years to make artificial

intelligence accessible for everyone. Or as they put it on their website: They are dedicated to bringing consumer robotics into everyday life.

## **LittleBits Electronics**

LittleBits (Little Bits Electronics, 2014) provides product for DIY projects. It is an easy way to learn to prototype with electronics. It ranges from very simple electronics to more complex electronics and is fun for younger and older children. It can be used from the age of 7 and up. The vision of LittleBits is to bring electronics to everyone and to inspire people to design and to learn problem solving.

## **Ubooly Inc.**

Ubooly (Ubooly, 2014) uses an app and a specially designed soft case. It transforms an iPhone or iPad into a plush toy, which interacts through the app. Ubooly can entertain a child by reading stories or playing games with the child. It even helps with daily routines like brushing teeth and help with school. Ubooly has several expansion packs and is downloaded on the users phone.

The company Ubooly was founded by a Kickstarter and the idea was to create make a fun and entertaining learning experience.

## **Hasbro**

Hasbro (Hasbro, 2014) makes a robot toy called Furby (Hasbro, 2014). Furby is a soft colourful toy that makes noises and moves in his place. Furbies can interact with each other and their personality changes by how a child plays with it.

Hasbro also makes other toys like Jenga, Play-Doh, transformers and much more. Hasbro is a large company, which is established over the whole world. They focus on safe toys, which inspire creativity and connect people.

## Appendix G

# Battery

Table G.1: Battery options

	Voltage (V)	Capacity (mAh)	Type	Price per piece	Price for requirements
Option 1	3.7	4400	Li-Ion	\$19.90	\$59.70
Option 2	11.1	2200	Li-Ion	\$26.99	\$53.98
Option 3	12	9500	NiMH	\$84.15	\$84.15
Option 4	12	3700	NiMH	\$44.99	\$44.99

Table G.2: Battery requirements

Name	Current (A)	Time type	Maximum Capacity 30 min (Ah)	Effective Required Capacity min (Ah)	Minimum Capacity 30 min (Ah)	Effective Required Capacity (Ah)	Average Required Capacity (Ah)	Effective Capacity (Ah)
Shooting Motor	4	While Shooting	2	2.8571	0	0	1.4285	
Wheel motors	1	While Driving	0.5	0.7142	0	0	0.3571	
RFID Reader	0.01	Full Time	0.005	0.0071	0.005	0.0071	0.00714	
Ultrasonic Sensors	0.06	Full Time	0.03	0.0428	0.03	0.0428	0.0428	
LEDs	0.6	Full Time	0.3	0.4285	0.3	0.4285	0.4285	
BeagleBone Display	0.46	Full Time	0.23	0.3285	0.23	0.3285	0.3285	
Sound	0.04	Full Time	0.02	0.0285	0.02	0.0286	0.0285	
Total	6.172	While Speaking	3.086	4.4085	0.585	0.8357	2.6221	

## **Appendix H**

### **Parts**

<b>Part number</b>	<b>Part name</b>	<b>Dealer</b>	<b>Qty/size</b>	<b>Price/unit (ex. Btw)</b>	<b>Price total</b>
404748	WormWiel Gearbox 3Nm	Eisses	1	42,3	€ 42,30
T1060	Trekveer	Alcomex	3	2,45	€ 7,35
9901957	Microswitch tandheugel	Farnell	1	0,924	€ 0,92
2422228	Beaglebone black	Farnell	1	47,44	€ 47,44
458599	Tandwiel M1 30T	ATD	1	3,79	€ 3,79
458039	Tandheugel M1 500mm	ATD	1	8,93	€ 8,93
83111240	LCD Screen	iPrototype	1	22,95	€ 22,95
206040 - 89	NiMh accu 3700mAh, 12V, 45*22*218mm	Conrad	1	44,99	€ 44,99
HE0216-220	RFID tag sticker 25mm dia.	HobbyElectronica	20	0,95	€ 19,00
801144	Styropor bal 50mm	Rienda	20	0,12	€ 2,40
HE0136-210	RFID Reader	HobbyElectronica	1	9,95	€ 9,95
506167	Trust Bluetooth 3.0 USB Adapter	Dixons	1	9,99	€ 9,99
474-6168	Timing belt contitech 16 /T5 /550 SS	rs online	1	16,96	€ 16,96
286-5742	Timing belt pulley aluminium suit belt width 16	rs online	2	10,58	€ 21,16
298-5391	DC Geared motor, brushed 6 volt dc 8Ncm 13 rpm	rs online	1	24,82	€ 24,82
586682	Hoekanker met ril	gamma	2	1,25	€ 2,50
no number	Kitelijn 275kg per meter	CheapKiteLines	2	0,37	€ 0,74
1400-06307X	PVC buis meterstuk [63*2,0]	pvc online	1	2,65	€ 2,65
1426-063063	PVC T stuk 45 graden [63*63*63]	pvc online	1	10,68	€ 10,68
770-3006	Hinge 30*30*3	rs online	2	4,57	€ 9,14
275460 - 89	Microservo	Conrad	1	5,99	€ 5,99
	PVC Buis 160*2,5		1	20	€ 20,00

## PMB Parts

			<b>qty/size/surface</b>		
11104	Glijlager PMB 6-9-11	PMB	4	0,18	€ 0,72
11105	Glijlager PMB 8-11-13	PMB	3	0,2	€ 0,60
11102	Glijlager PMB 4-6-8	PMB	2	0,17	€ 0,34
	Perspex plaat 4mm [300*300mm]	Bouwkunde	0,09	105,04	€ 9,45
	Perspex plaat 8mm [600*300mm]	Bouwkunde	0,18	199,87	€ 35,98
71905	Asborgring PMB 6mm	PMB	4	0,03	€ 0,12
71907	Asborgring PMB 8mm	PMB	2	0,06	€ 0,12

72115	Afstandsbus 5,2x10x8	PMB	1	0,08	€ 0,08
60306	MDF 18 (16 platen van 0.50x0.50)	PMB	4	13,4	€ 53,60
30305	Alu Rondstaf 10		0,1	1,22	€ 0,12
30305	Alu Rondstaf 10		0,11	1,22	€ 0,13
30305	Alu Rondstaf 10		0,12	1,22	€ 0,15
30303	Alu Rondstaf 6		0,14	0,43	€ 0,06
30217	Alu Platstaf 20x8		0,015	2,08	€ 0,03
30405	Alu Vierkantstaf 25		0,02	8,57	€ 0,17
30405	Alu Vierkantstaf 25		0,02	8,57	€ 0,17
30408	Alu Vierkantstaf 40		0,04	21,9	€ 0,88
30408	Alu Vierkantstaf 40		0,02	21,9	€ 0,44
30403	Alu vierkantstaf 15		0,04	3,09	€ 0,12
30402	Alu vierkantstaf 10		0,06	1,38	€ 0,08
30402	Alu vierkantstaf 10		0,1	1,38	€ 0,14
30113	Alu plaat 20		0,0072	452,03	€ 3,25
30112	Alu plaat 15		0,0128	338,82	€ 4,34
30112	Alu plaat 15		0,004	338,82	€ 1,36
30112	Alu plaat 15		0,0063	338,82	€ 2,13
30110	Alu plaat 4		0,0168	81,93	€ 1,38
30105	Alu plaat 2		0,0036	29,39	€ 0,11
30105	Alu plaat 2		0,056	29,39	€ 1,65
30105	Alu plaat 2		0,0056	29,39	€ 0,16
30105	Alu plaat 2		0,0168	29,39	€ 0,49
30105	Alu plaat 2		0,0176	29,39	€ 0,52
30105	Alu plaat 2		0,0068	29,39	€ 0,20
30105	Alu plaat 2		0,0014	29,39	€ 0,04
30601	Alu Buis 15*15*1,5		0,035	1,44	€ 0,05
30601	Alu Buis 15*15*1,5		0,2	1,44	€ 0,29
30601	Alu Buis 15*15*1,5		0,25	1,44	€ 0,36
30601	Alu Buis 15*15*1,5		0,25	1,44	€ 0,36
30601	Alu Buis 15*15*1,5		0,5	1,44	€ 0,72
30601	Alu Buis 15*15*1,5		0,28	1,44	€ 0,40
30601	Alu Buis 15*15*1,5		0,29	1,44	€ 0,42

50503	POM plaat 20		0,00375	897,51	€ 3,37
50503	POM plaat 20		0,003	897,51	€ 2,69
51202	Nitril rubber 2mm		0,02	26,3	€ 0,53
51106	PS Foam 625*600*80		3	5,36	€ 16,08

## Own Parts

USB Sound card	Hugo	1	0	€ 0,00
Bob's 5 mm perspex plaat [80*60mm]	bob	0,0048	0	€ 0,00
Resin en glassfiber voor schild (via kennis)	Anne			€ 50,00

## Maybe's:

Askoppeling 8mm->8mm

Askoppeling 6mm->4mm

total

€ 529,05

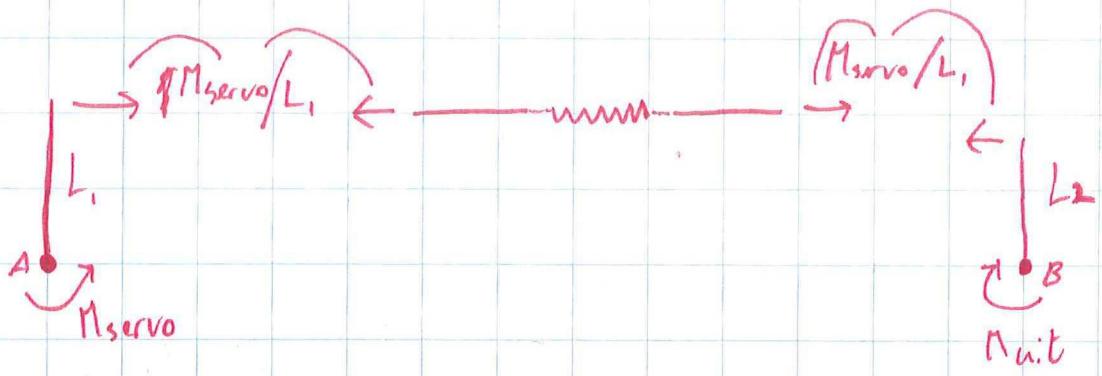
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Pioneer-1_Doosje		1
2	MotorWiel_und_enco der		2
3	Afschietbuis		1
4	Wheel_Drive		2
5	Assembly_caster		1
6	Slider_Platform		1
7	containment_ring		1
8	improved_slider_rack V2		1
9	Top_Cover		1
10	accupack		1
11	BijnaUBeugel		2
12	transportbuis		1
13	pulley 27 T5 12-2		1
14	Timing belt 16 T5 550		1
15	Ball		1
16	rubber stripje		8
17	T-stuk afgesneden		1
18	nek		1
19	motor		1
20	staander achter		2
21	staander voor		1
22	ligger		1
23	ligger platstaf		1
24	ligger 2		1
25	plaatje voorkant		1
26	ring		1
27	Motor-404748-KGK		1
28	motormount		1
29	staander voor rechts		1
30	blokje		1
31	blokje voor bevestiging frame		4
32	motordakje		1
33	ISO 1580 - M4 x 10 --- 10N		8
34	ISO 1580 - M4 x 40 --- 40N		5
35	ISO 1580 - M4 x 20 --- 20N		4

36	ISO 1580 - M4 x 25 --- 25N	2
37	ISO 1580 - M3 x 10 --- 10N	2
38	ISO 1580 - M3 x 16 --- 16N	2
39	hinge30x30x3	8
40	hinge30x30x3As	4
41	fixatie_pvc_onder	1
42	ISO 7046-1 - M3 x 10 - Z --- 10N	14
43	ISO 7046-1 - M4 x 16 - Z --- 16N	4
44	ISO 7046-1 - M3 x 20 - Z --- 20N	2
45	Hexagon Nut ISO - 4032 - M3 - D - N	18
46	Hexagon Nut ISO - 4032 - M4 - D - N	15
47	ligger rechts	1
48	ondersteuningBuis	2
49	hoekanker 90 90	1
50	gamma links	
51	hoekanker 90 90	1
52	gamma rechts	
53	pulley 27 T5 12-2	1
54	onder	
55	ISO 10673-3.2-S	4
56	53 as pulley beneden	1
57	ISO 7045 - M3 x 8 - Z ---	
58	8N	1
59	vierkantas	1
60	Bearing	1
61	Acople Flexible	1
62	Pulleyblockassembly	1
63	assembly_hoofd	1
64	Shell	1
65	shell_fastener	2
66	new_lagerhuis	2
67	glijlager_6_9_11	4
68	axle upper	1
69	houder as boven	2
70	motorbevestiging	1

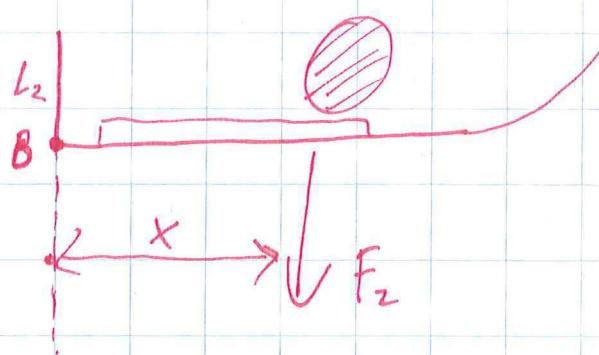
67	motorhouder_achter	1
68	Acople FlexibleSLDPRT	1
69	B27.7M - 3AM1-6	2

# **Appendix I**

## **Calculations**



$$M_{unit} = F \cdot L_2 = \frac{M_{servo}}{L_1} \cdot L_2 = M_{servo} \cdot \frac{L_2}{L_1}$$



$$F_2 \cdot x = M_{unit}$$

$$= M_{servo} \cdot \frac{L_2}{L_1}$$

Stel:  $F_2 = 2 \text{ N}$  (200 gsm)

$x = 50 \text{ mm}$  (0,05 m)



als  $M_{servo} = 0,15 \text{ Nm}$



$L_2$  groter dan  
dit is zo bijz

$$2 \cdot 0,05 = 0,15 \cdot \frac{L_2}{L_1}$$

$$0,1 = 0,15 \cdot \frac{L_2}{L_1}$$

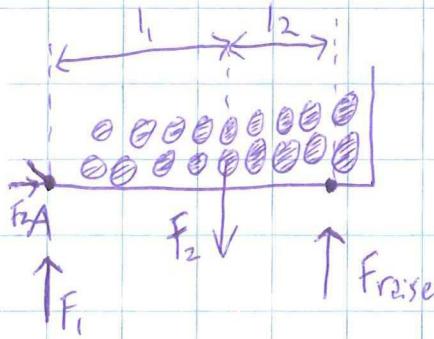
$$\frac{L_2}{L_1} = \frac{0,1}{0,15} = \frac{2}{3}$$

prim.

$$L_2 \Rightarrow \frac{2}{3} L_1$$

## Proof of concept calculations

T-Ruck



$$l_1 \approx 0,15 \text{ m}, \quad L_2 \approx 0,1 \text{ m}$$

A = tipping point,  $m \approx 500 \text{ gr.}$

$$F_2 = m \cdot g = 0,5 \cdot 9,81 \approx 5 \text{ N}$$

$F_{fraise}, F_1, F_2$  onbekend

$$\sum F_y = 0 \rightarrow F_{fraise} + F_1 - F_2 = 0$$

↓

$$F_{fraise} + F_1 = 5$$

$$\sum F_x = 0 \rightarrow F_2 = 0$$

$$\sum M_A = 0 \rightarrow -F_2 \cdot l_1 + F_{fraise} \cdot (l_1 + l_2) = 0$$

↓

$$F_{fraise} \cdot 0,25 = 5 \cdot 0,15 = 0,75$$

↓

$$F_{fraise} \approx 3 \text{ N}$$

$$F_1 \approx 2 \text{ N}$$

Lifting 3N is no problem with 2 screw spindle

and small motor.

# Proof of concept

## Spring launching

$$m_{\text{balls}} = 0,00 \text{ kg}$$

$$V_{\text{Launch}} = \sqrt{s_{\text{travel-balls}} / g_{0,5\text{m}}} = 4,43 \text{ m/s}$$

$$s_{\text{springs}} = 0,078 \text{ m}$$

$$s_{\text{travel-balls}} = 1 \text{ m}$$

$$n_{\text{springs}} = 3$$

$$m_{\text{min. weight}} = 0,3 \text{ kg}$$

$$\frac{1}{2} \cdot m_{\text{min. weight}} \cdot V_{\text{Launch}}^2 + m_{\text{balls}} \cdot s_{\text{travel-balls}} \cdot g_{0,5\text{m}} = n_{\text{springs}} \cdot \frac{1}{2} \cdot k \cdot s_{\text{springs}}^2$$

↓

$$k \cdot 0,00g_1 = 3,73$$

↓

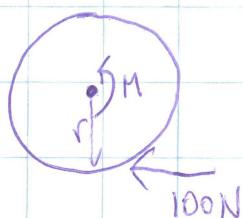
$$k = 410 \text{ N/m}$$

$$F_{\text{total}} = n_{\text{springs}} \cdot h \cdot s_{\text{springs}} \approx 96 \text{ N}$$

We will be doing all the strength calculations with 100 N and will take a certain factor for friction and other effects in account.

$$r_{\text{gear}} = \frac{s_{\text{springs}} + (0,015)}{2 \cdot \pi} \rightarrow \text{for milled saw teeth} \\ \approx 0,0135 \text{ m}$$

Picked 2 gear that is 0,03 m  $\phi$  (d2)



$$M = 100 \cdot r = 1,5 \text{ Nm}$$

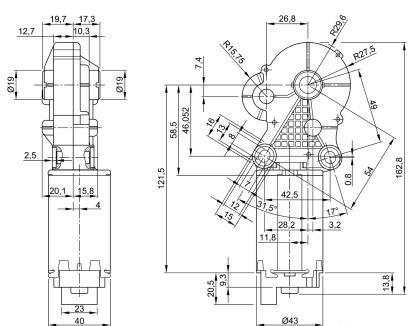
## **Appendix J**

### **Motor specifications**

**Design Data**

Commutation	Brushed
Direction of rotation	Bi-directional
Bearing type	A:Sleeve - B:Sleeve

**0320 BR**



**Motor picture**



**Performance data**

Rated voltage [V]	$U_N$	12
Nominal torque [Nm]	$M_N$	3.00
No-load speed [ $\text{min}^{-1}$ ]	$n_0$	21.0
Nominal power [W]	$P_N$	5.59
Nominal current [A]	$I_N$	3.5
Nominal force [kN]	$F_N$	0.00
Duty cycle		s3

**Sensor data**

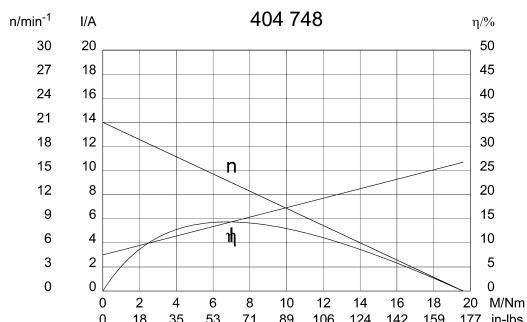
Pulses	210
Output channels	1

**Other data**

Gear ratio	210/1
Gear wheel material	plastic
Suppression components	5,5 $\mu\text{H}$ , 47nF, (0,47 $\mu\text{F}$ )
Enclosure class	IP 40
Weight [kg]	0.440

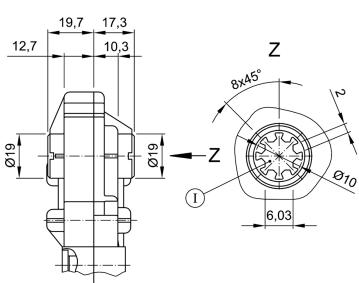
Remarks:

**Characteristic curves**

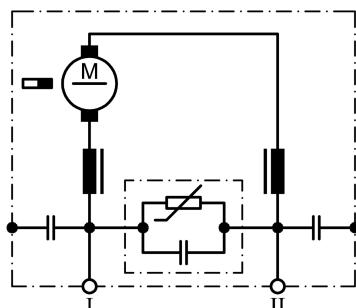


**Output shaft drawing (W), Wiring diagrams (S) and Connector layout (K)**

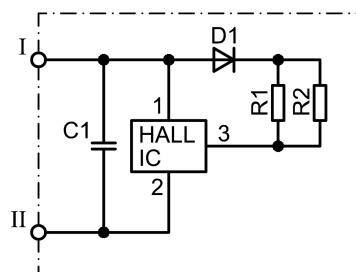
**W 270**



**S 86**



**S 85**



I through profile

I Terminal 1

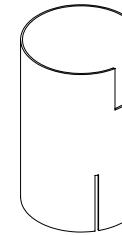
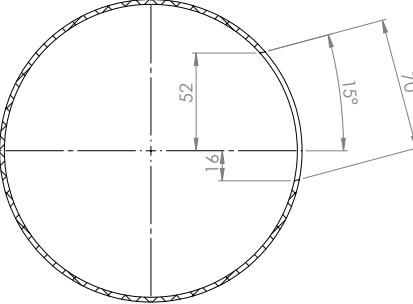
II Terminal 5

I Terminal 4, Hall-IC +

II Terminal 2, Hall-IC -

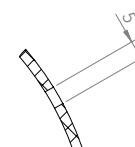
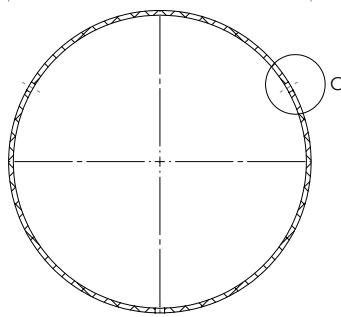
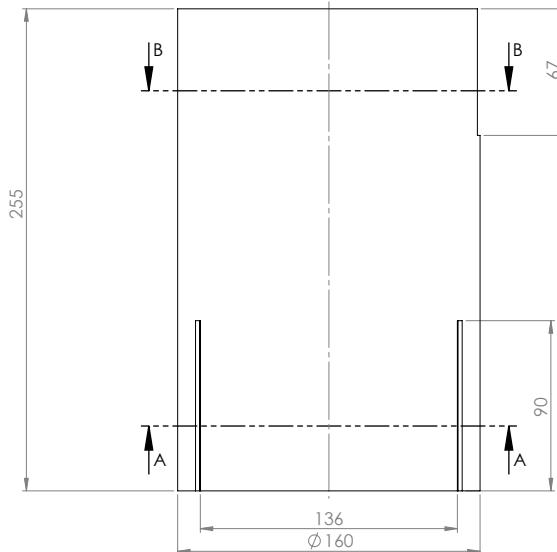
## **Appendix K**

### **Technical drawings**



SCALE 1 : 5

SECTION B-B



DETAIL C  
SCALE 1 : 1

SECTION A-A

thickness is 2.5 mm

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: **Afschietbuis**

Quantity:  
1



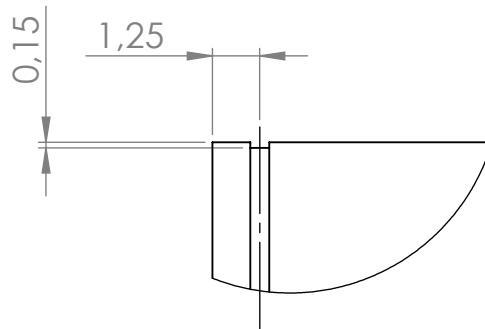
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
PVC

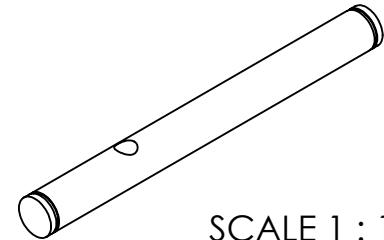
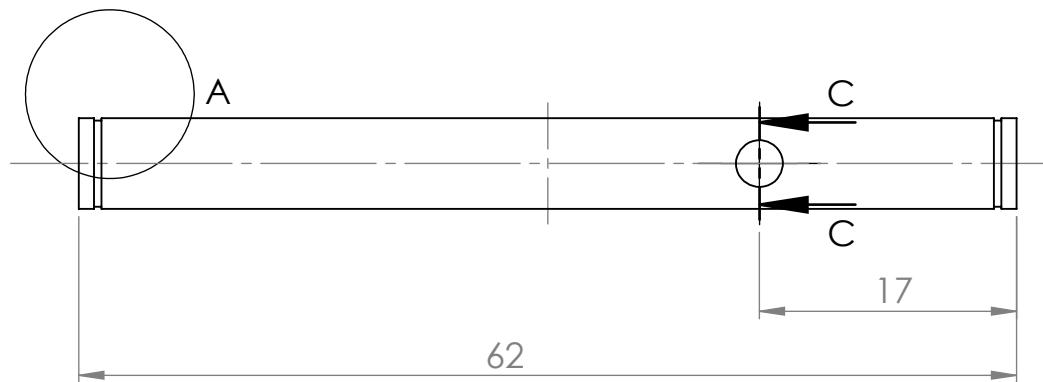
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24-10-2014

A4

SCALE 1:2 SHEET 1 OF 1

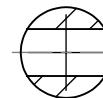


DETAIL A  
SCALE 5 : 1



SCALE 1 : 1

$\phi 3,10$



SECTION C-C

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: as pulley beneden

Quantity:  
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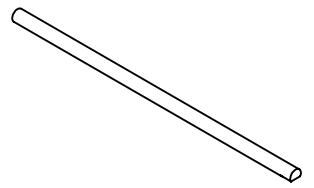
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

Date:

24-10-2014

A4



SCALE 1 : 2



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:  
**as\_onderkaak**

Quantity:  
1



DEBUR AND  
BREAK SHARP  
EDGES

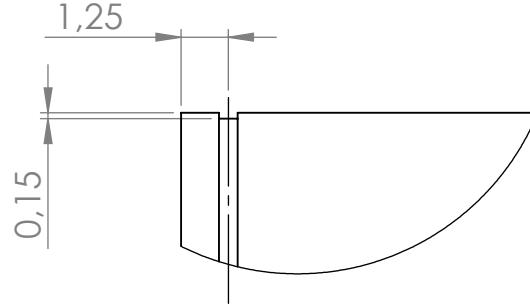
MATERIAL:  
Aluminum  
6082

Date:  
21-10-2014

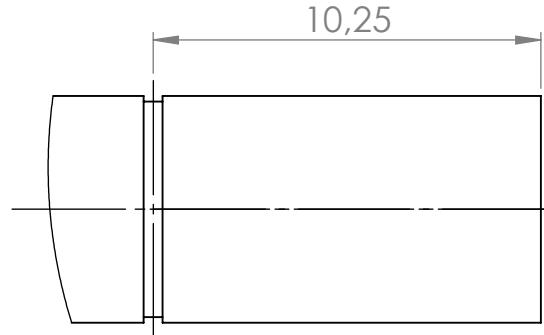
A4

SCALE:1:1

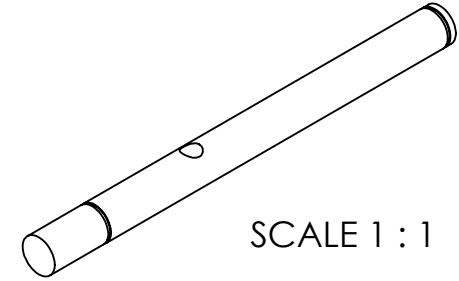
SHEET 1 OF 1



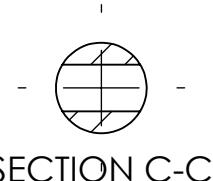
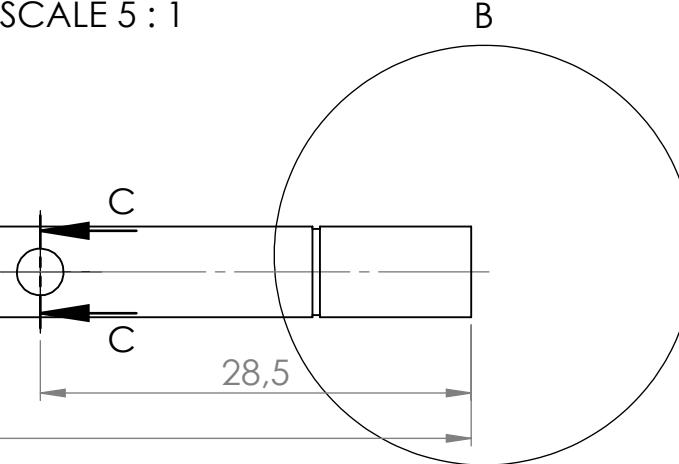
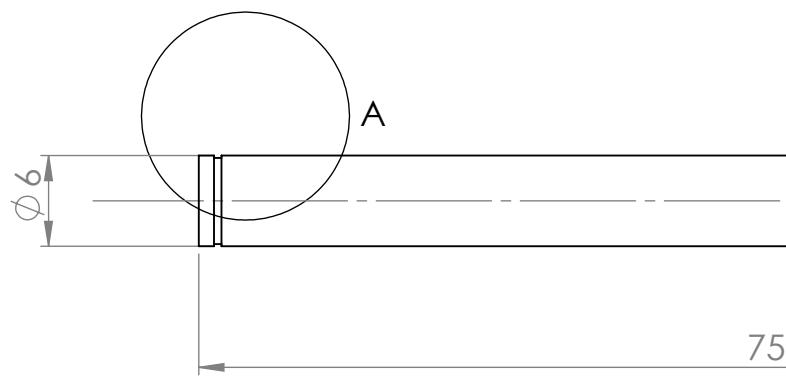
DETAIL A  
SCALE 5 : 1



DETAIL B  
SCALE 5 : 1



SCALE 1 : 1



UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: axle upper

Date: 24-10-2014

A4

Quantity:  
1

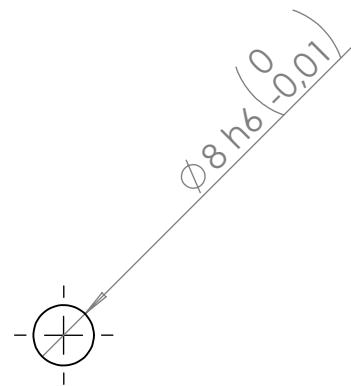
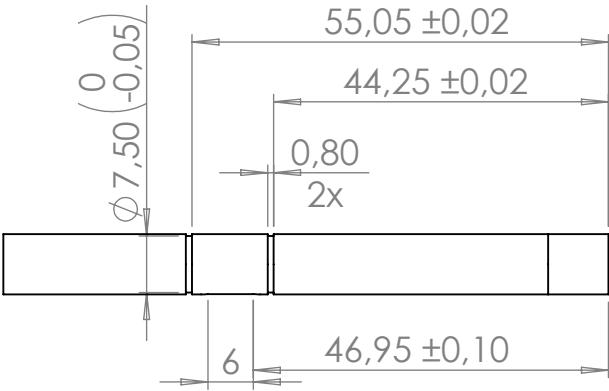
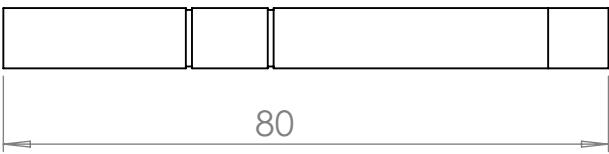


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

SCALE 2:1

SHEET 1 OF 1



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0,2$  mm  
ANGULAR:  $\pm 0,5^\circ$



Quantity:  
1



DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

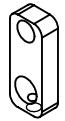
TITLE:

Axle

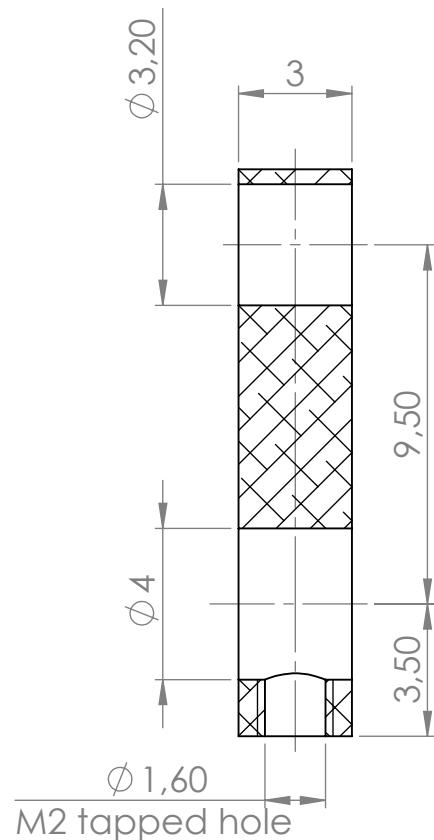
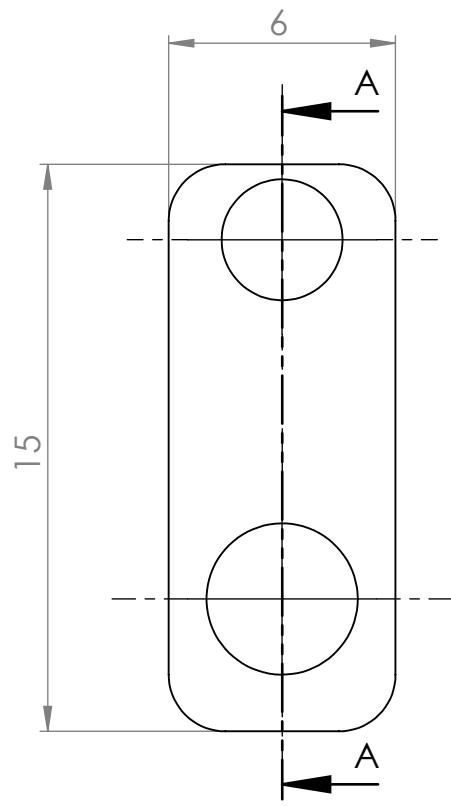
Date:

21-10-2014

A4



SCALE 1 : 1



SECTION A-A

Fillets are 1.5 mm

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$

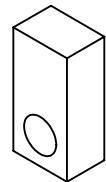


DO NOT SCALE DRAWING

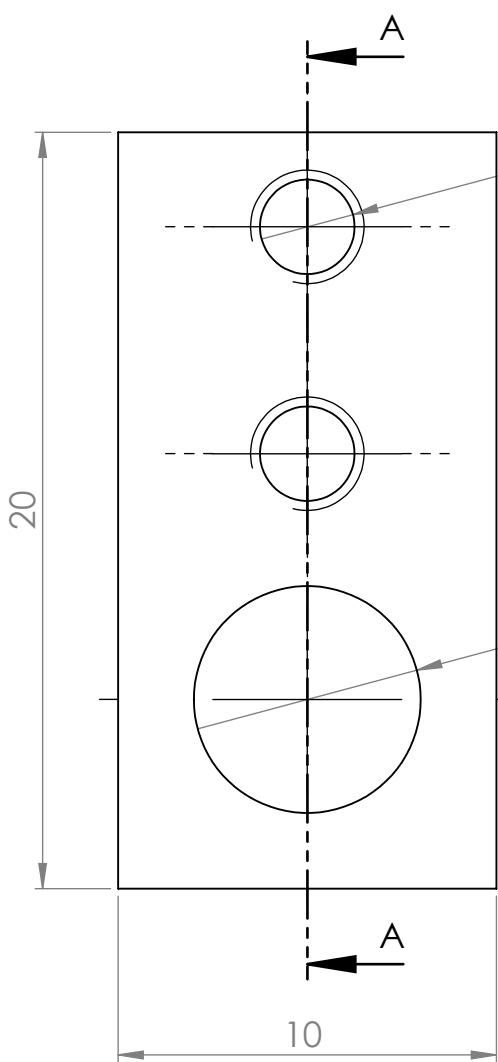
Robotics Minor Group 5: Tawi

TITLE:

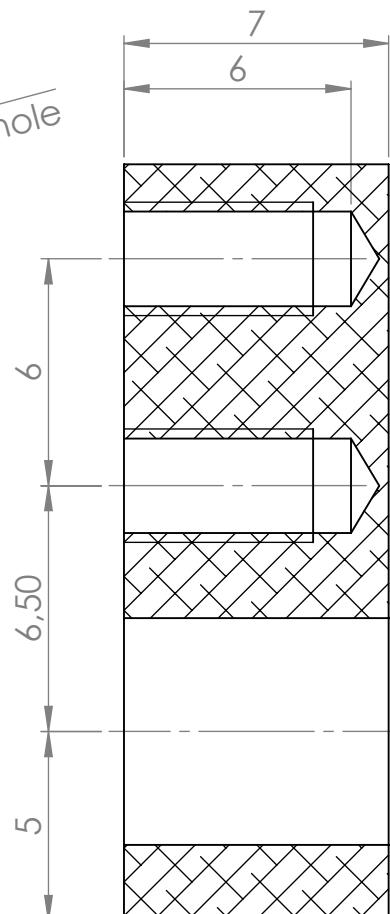
axle\_to\_pushrod



SCALE 1 : 1



$\phi 2,50$   
2x M3 x0.5 tapped hole  
 $\phi 6$  H7 +0,012 0



SECTION A-A

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$

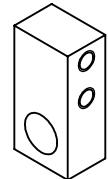


DO NOT SCALE DRAWING

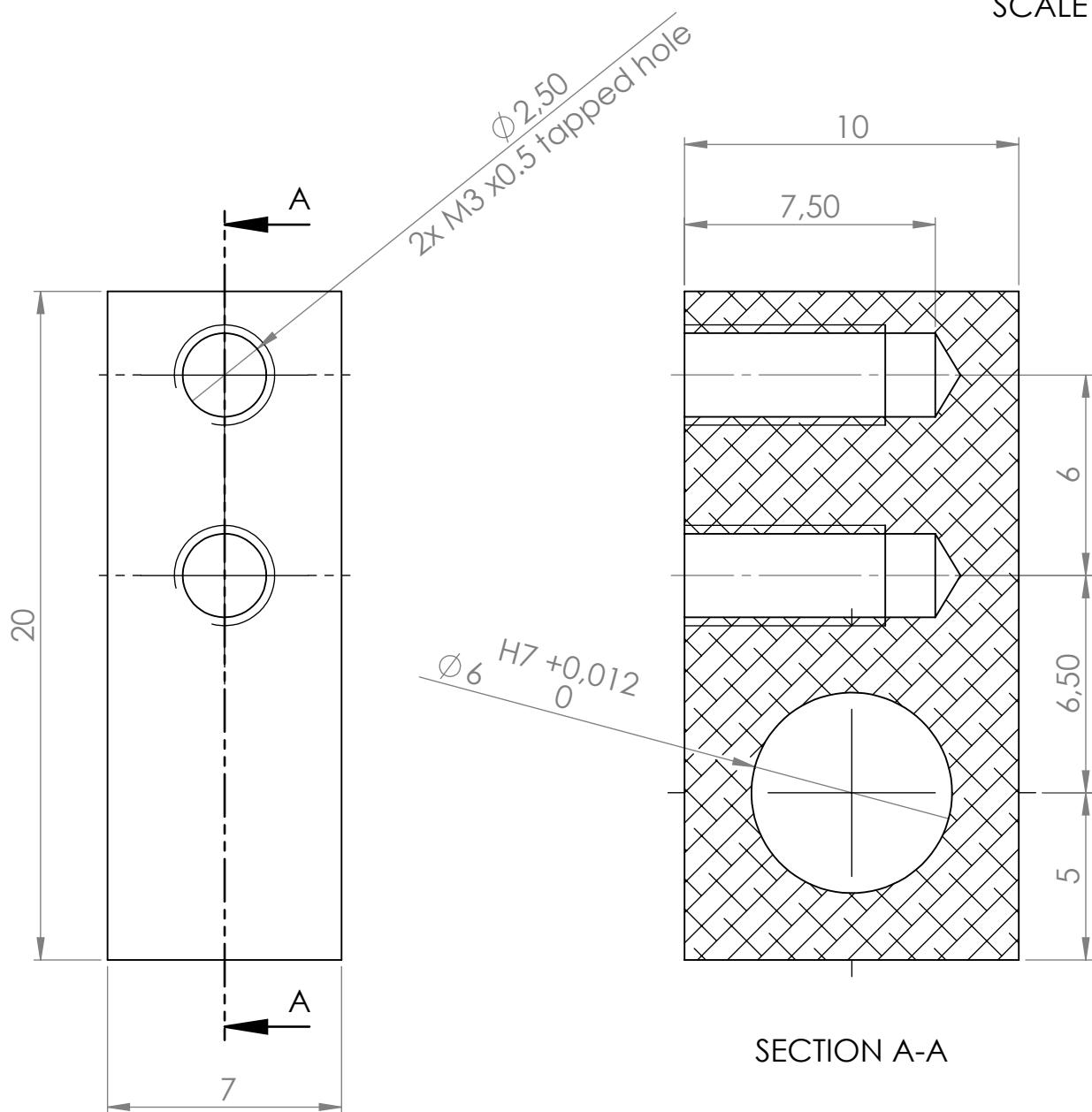
Robotics Minor Group 5: Tawi

TITLE:

axlemount



SCALE 1 : 1



SECTION A-A

**UNLESS OTHERWISE SPECIFIED:**

DIMENSIONS ARE IN MILLIMETERS

SURFACE FINISH:

TOLERANCES:

LINEAR:  $\pm 0,2$  mm

ANGULAR:  $\pm 0,5^\circ$

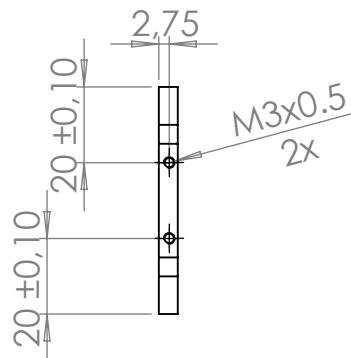
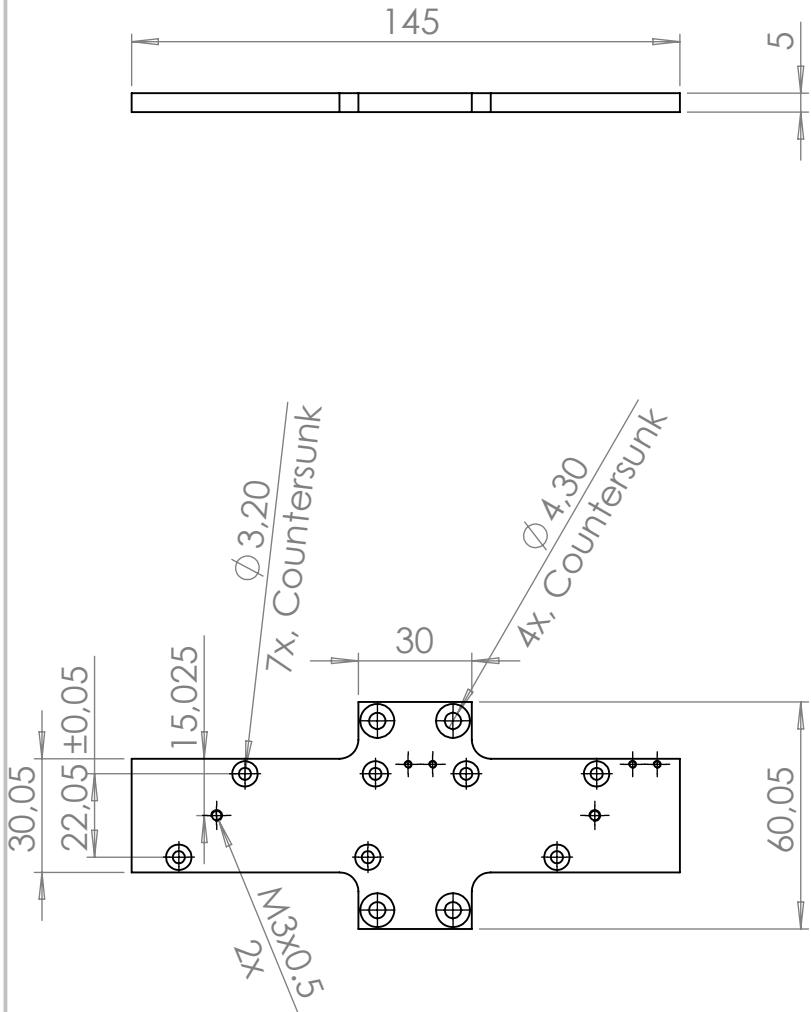


DO NOT SCALE DRAWING

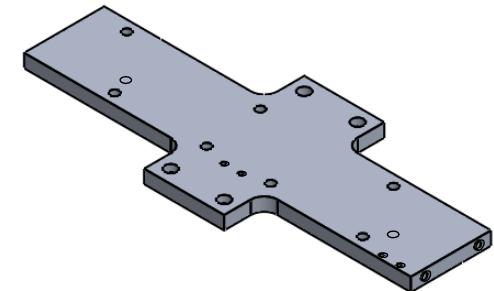
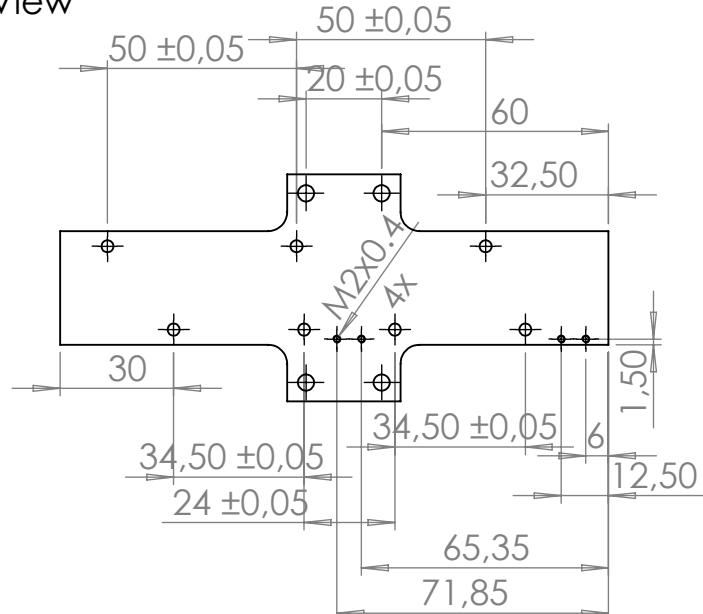
Robotics Minor Group 5: Tawi

TITLE:

axlemountRight



Top View



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0,2$  mm  
ANGULAR:  $\pm 0,5$  °



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

BaseV2

Date:

21-10-2014

A4

Quantity:

1

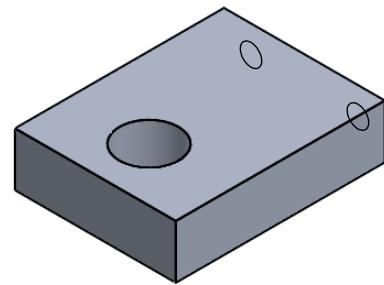
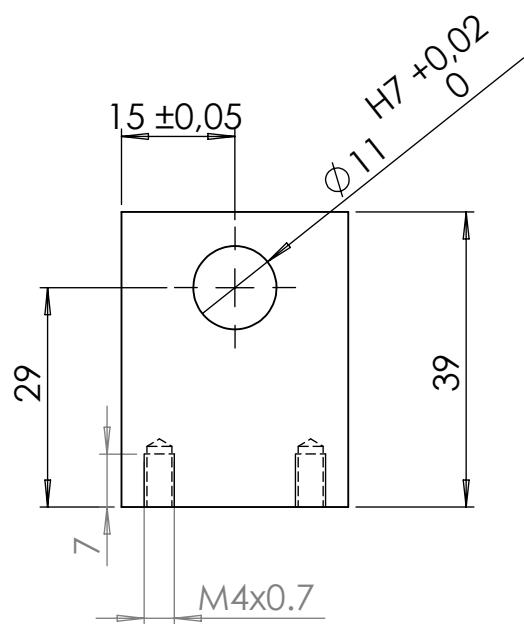
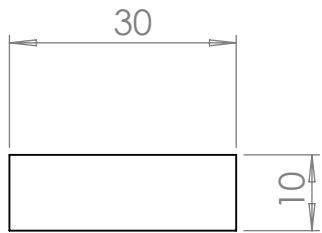


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

SCALE:1:2

SHEET 1 OF 1



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR: ±0.2 mm  
ANGULAR: ±0.5°



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

BearingBlock



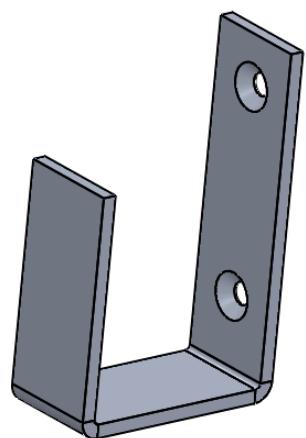
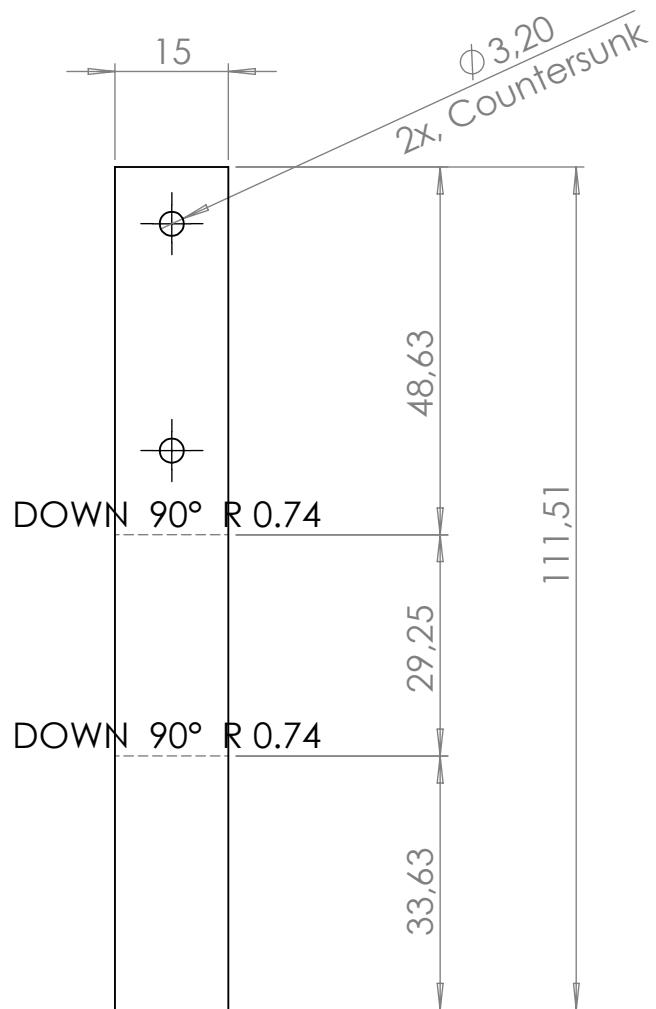
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

Date:  
21-10-2014

Quantity:  
2

A4



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$

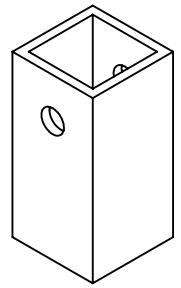


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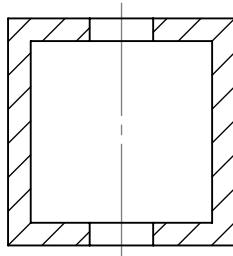
Robotics Minor Group 5: Tawi

TITLE:

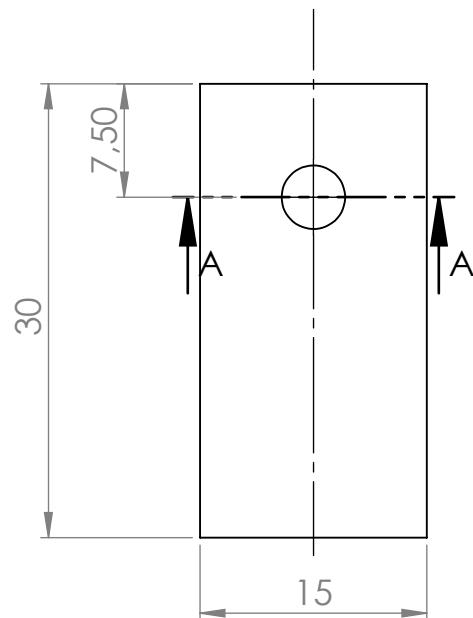
BijnaUBeugel



SCALE 1 : 1



SECTION A-A



thickness is 1.5 mm  
holes are 4.20 mm

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS

SURFACE FINISH:

TOLERANCES:

LINEAR:  $\pm 0.2$  mm

ANGULAR:  $\pm 0.5^\circ$

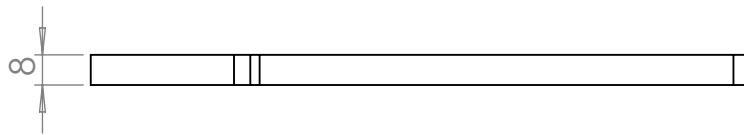
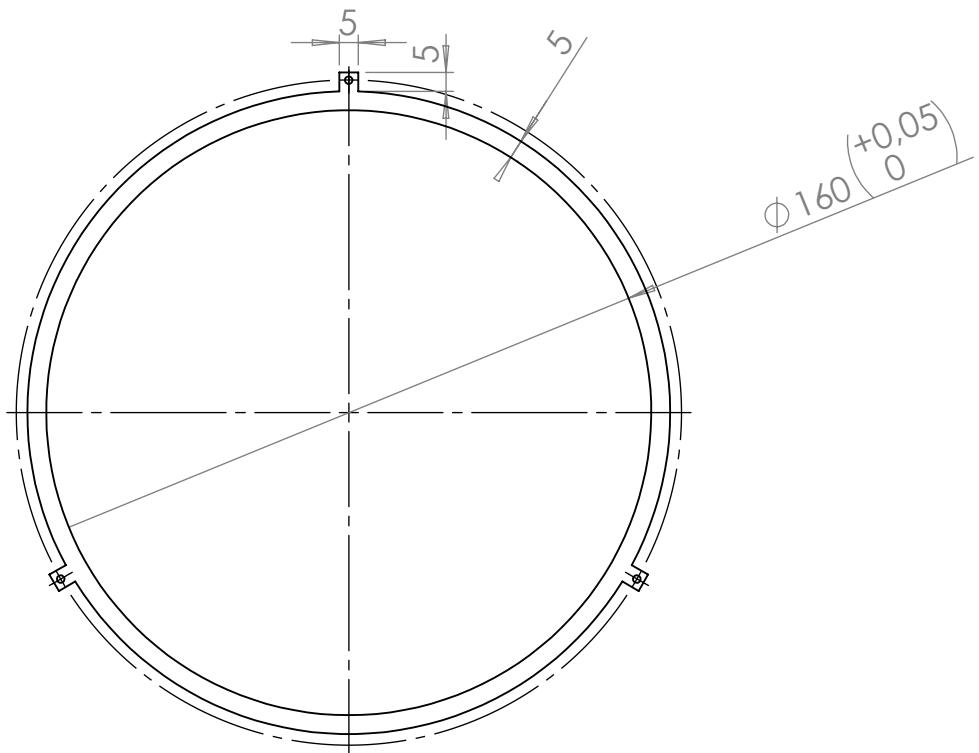


DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

blokje



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi  
**containment\_ring**

TITLE:

Quantity:

1



DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:

Perspex

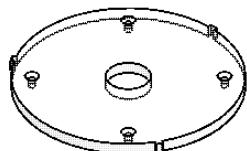
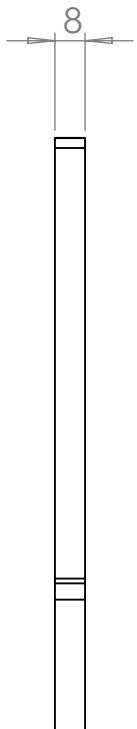
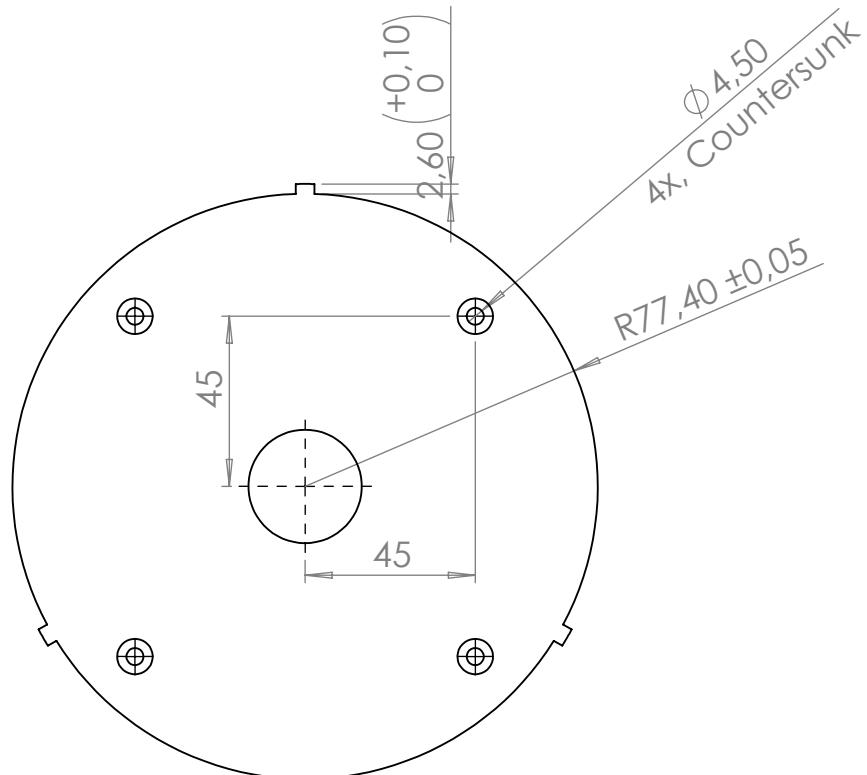
Date:

22-10-2014

A4

SCALE:1:2

SHEET 1 OF 1



**UNLESS OTHERWISE SPECIFIED:**  
 DIMENSIONS ARE IN MILLIMETERS  
 SURFACE FINISH:  
 TOLERANCES:  
 LINEAR:  $\pm 0.2$  mm  
 ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: fixatie\_pvc\_onder

Quantity:  
1



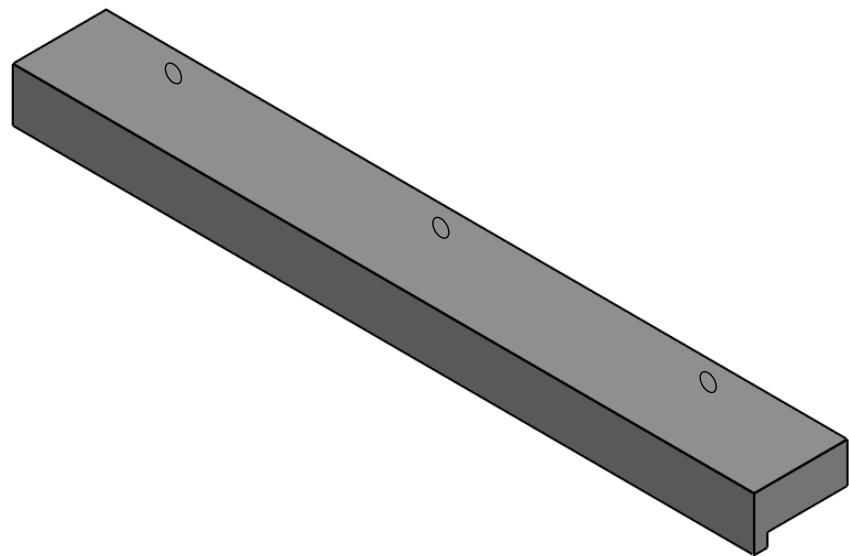
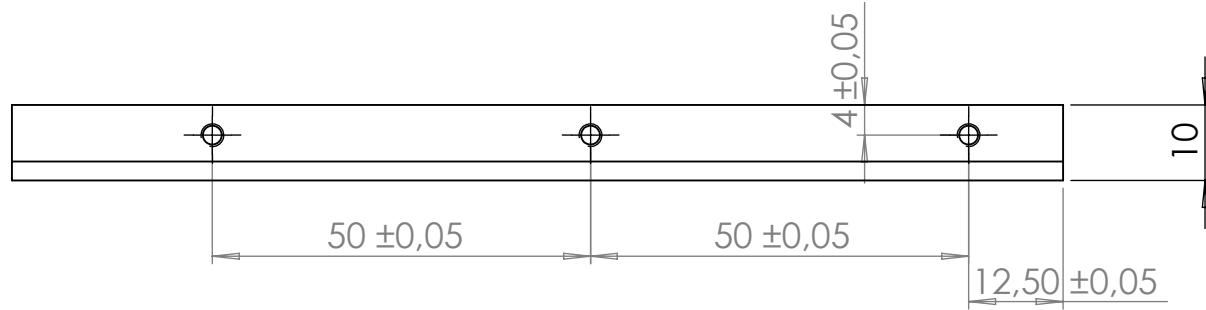
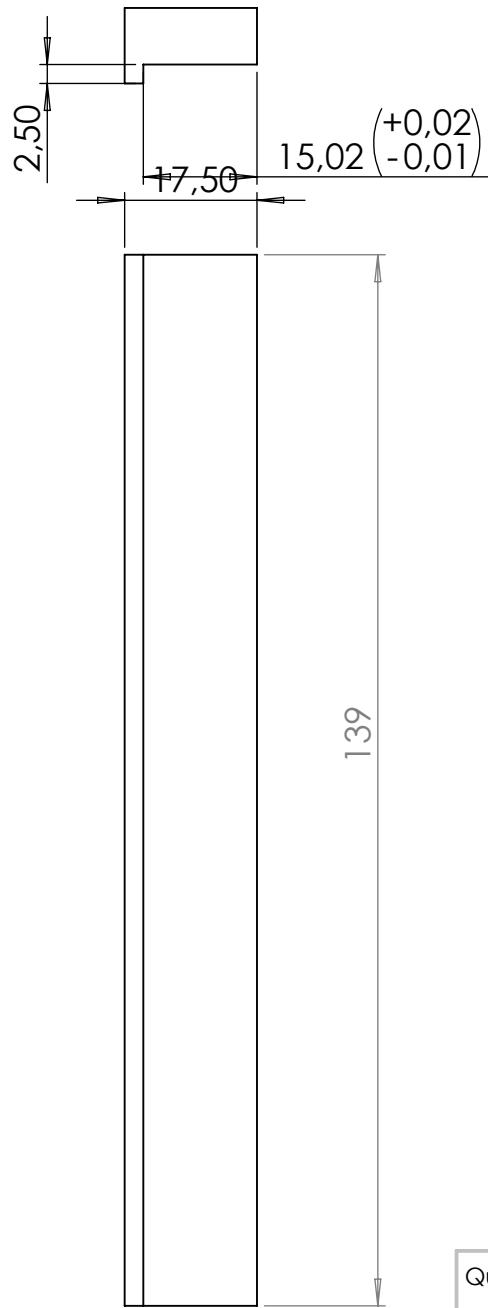
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Perspex

Date:

22-10-2014

A4



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0,2$  mm  
ANGULAR:  $\pm 0,5^\circ$



Quantity:  
1



DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
POM

DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

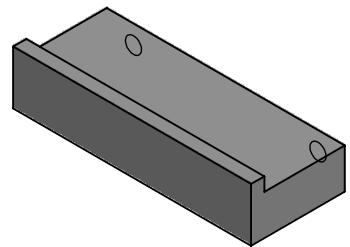
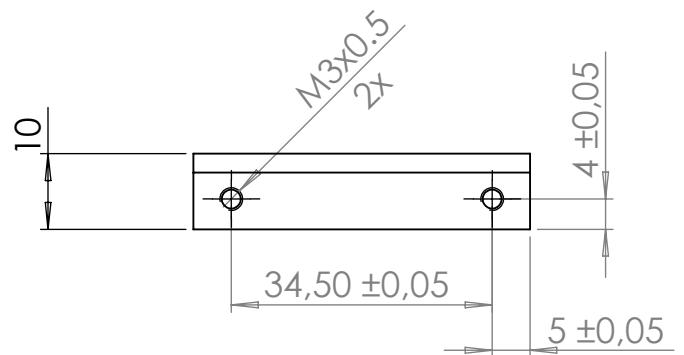
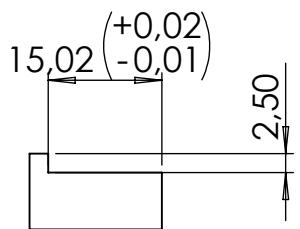
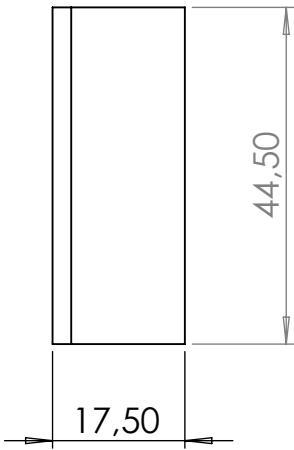
TITLE:

GuideRail1

Date:

21-10-2014

A4



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0,2$  mm  
ANGULAR:  $\pm 0,5^\circ$

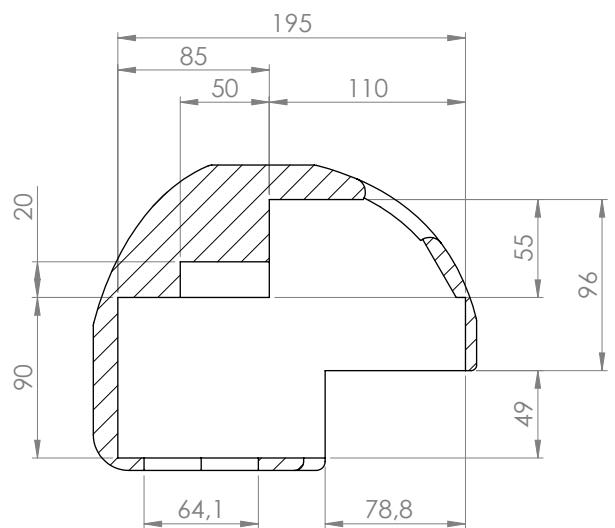
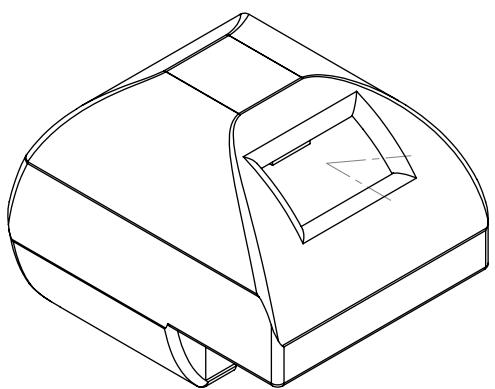
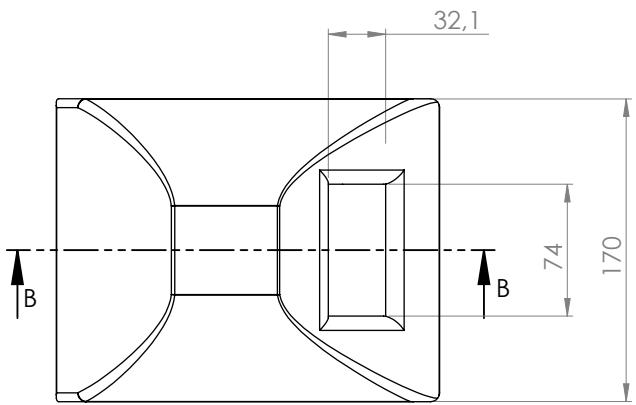


DO NOT SCALE DRAWING

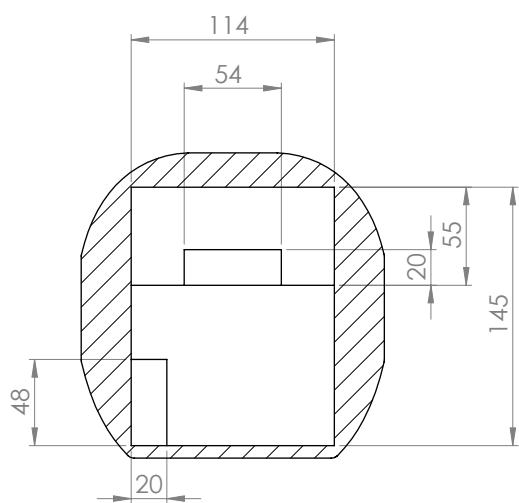
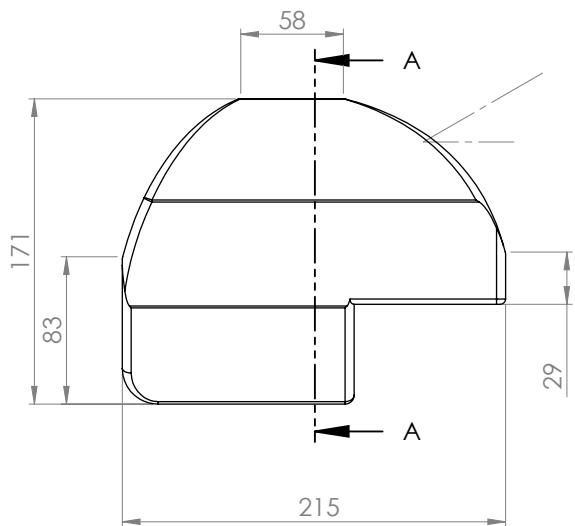
Robotics Minor Group 5: Tawi

TITLE:

GuideRail2



SECTION B-B



SECTION A-A

Fillet is 5 mm in radius, if not mentioned otherwise.

Wall thickness should be at least 5 mm.

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

Head

Quantity:  
1



DEBUR AND  
BREAK SHARP  
EDGES

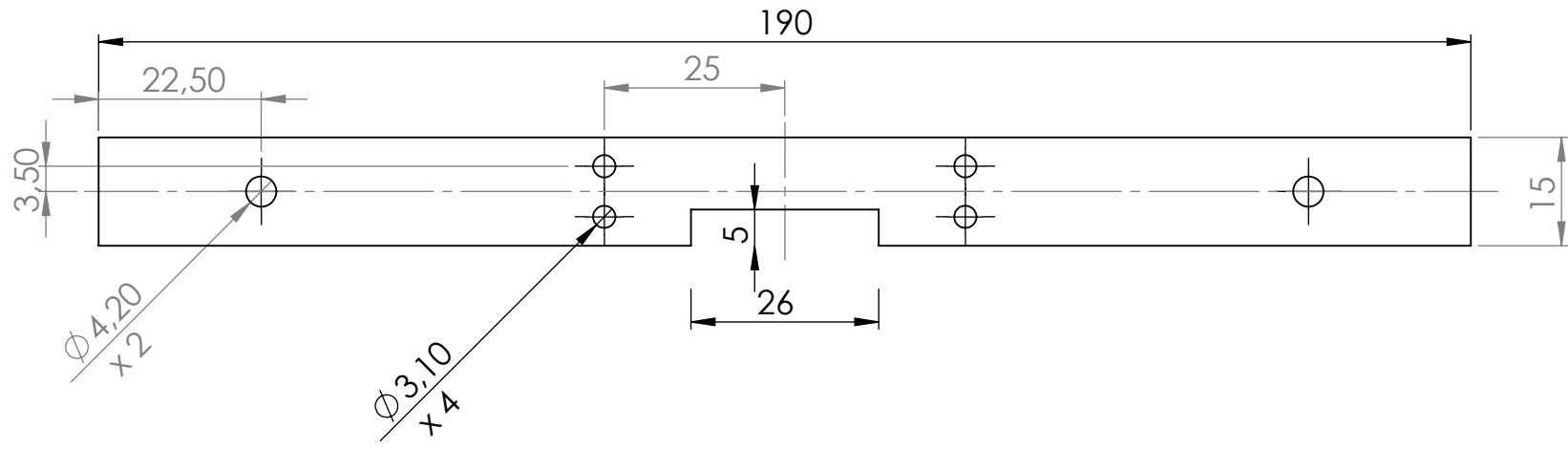
MATERIAL:  
PS, foam

Date: 21-10-2014

A4

SCALE:1:3

SHEET 1 OF 1



5 mm thickness

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: Horizontal bar front

Date:

24-10-2014

A4

**SolidWorks Educational Edition.**  
**For Instructional Use Only.**

1

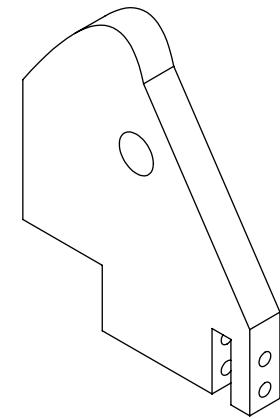
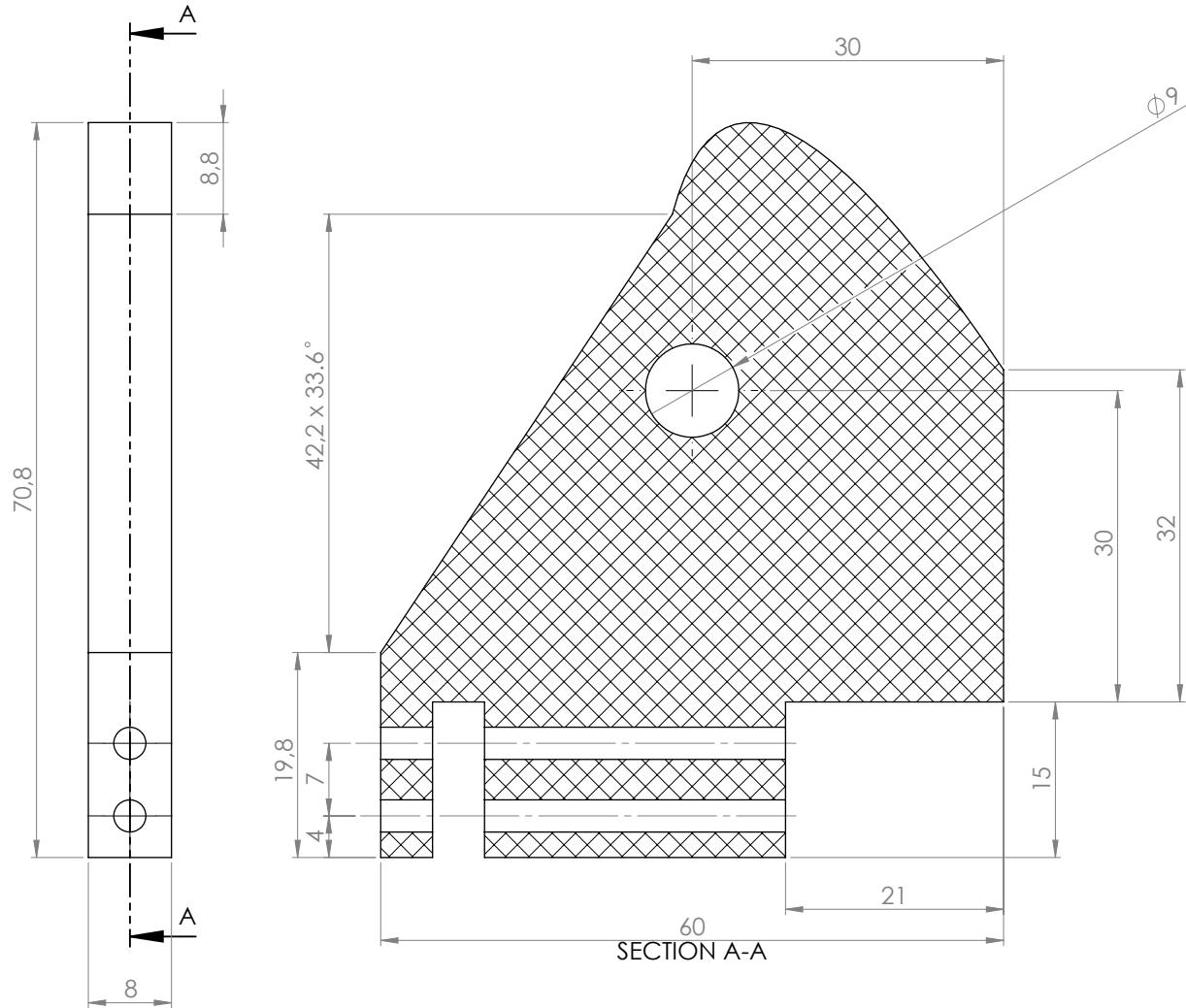


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

SCALE:1:1

SHEET 1 OF 1



SCALE 1 : 1

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

houder as boven

Quantity:  
2

**TUDelft**

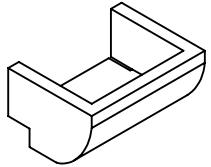
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Perspex

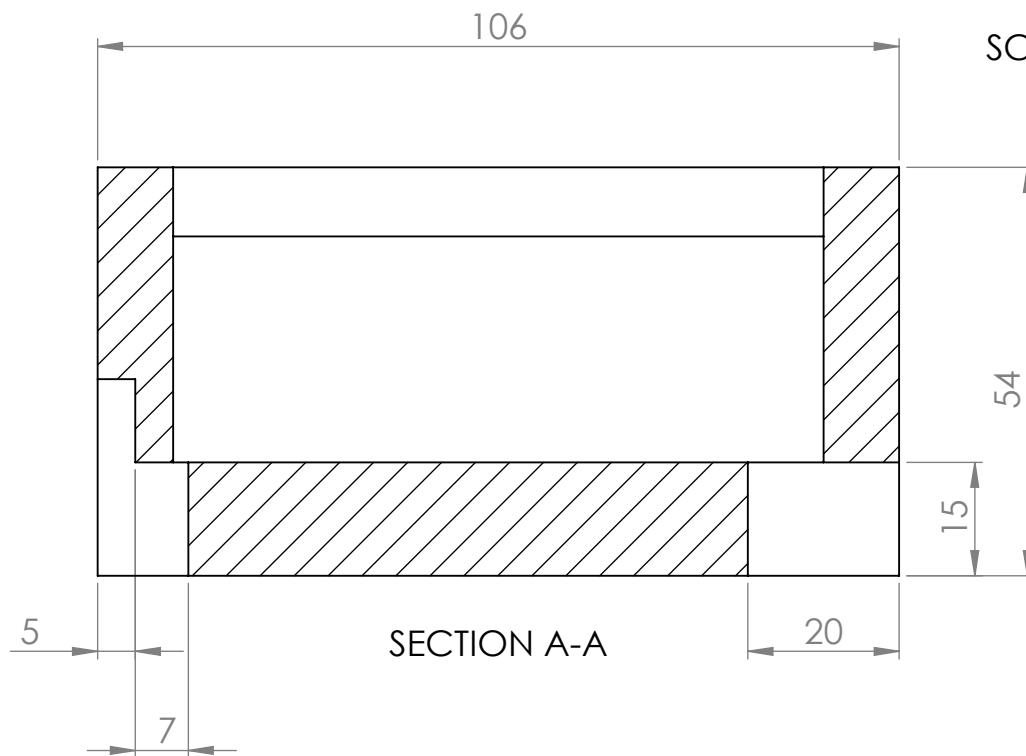
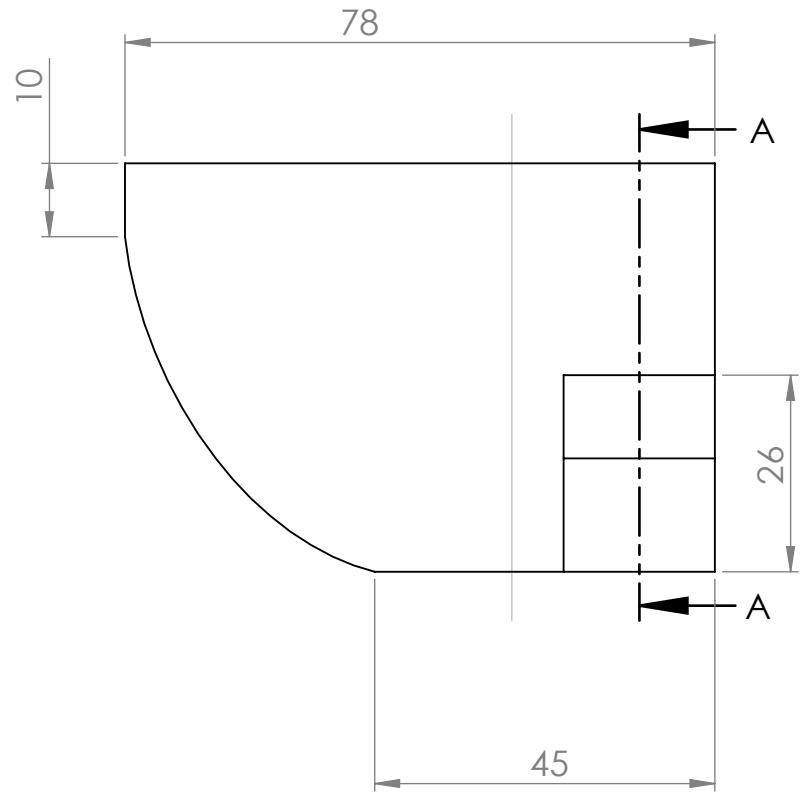
Date:

24-10-2014

A4



SCALE 1 : 5



wall thickness is 10  
unless mentioned  
otherwise

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

Jaw Head

Date:

21-10-2014

A4

Quantity:  
1

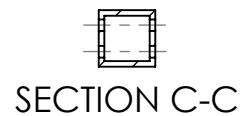
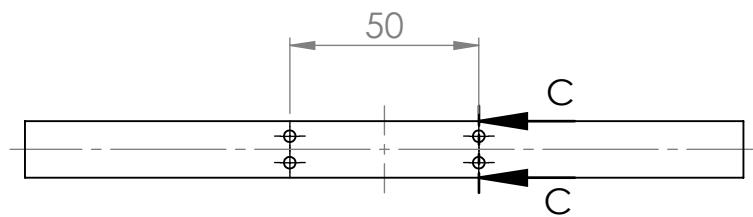
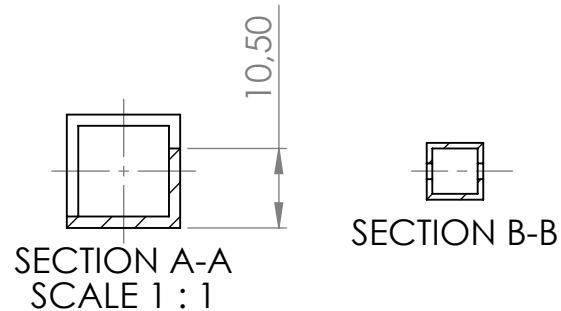
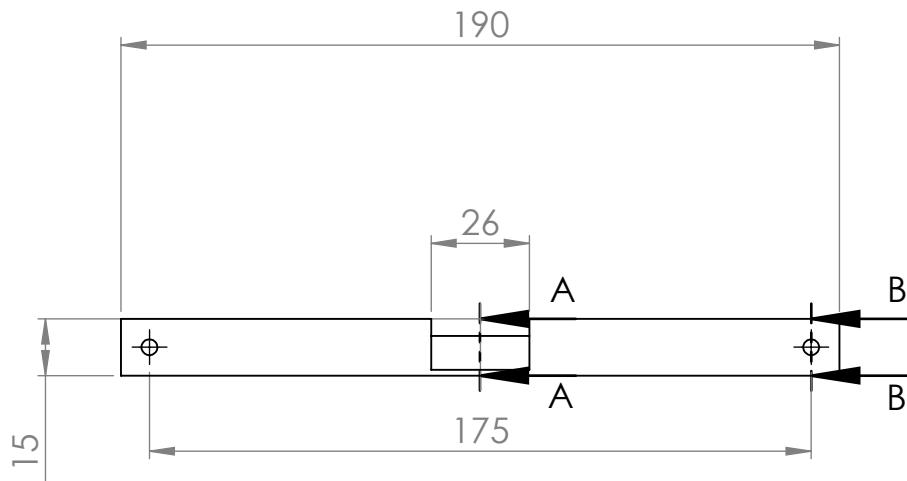


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
PS, foam

SCALE:1:1

SHEET 1 OF 1



thickness is 1.5 mm  
holes are 4.20 mm (12x)

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi  
ligger 2

TITLE:

Quantity:  
1



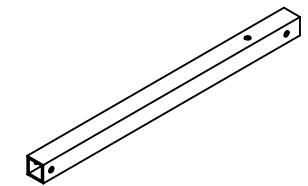
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

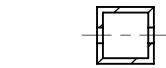
Date:

24-10-2014

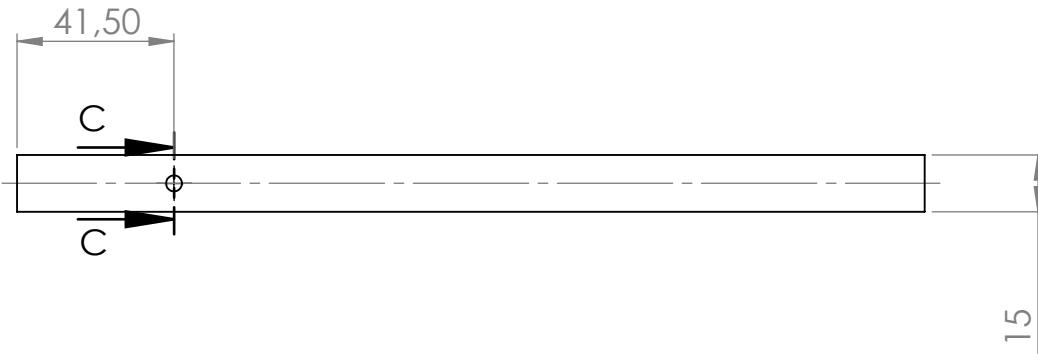
A4



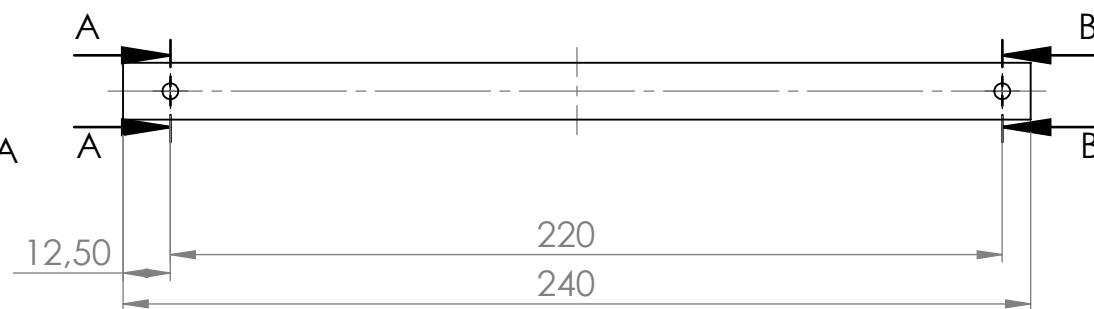
SCALE 1 : 5



SECTION C-C



SECTION A-A



SECTION B-B

thickness is 1.5 mm  
holes are 4.2 mm (6x)

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi  
**ligger rechts**

TITLE:

Date:

24-10-2014

A4

Quantity:

1

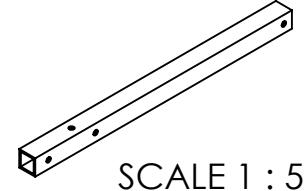


DEBUR AND  
BREAK SHARP  
EDGES

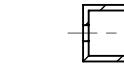
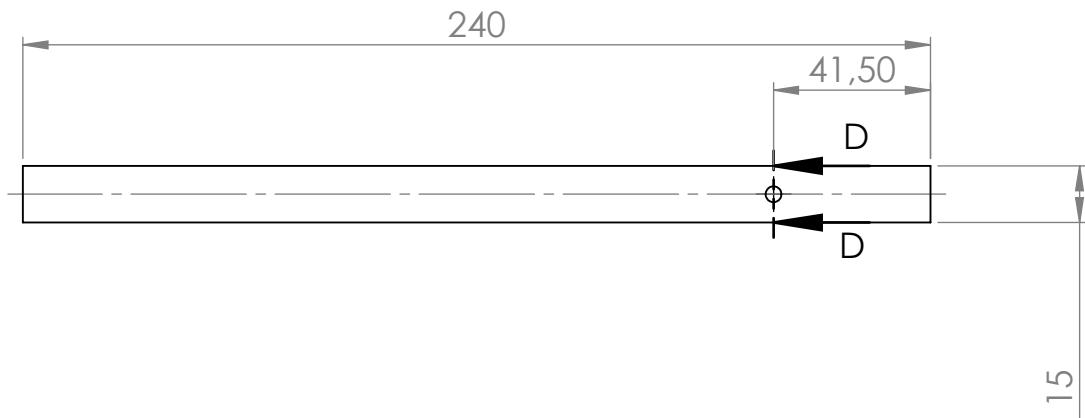
MATERIAL:  
Aluminium 6082

SCALE:1:2

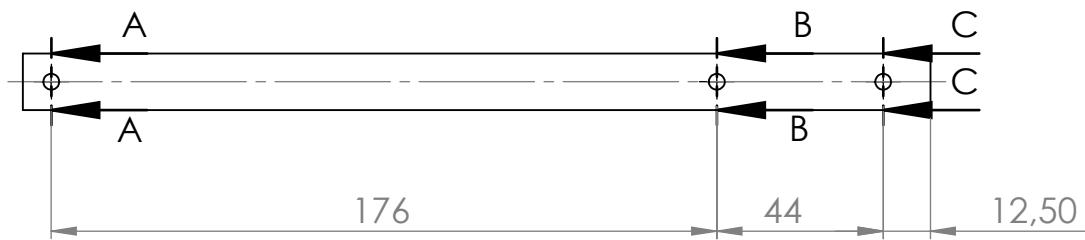
SHEET 1 OF 1



SCALE 1 : 5



SECTION D-D



SECTION A-A



SECTION B-B



SECTION C-C

thickness is 1.5 mm  
holes are 4.20 mm (8x)

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi  
trigger

TITLE:

Quantity:  
1



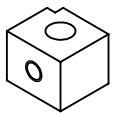
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

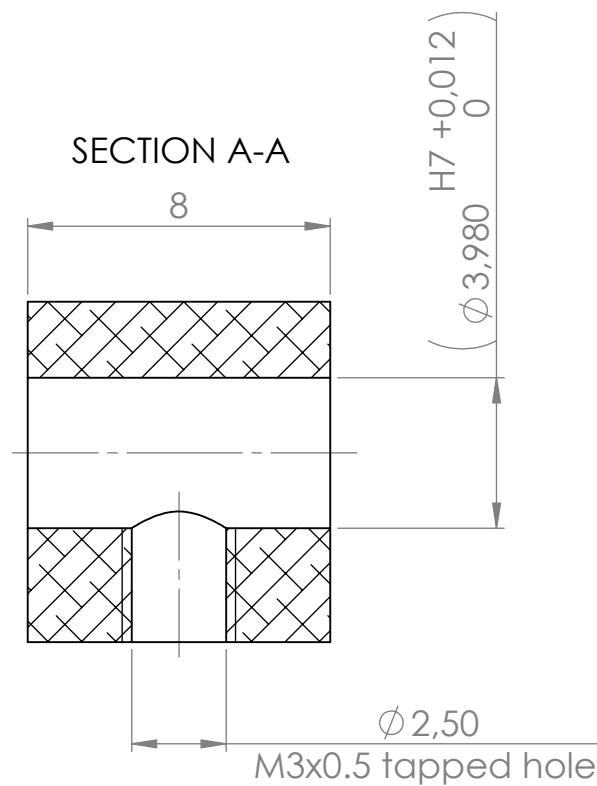
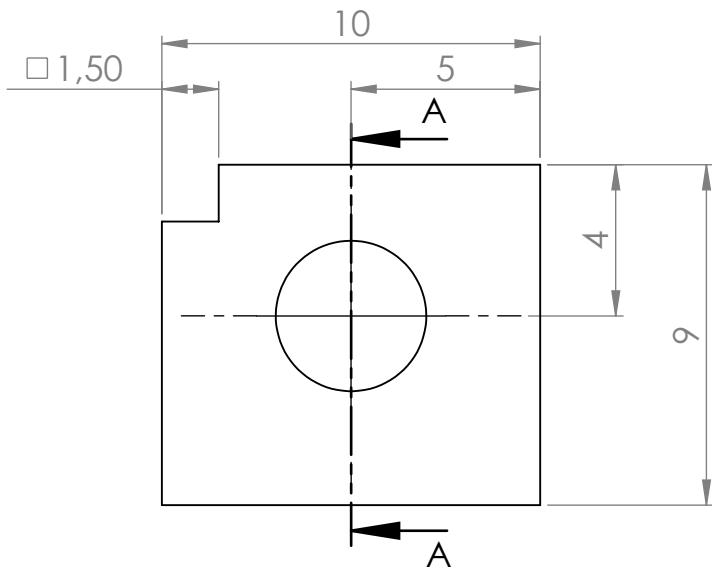
Date:

24-10-2014

A4



SCALE 1 : 1



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: linkage\_mouthplate

Quantity:  
2



DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminum  
6082

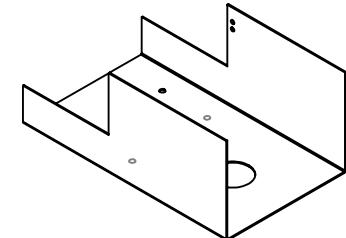
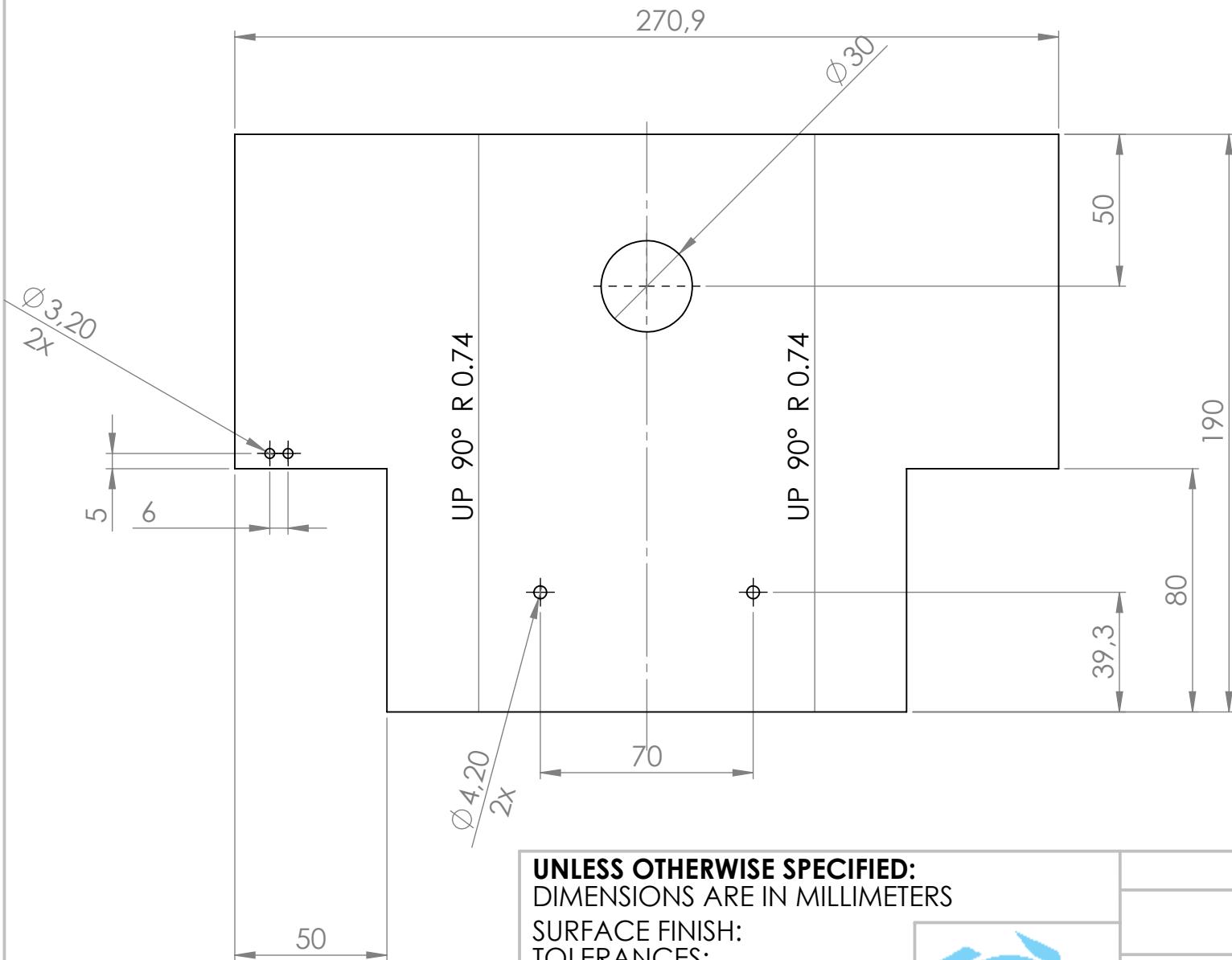
Date:

21-10-2014

A4

SCALE:5:1

SHEET 1 OF 1



SCALE 1 : 5

thickness is 1 mm

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

mainframe

Date:

21-10-2014

A4

Quantity:  
1

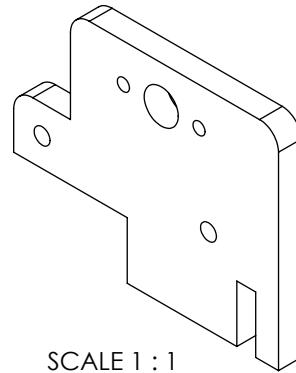
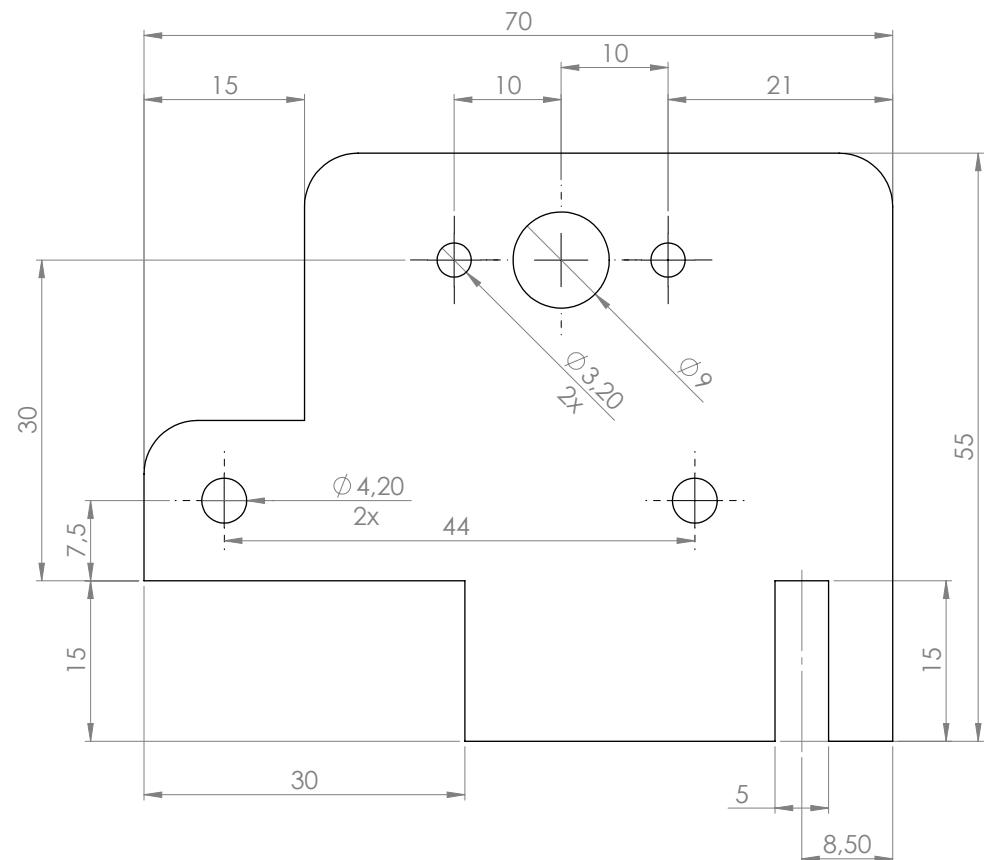


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
steel,  
sheetmaetal

SCALE:1:2

SHEET 1 OF 1



Thickness is 6 mm  
Fillet's are R5

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR: ±0,2 mm  
ANGULAR: ±0,5°



DO NOT SCALE DRAWING  
Robotics Minor Group 5: Tawi  
TITLE: motorbevestiging

Quantity:  
2

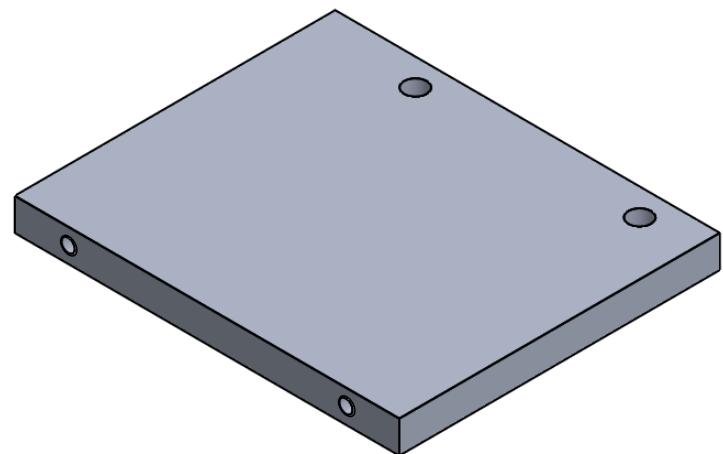
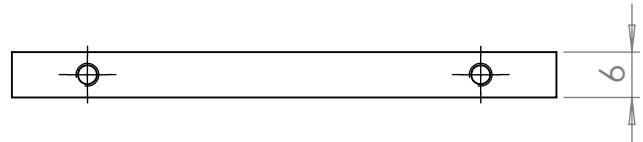
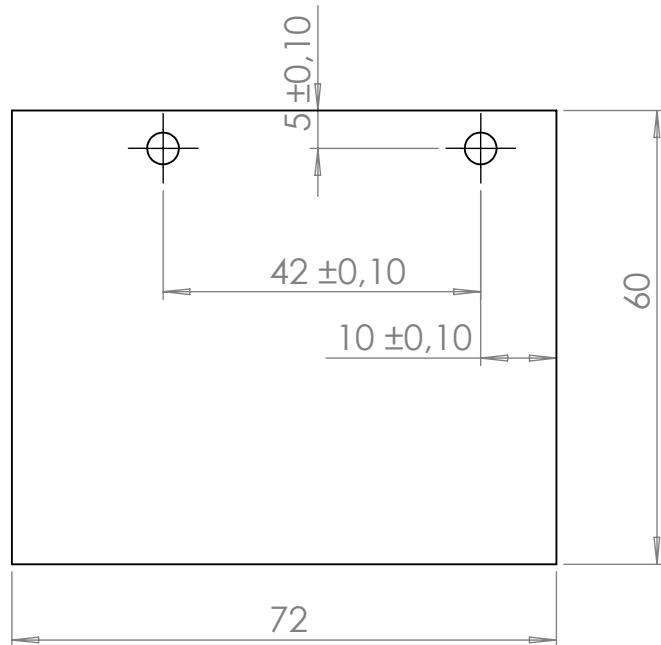
**TU Delft**

DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Perspex

Date:  
24-10-2014

A4



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:  
**motordakje**

Quantity:  
1

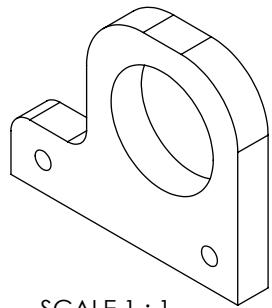


DEBUR AND  
BREAK SHARP  
EDGES

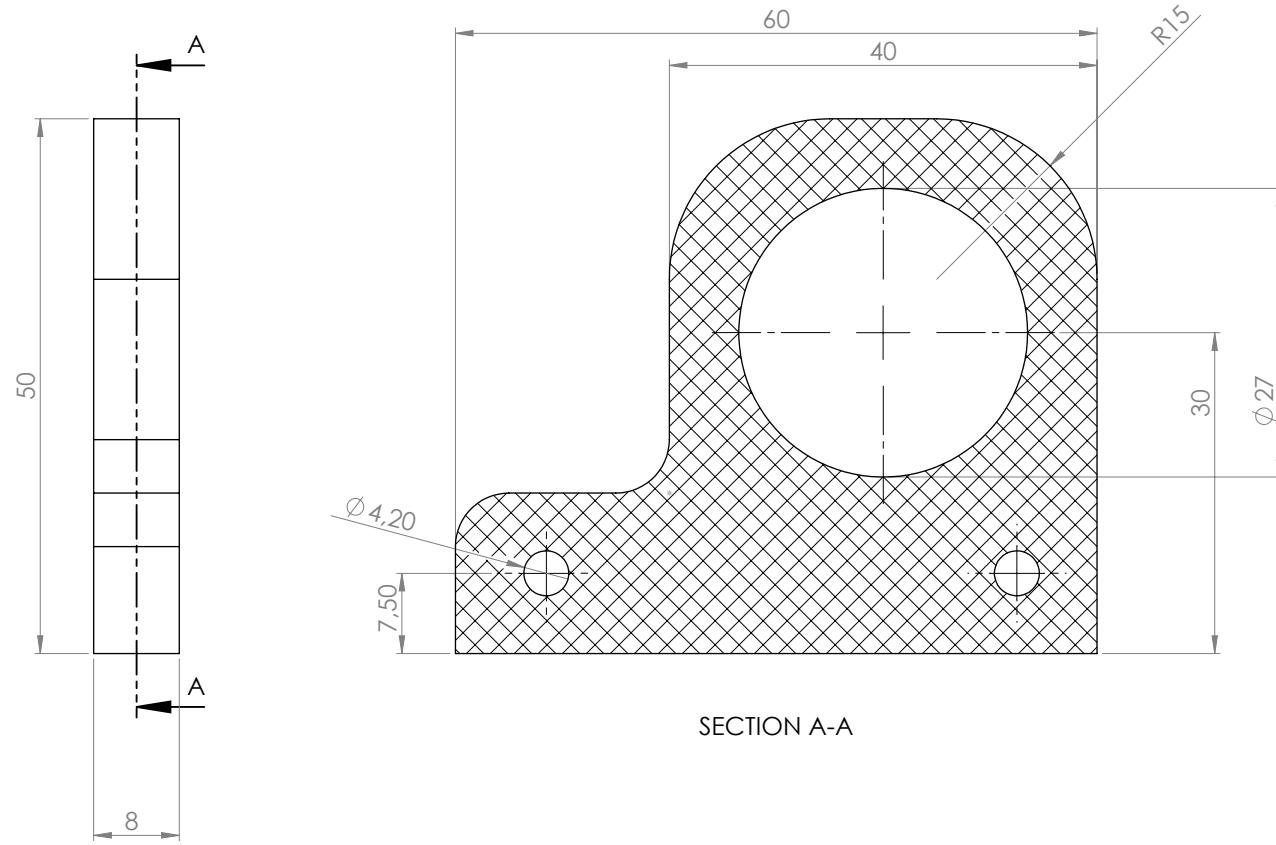
MATERIAL:  
Aluminium 6082

Date:  
21-10-2014

A4



SCALE 1 : 1



Fillets are R5 if not mentioned otherwise

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$

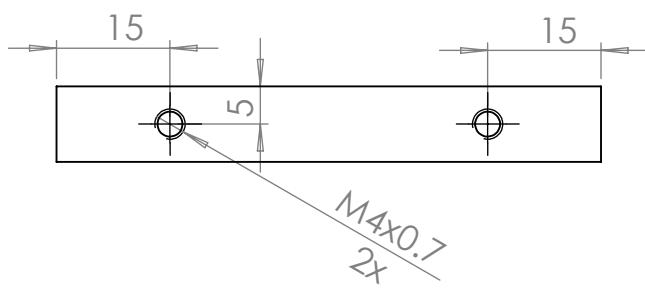
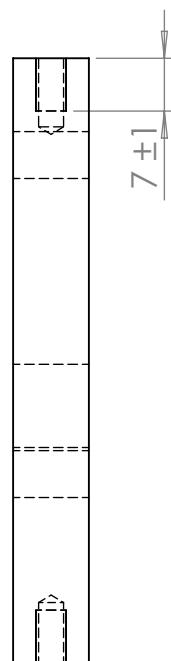
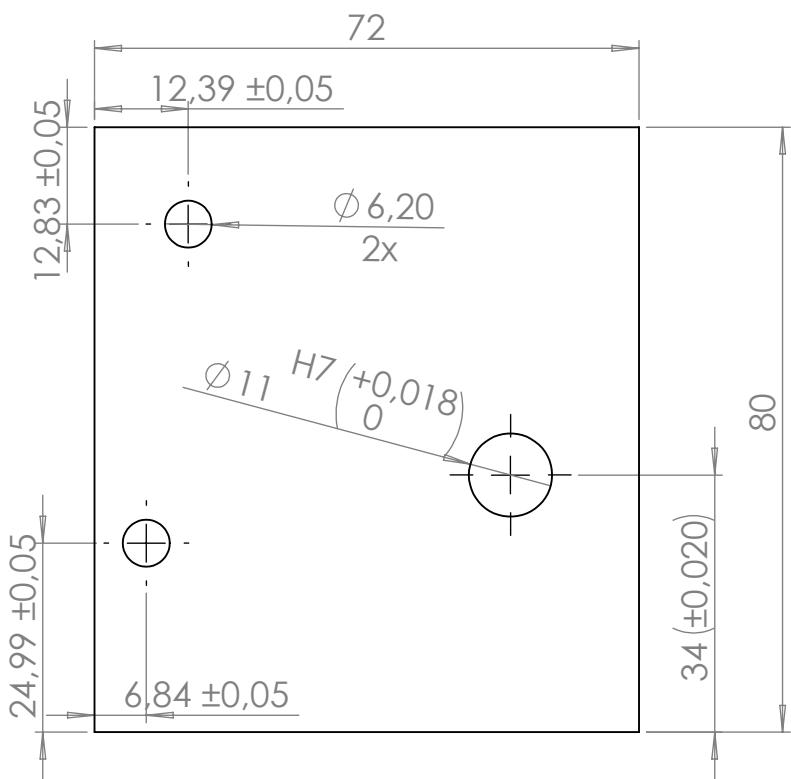
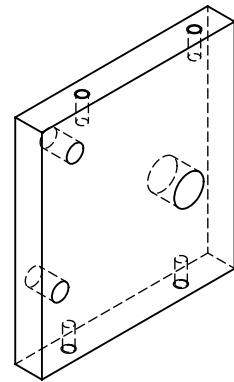
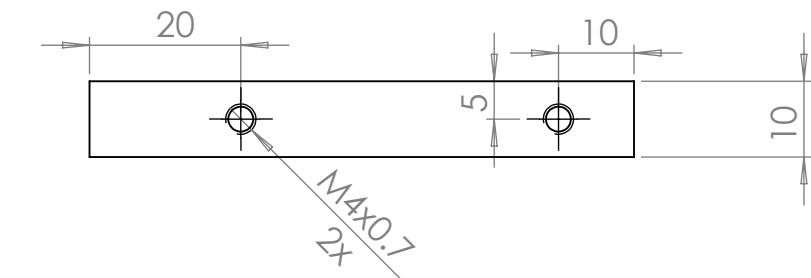


DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: motorhouder\_achter

Quantity:	1	<b>TUDelft</b>	DEBUR AND BREAK SHARP EDGES	MATERIAL: Perspex	Date: 24-10-2014	A4
SCALE:2:1						SHEET 1 OF 1



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS

SURFACE FINISH: ✓  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$

6.3/

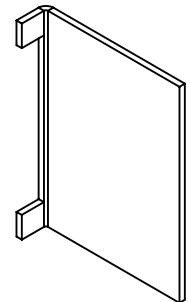
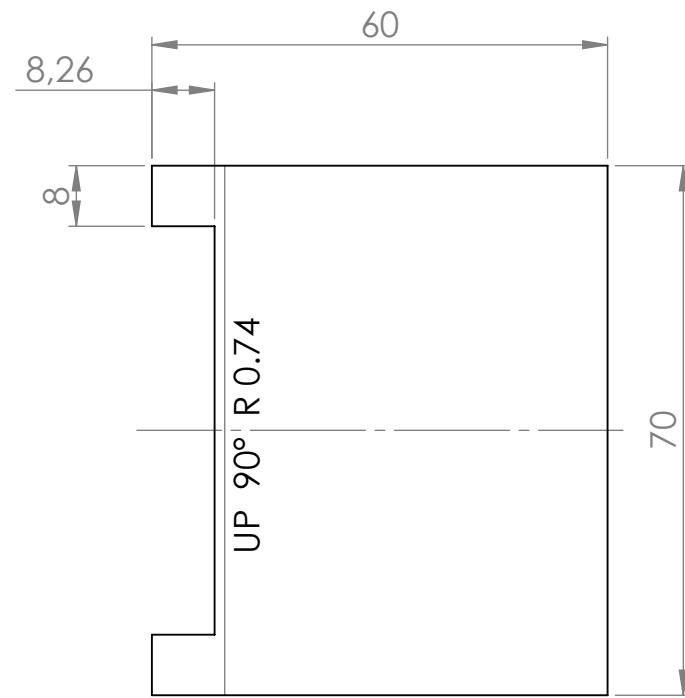


DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

motormount



SCALE 1 : 2

thickness is 1 mm.

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:  
**mouthplate**

Quantity:  
1

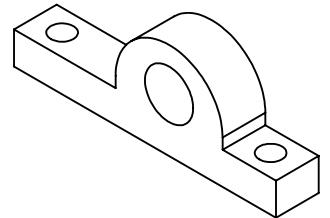
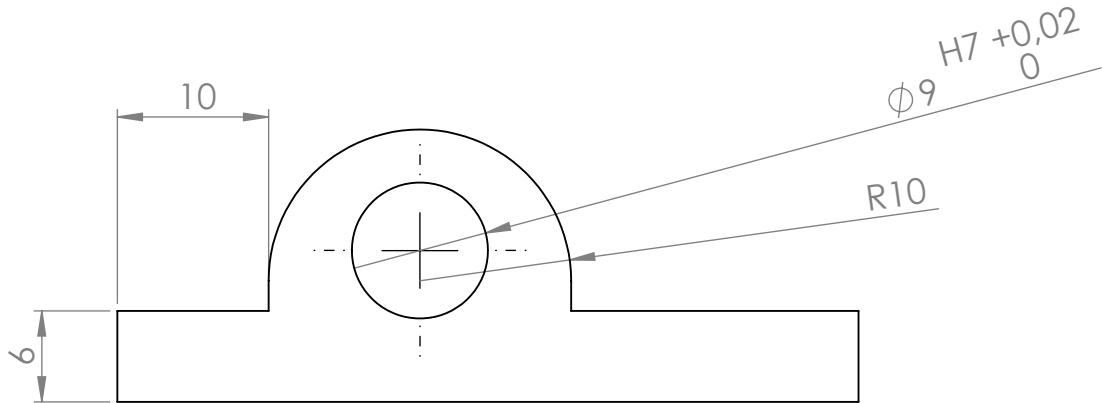


DEBUR AND  
BREAK SHARP  
EDGES

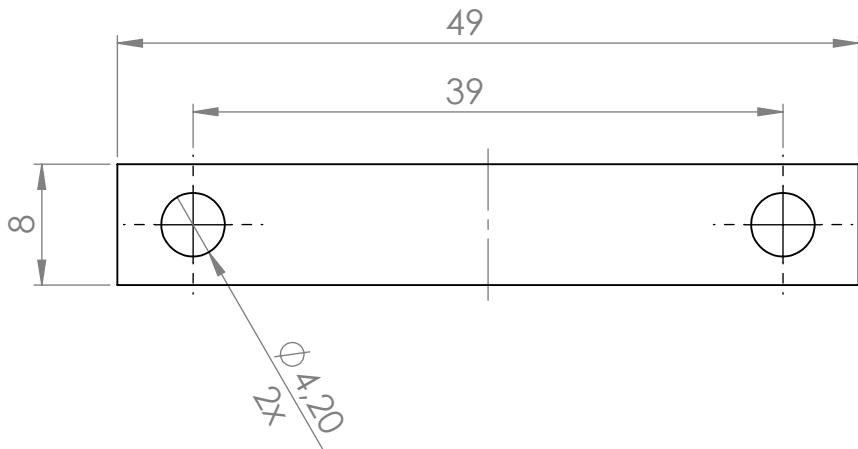
MATERIAL:  
steel, sheet  
metal

Date:  
21-10-2014

A4



SCALE 1 : 1



UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:  
**new\_lagerhuis**

Quantity:  
2

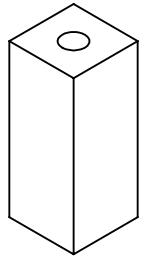


DEBUR AND  
BREAK SHARP  
EDGES

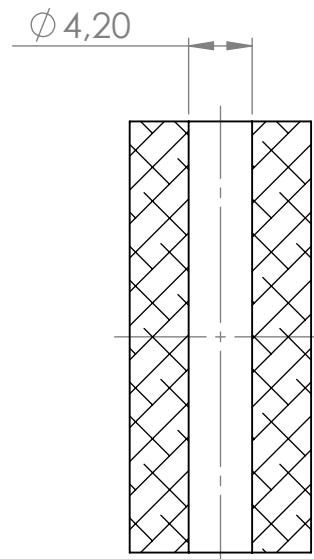
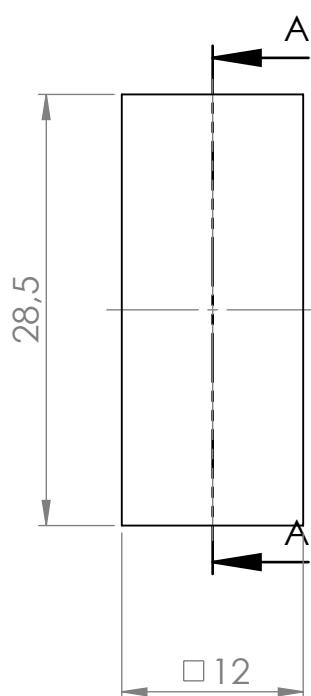
MATERIAL:  
Perspex

Date:  
24-10-2014

A4



SCALE 1 : 1



SECTION A-A

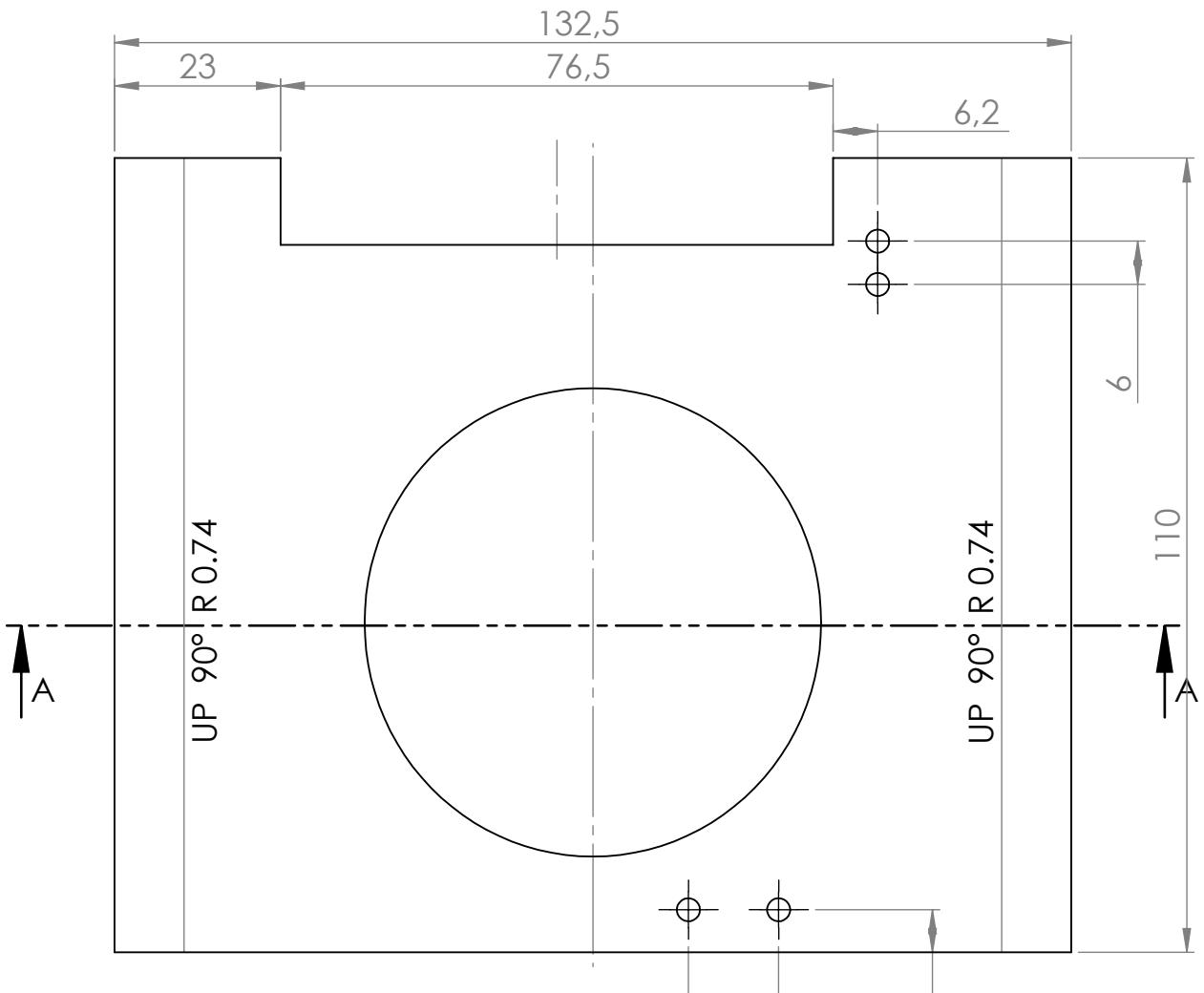
UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

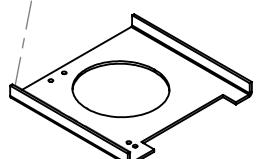
TITLE: ondersteuningBuis



SECTION A-A

thickness is 1 mm.

holes have a diameter  
of 3.20 mm.



SCALE 1 : 5

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$

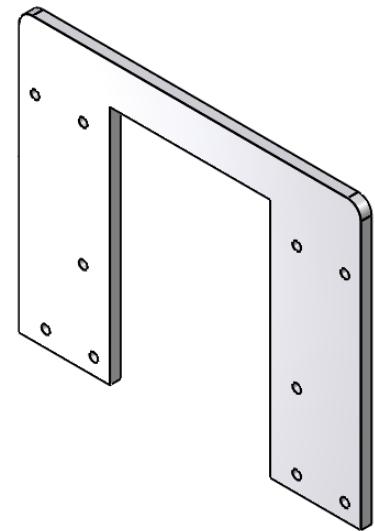
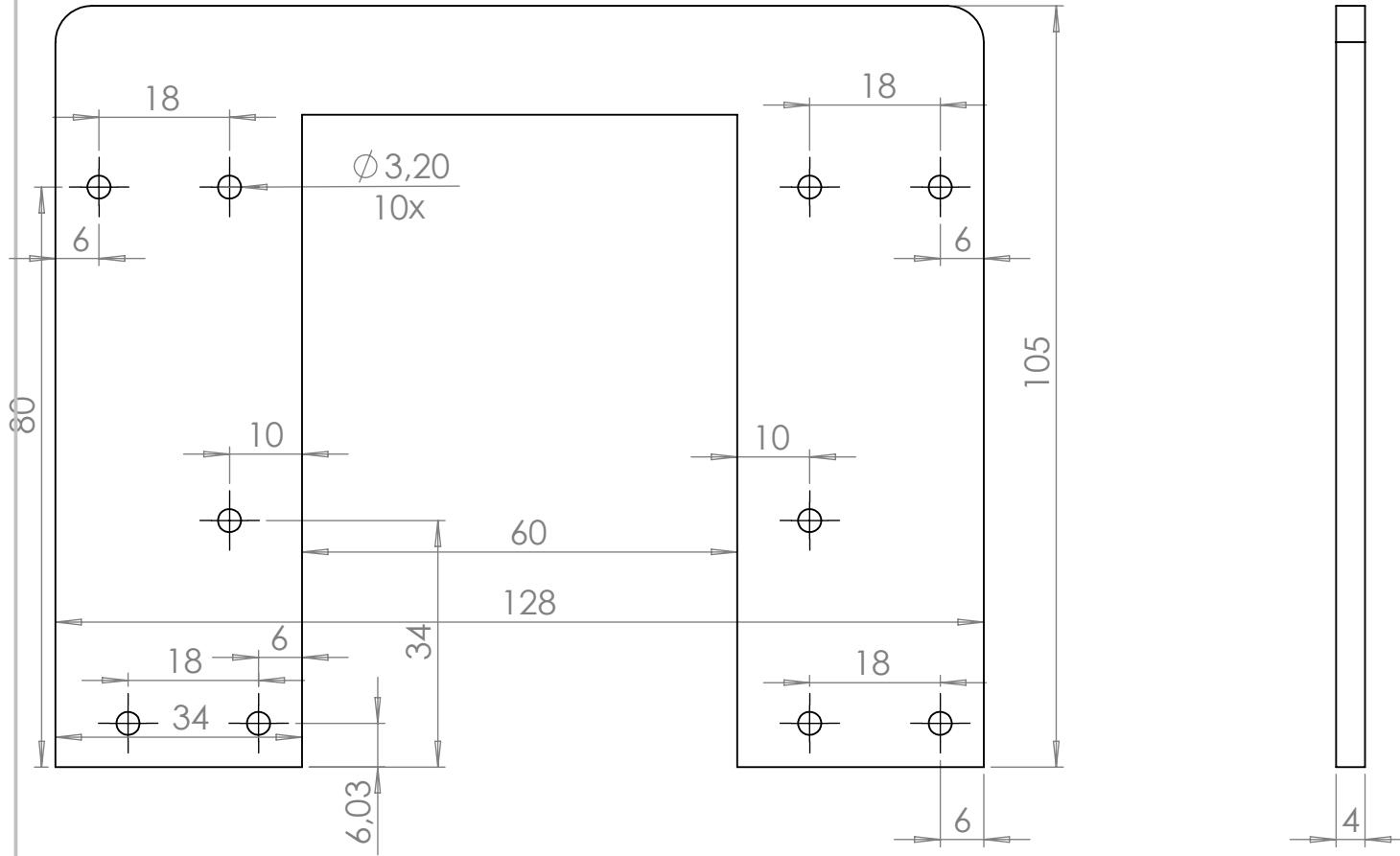


DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

pipe\_catcher



SCALE 1 : 2

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi  
TITLE: plaatje voorkant

Quantity:

1



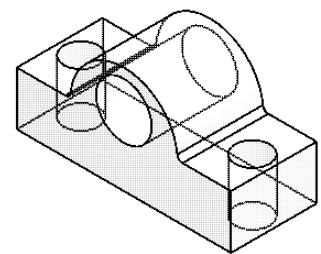
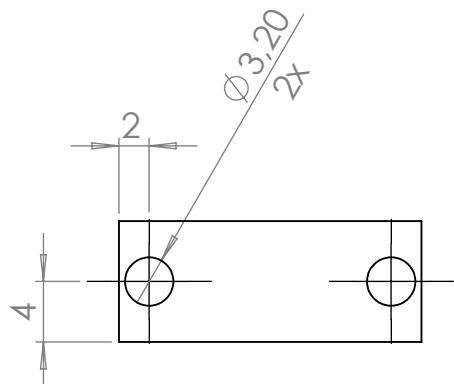
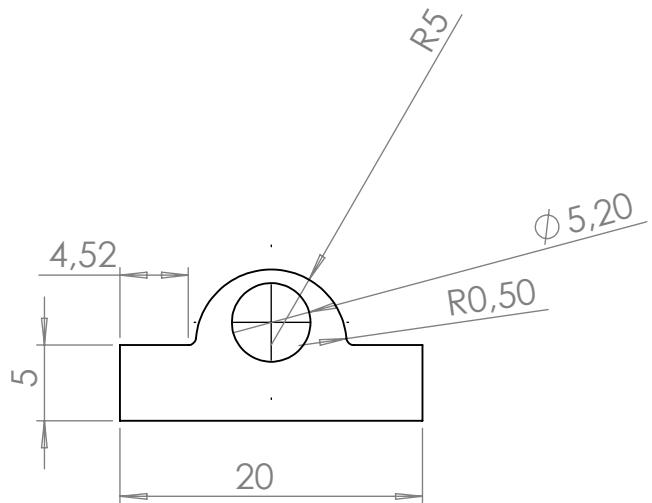
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

Date:

23-10-2014

A4



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

pulleyblock



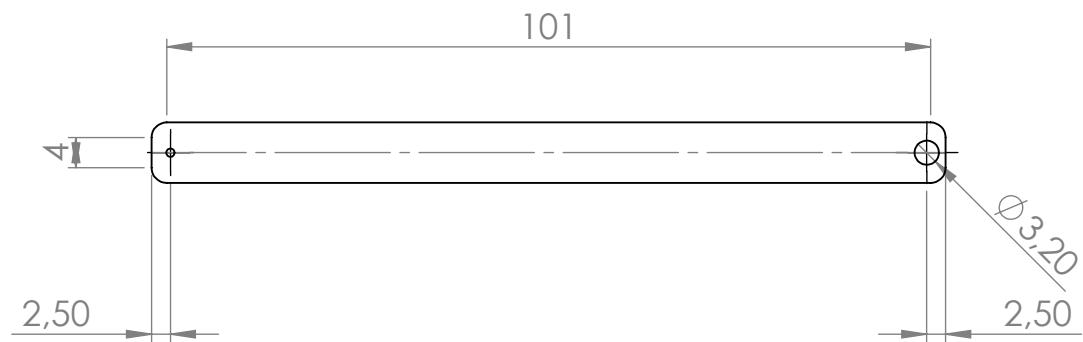
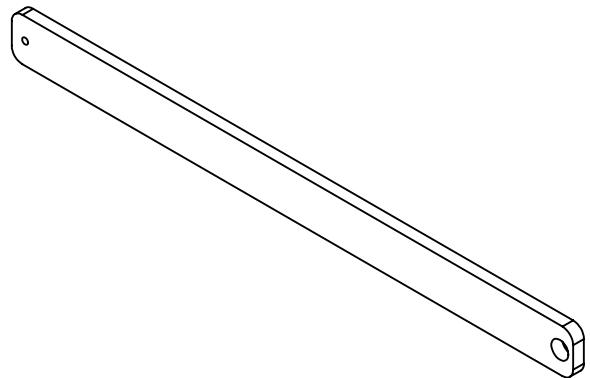
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
PERSPEX

Date:  
23-10-2014

Quantity:  
2

A4



thickness is 2 mm.

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi  
**pushrod**

TITLE:

Date:

21-10-2014

A4

Quantity:  
1

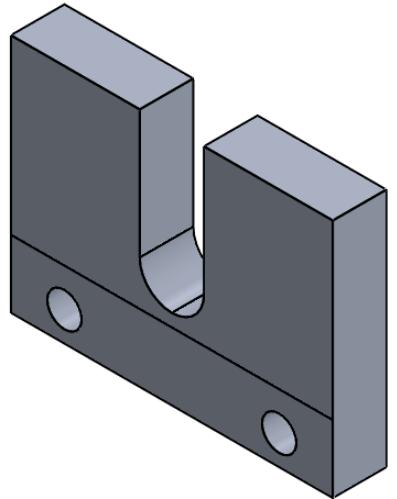
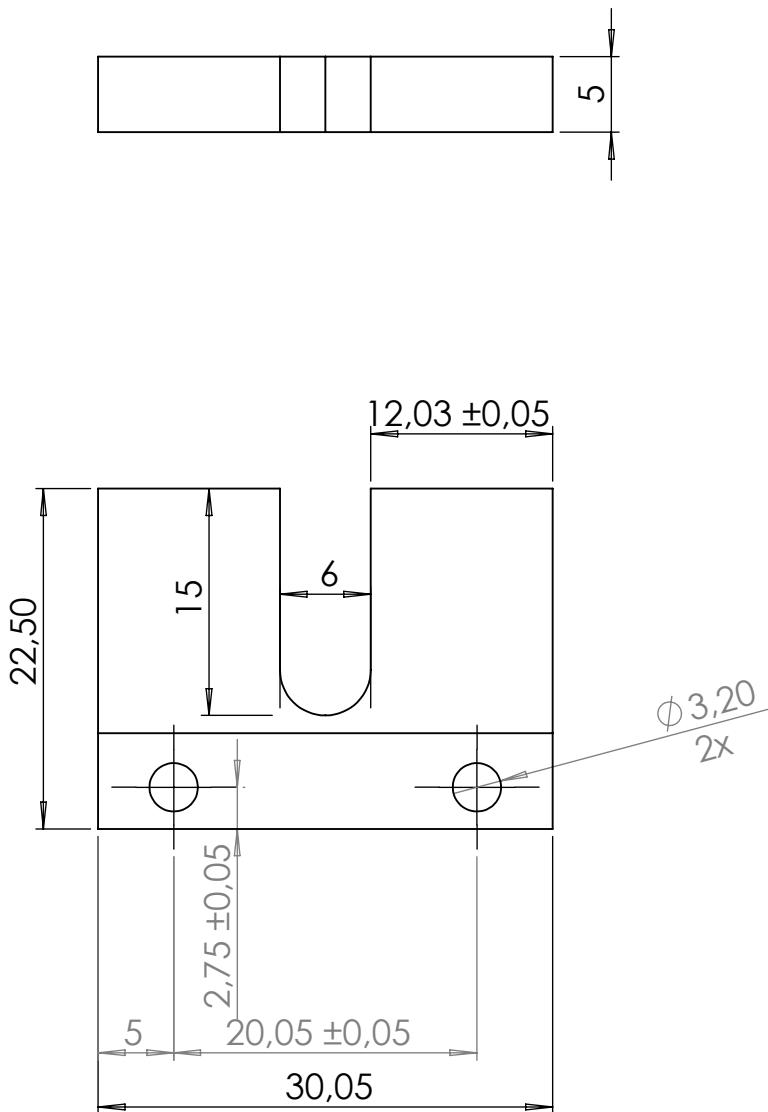


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminum 6082

SCALE:1:1

SHEET 1 OF 1



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR: ±0,2 mm  
ANGULAR: ±0,5°

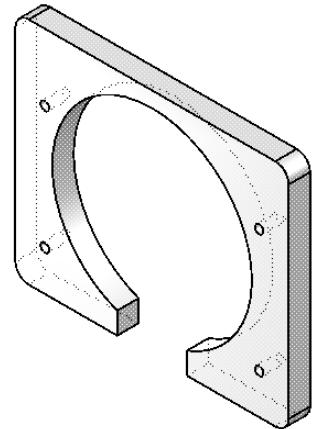
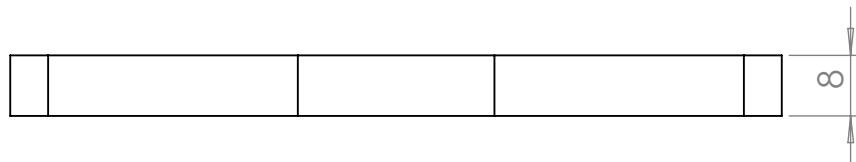
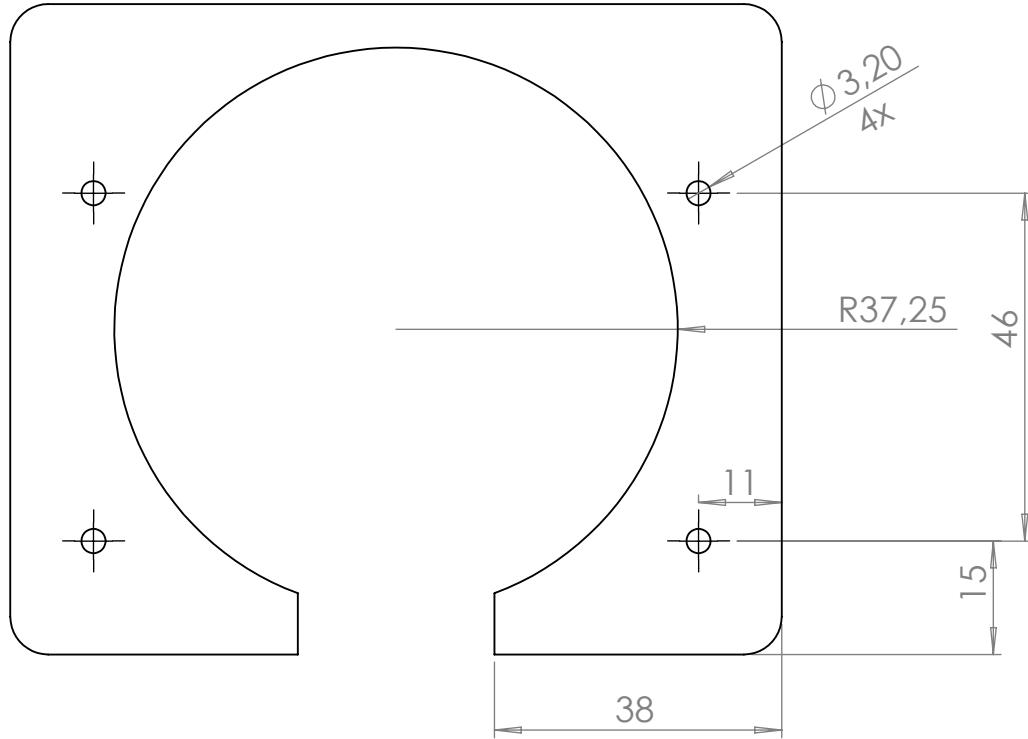


DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

RackStopper



SCALE 1 : 2

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$

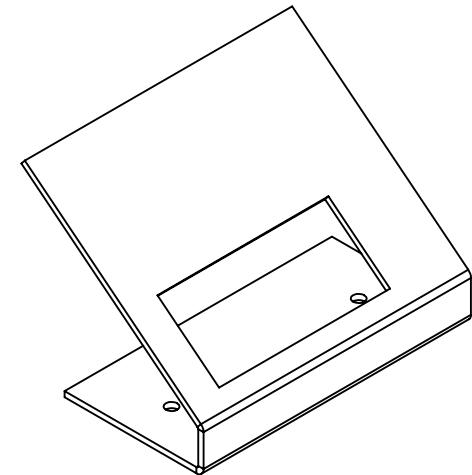
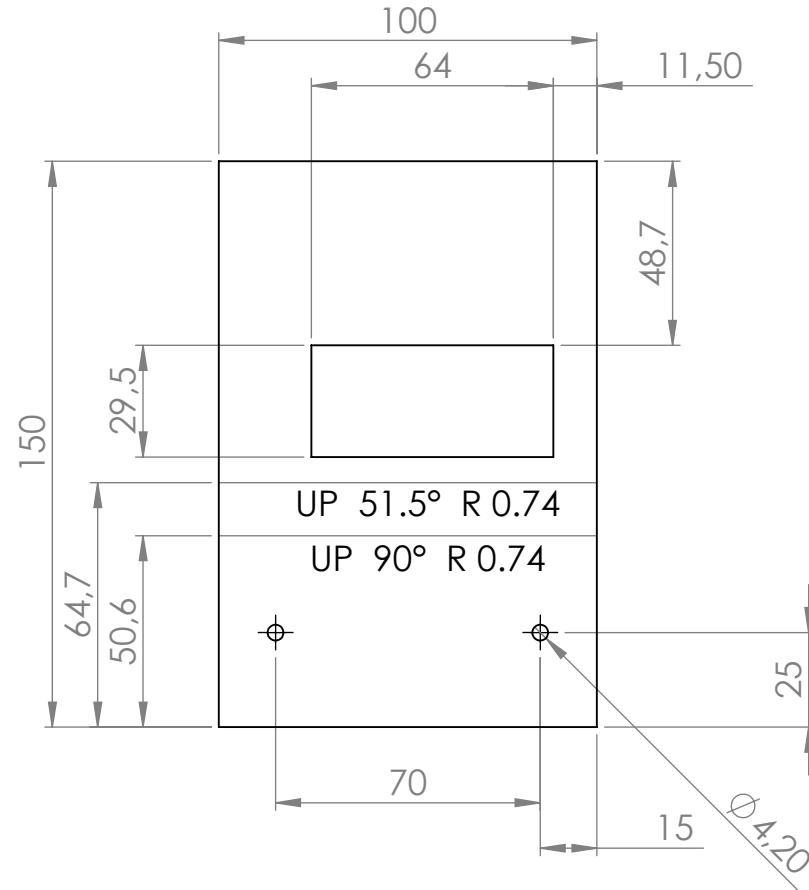


DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

ring



thickness sheet is 1mm.

**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: screenholderV2

Date:

21-10-2014

A4

Quantity:

1

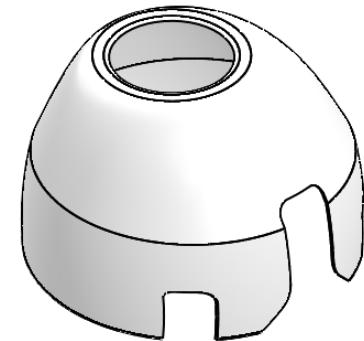
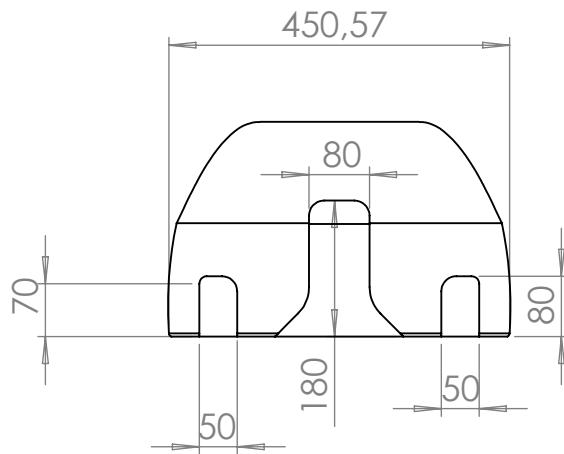
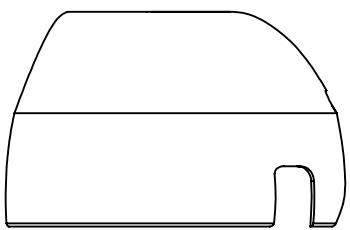
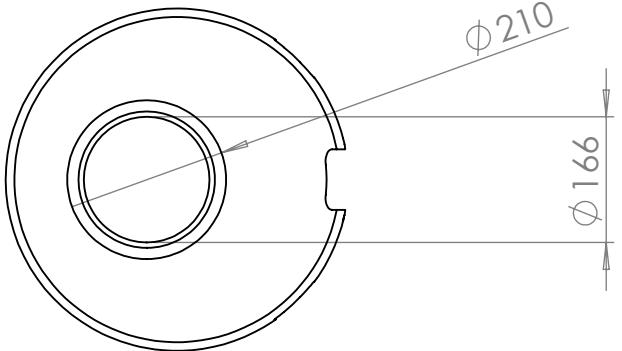


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
steel, sheet  
metal

SCALE:1:2

SHEET 1 OF 1



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

Shell

Date:

24-10-2014

A4

Quantity:

1

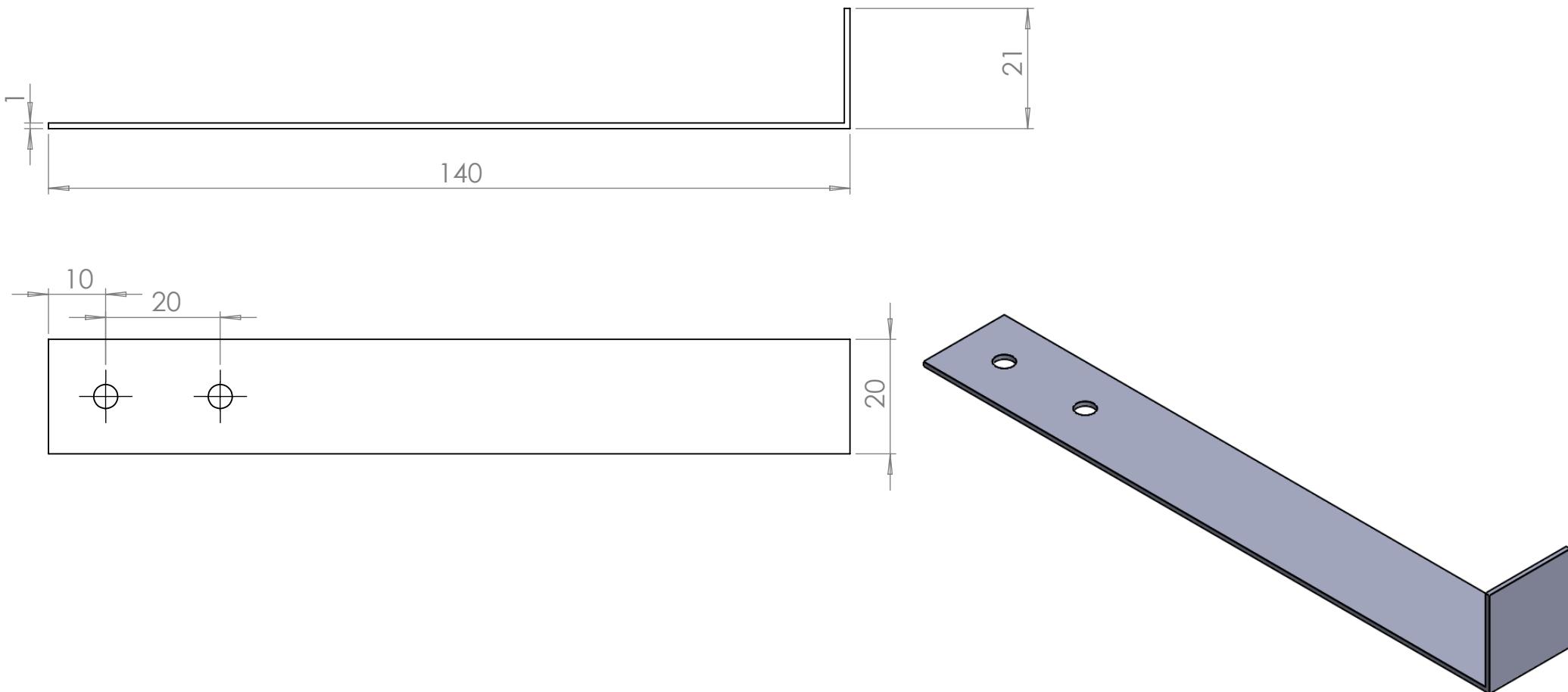


DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Glassfiber  
Composite

SCALE:1:10

SHEET 1 OF 1



**UNLESS OTHERWISE SPECIFIED:**  
 DIMENSIONS ARE IN MILLIMETERS  
 SURFACE FINISH:  
 TOLERANCES:  
 LINEAR:  $\pm 0.2$  mm  
 ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: shell\_fastener

Quantity:

2



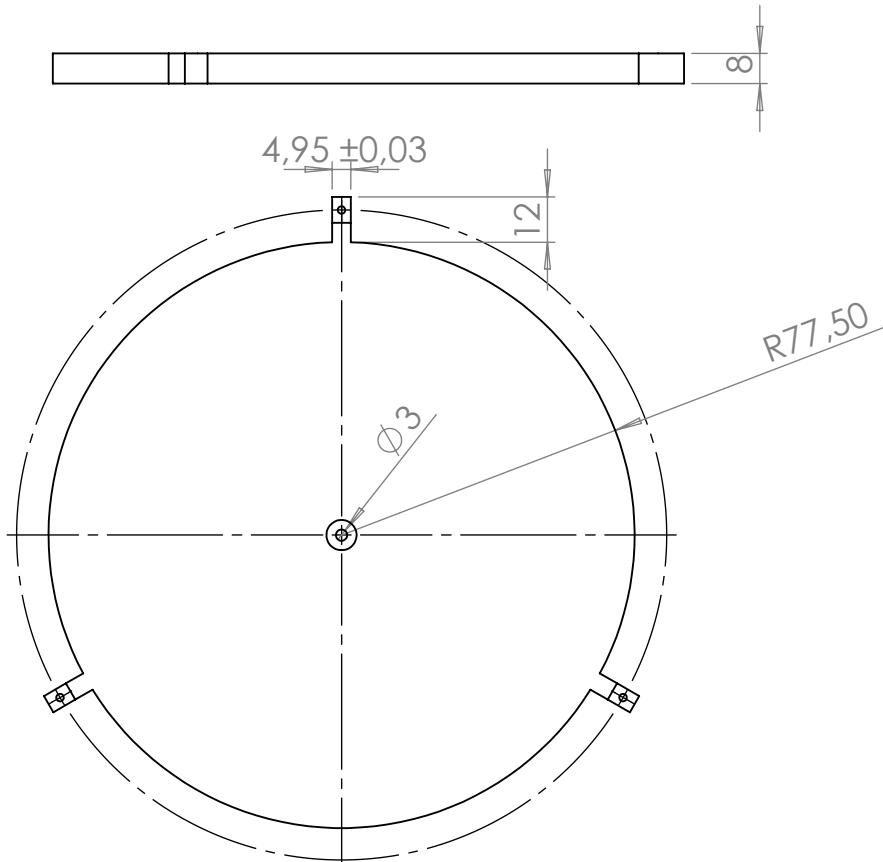
DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

Date:

23-10-2014

A4



**UNLESS OTHERWISE SPECIFIED:**  
 DIMENSIONS ARE IN MILLIMETERS  
 SURFACE FINISH:  
 TOLERANCES:  
 LINEAR:  $\pm 0.2$  mm  
 ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:  
**Slider\_Platform**

Quantity:

1



DEBUR AND  
BREAK SHARP  
EDGES

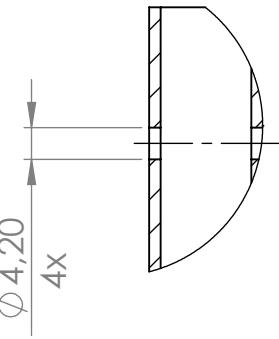
MATERIAL:

Perspex

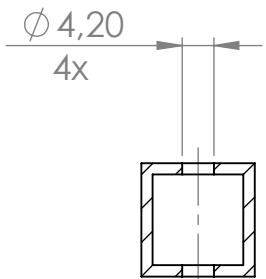
Date:

22-10-2014

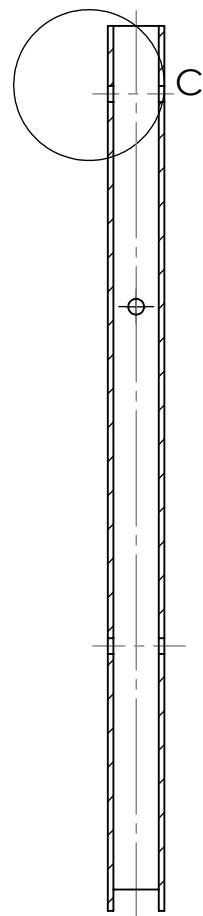
A4



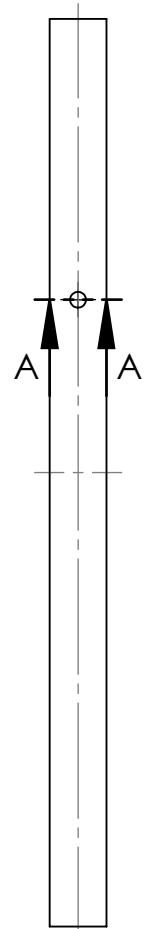
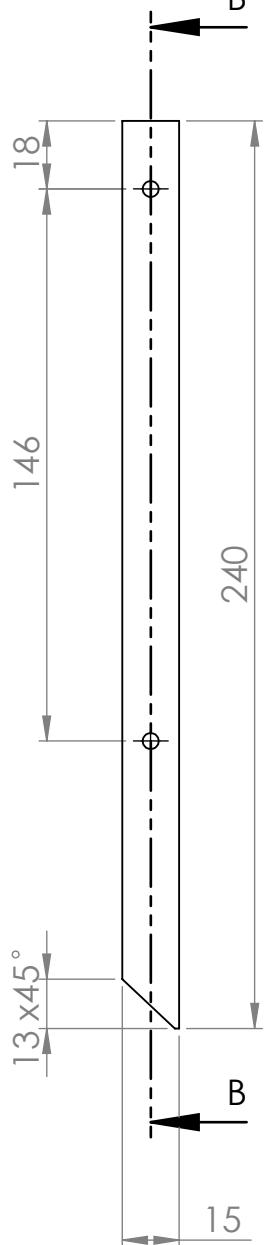
DETAIL C  
SCALE 1 : 1



SECTION A-A  
SCALE 1 : 1



SECTION B-B



SCALE 1 : 5

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:

LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



thickness is 1.5 mm

DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

staander achter



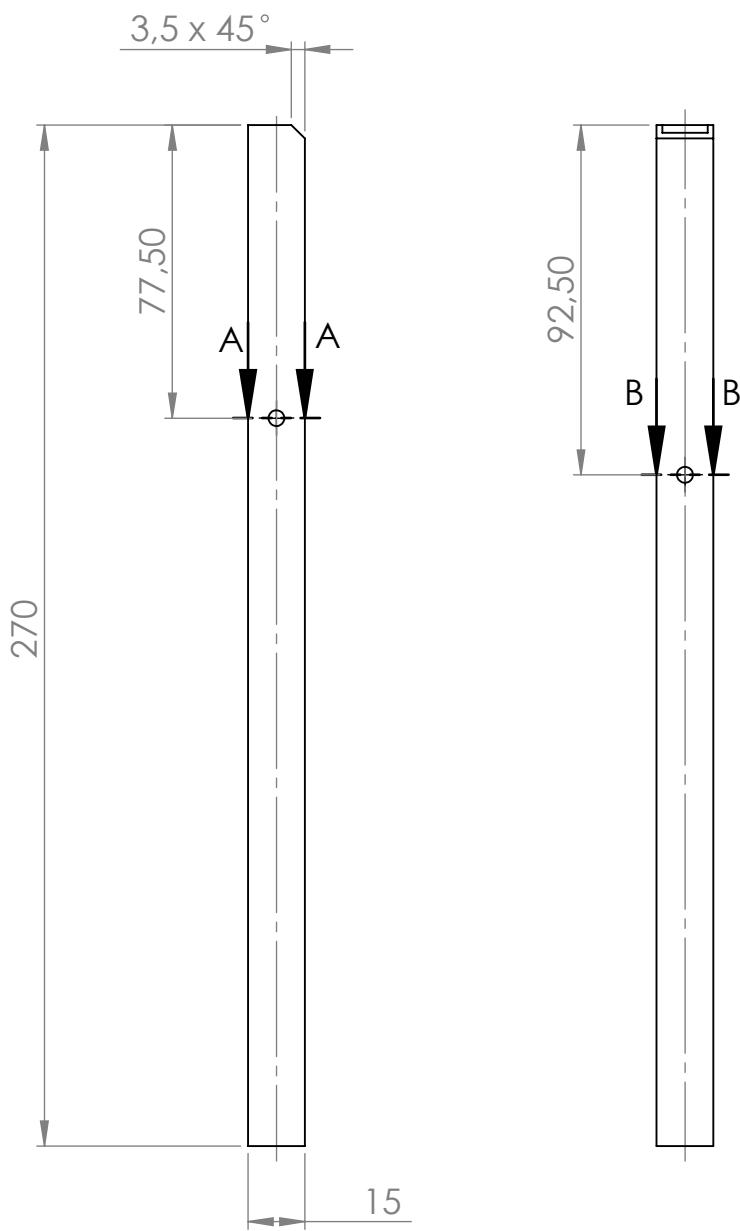
SECTION A-A



SECTION B-B



SCALE 1 : 5



thickness is 1.5 mm  
holes are 4.20 mm

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS

SURFACE FINISH:

TOLERANCES:

LINEAR:  $\pm 0.2$  mm

ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

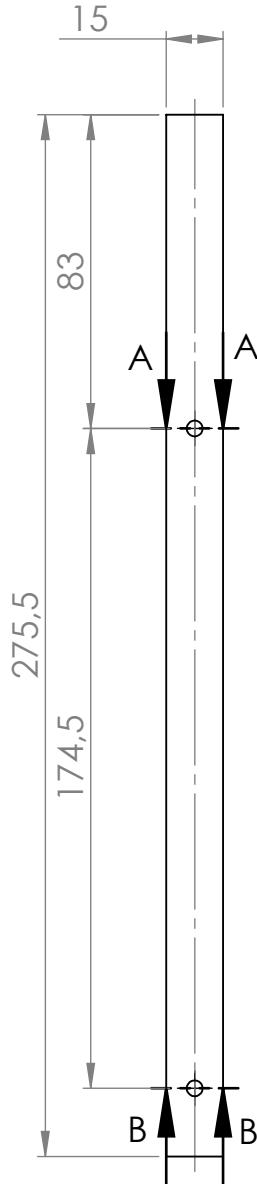
Robotics Minor Group 5: Tawi

TITLE:

staander voor rechts



SECTION A-A



SCALE 1 : 5



SECTION B-B

thickness is 1.5 mm  
holes are 4.20 mm (4x)

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MILLIMETERS

SURFACE FINISH:

TOLERANCES:

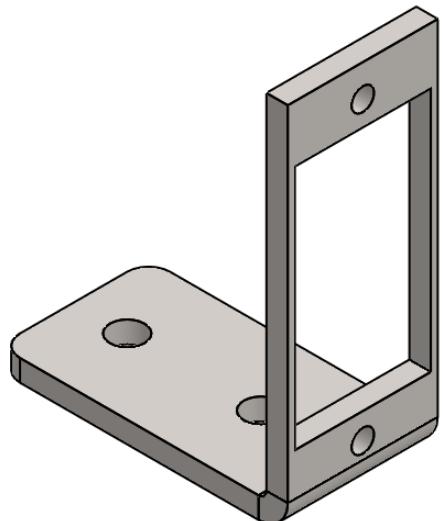
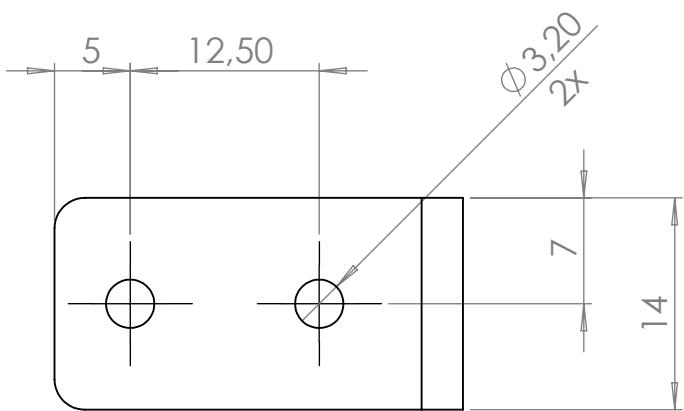
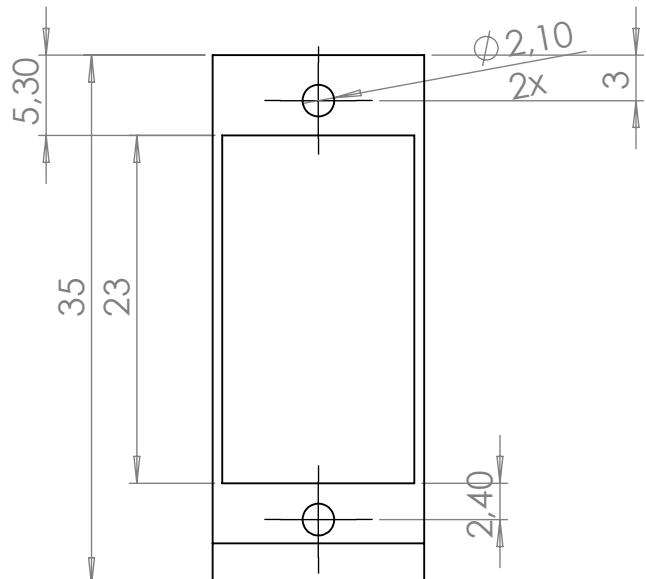
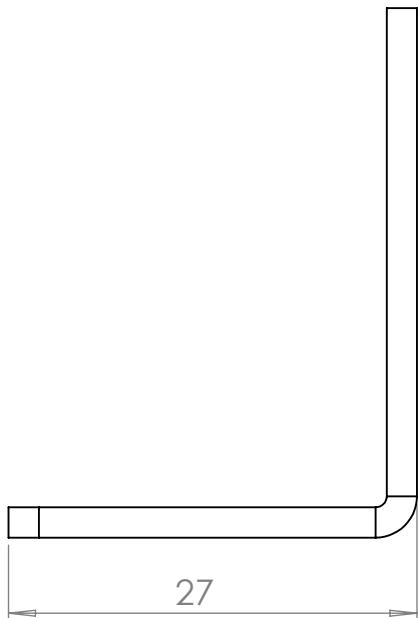
LINEAR:  $\pm 0.2$  mmANGULAR:  $\pm 0.5^\circ$ 

DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE:

staander voor



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0.2$  mm  
ANGULAR:  $\pm 0.5^\circ$



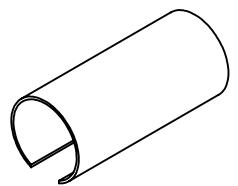
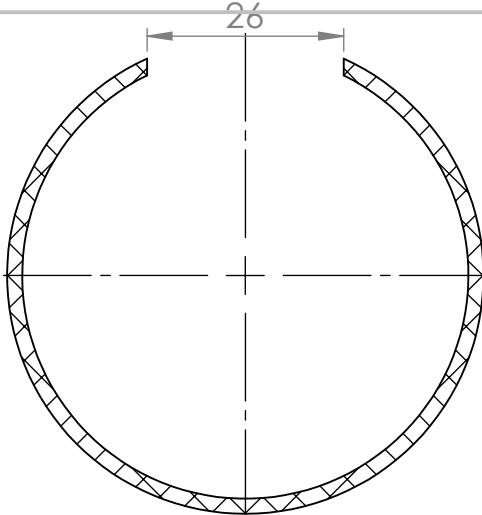
DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

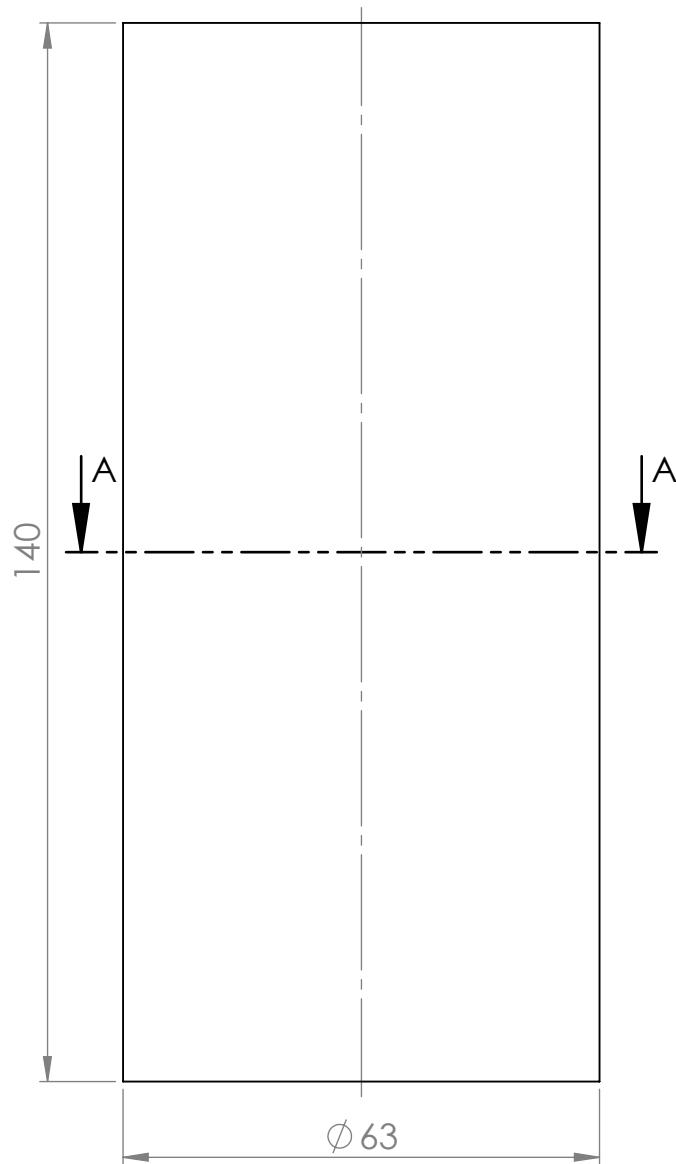
TITLE:

steun

SECTION A-A



SCALE 1 : 5



UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS

SURFACE FINISH:

TOLERANCES:

LINEAR:  $\pm 0.2$  mm

ANGULAR:  $\pm 0.5^\circ$

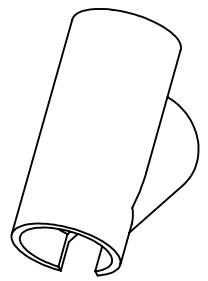


DO NOT SCALE DRAWING

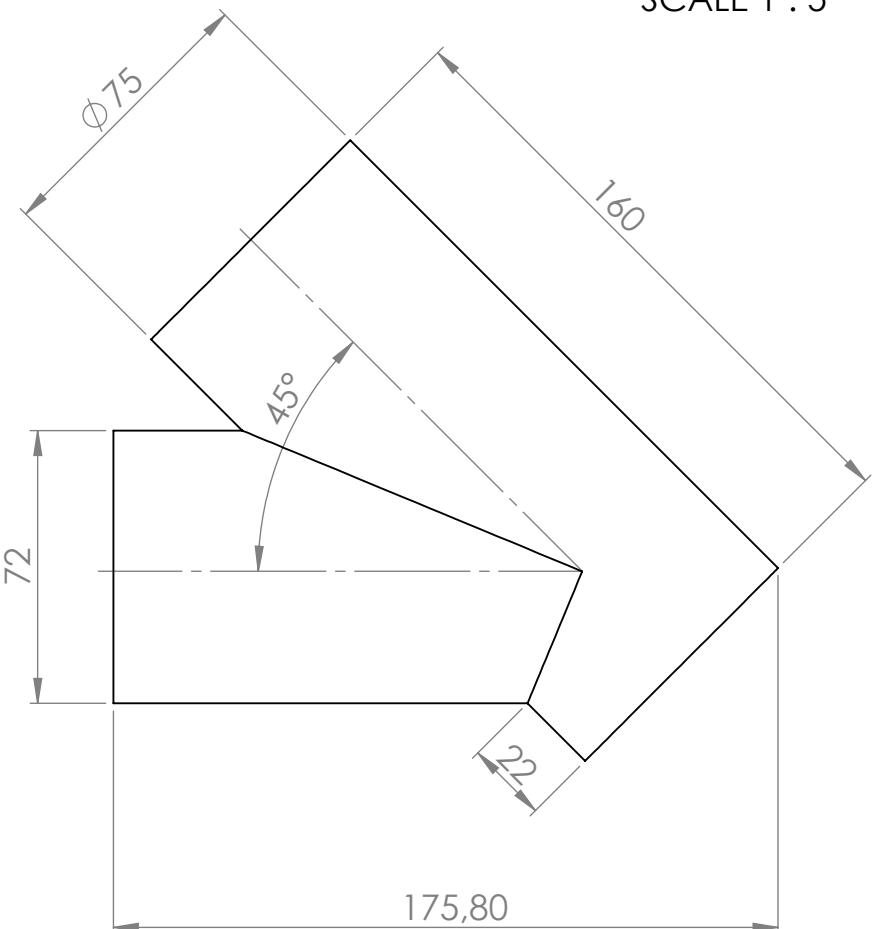
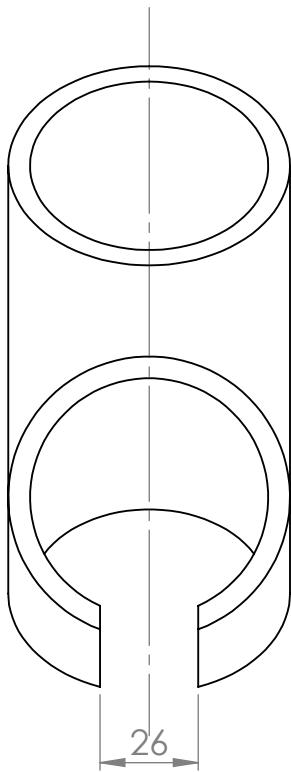
Robotics Minor Group 5: Tawi

TITLE:

transportbuis



SCALE 1 : 5



thickness 5.75 mm

UNLESS OTHERWISE SPECIFIED:  
DIMENSIONS ARE IN MILLIMETERS

SURFACE FINISH:

TOLERANCES:

LINEAR:  $\pm 0.2$  mm

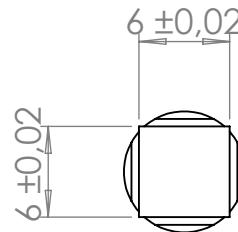
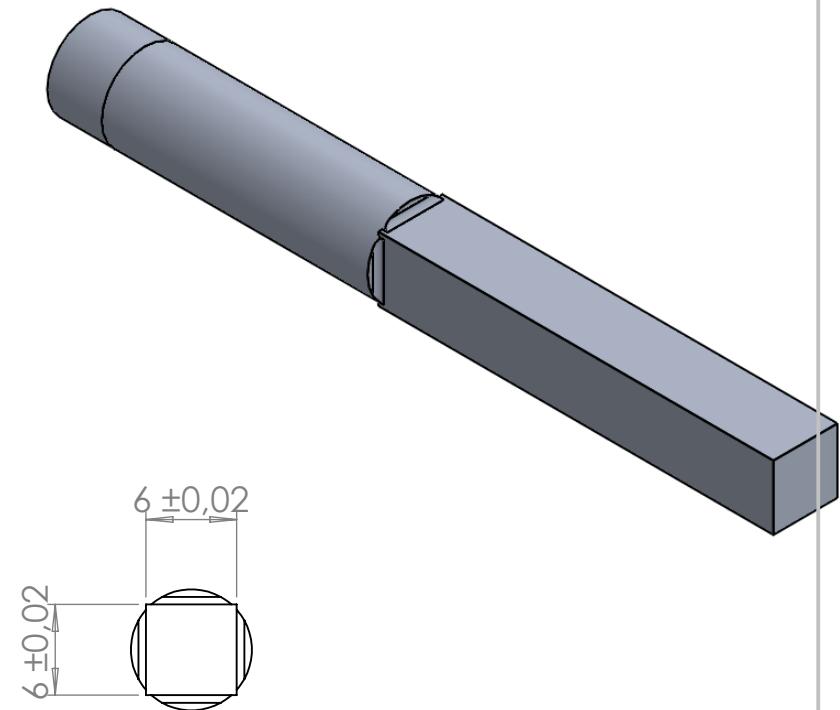
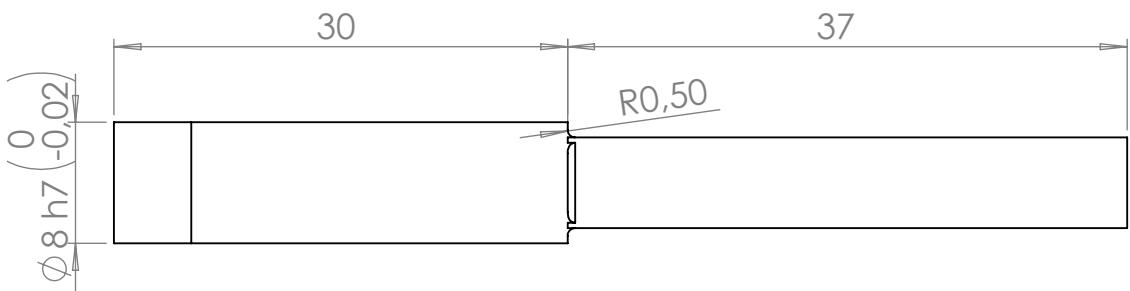
ANGULAR:  $\pm 0.5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: T-stuk afgesneden



**UNLESS OTHERWISE SPECIFIED:**  
DIMENSIONS ARE IN MILLIMETERS  
SURFACE FINISH:  
TOLERANCES:  
LINEAR:  $\pm 0,2$  mm  
ANGULAR:  $\pm 0,5^\circ$



DO NOT SCALE DRAWING

Robotics Minor Group 5: Tawi

TITLE: vierkantas

Quantity:

1



DEBUR AND  
BREAK SHARP  
EDGES

MATERIAL:  
Aluminium 6082

Date:

21-10-2014

A4