2nd Semester '14

Customisable Hydrophonic Rescue and Recovery Badge

Victor Rebagliato Monsonís

Hogeschool Rotterdam Student

Partnership

Imtech Marine

Customisable Hydrophonic Rescue and Recovery Badge (CHRRB)

Project Goal.

The goal of this project is using 3D printing technology to design a cheap small dispositive (CHRRB - Customisable Hydrophonic Rescue and Recovery Badge) working with battery that allows to detect a drowning body with help of some basic equipment. This small device should be placed into the pocket of the drowning person and has to be able to give a signal to the search party, this way is an easy way to find out the postion of the body. This dispositive has to be considered as a safety element, like a life vest or a helmet.

Promoter Details.

Dutch company Koninklijke Schuttevaer is interested in the development of this small device as an important advance in the field of drowned missing people.

Imtech marine is also collaborating in this innovative project.

Designer Details.

Designer:
Victor Rebagliato Monsonis, mechanical engineering student of Universidad Politécnica de Valencia and Exchange sutdent of Hogeschool Rotterdam.

INDEX

Chapter 1.- Introduction to the problem..Page 4

Chapter 2.- Functional Specification...Page 5

Chapter 3.- Technical Specification..Page 8

3D printing technology...Page 9

Chapter 4.- Prototypes...Page 14

Prototype 1...Page 14

Prototype 2...Page 16

Prototype 3...Page 19

Prototype 4...Page 23

Prototype 5...Page 28

Chapter 6: Personal Experiences, Reflection and Resources.............................Page 30

Chapter 1.- Introduction to the problem.

What is Drowning ?

Drowning is considered to be the death through respiratory impairment from submersion/immersion in liquid. Near drowning is the survival of a drowning event involving unconsciousness or water inhalation and can lead to serious secondary complications or death, possibly up to 72 hours after the event. It occurs more frequently in males and the young people.

Which is the problem of Drowning ?

One of the major problems of drowning is that when a person drowns as described before, there is a large probability that the body is never found. It results very expensive and a large amount of time is needed to carry out the searching, and most of the times body is never found.

Every year in the Netherlands, more than 200 bodies of drowned persons are recovered, many of which have been lost for days, weeks and longer. This exacerbates the trauma for the families, who are often left in uncertainty about the fate of the missing family, but also have to face possible repercussions for life insurance and pensions. Also it imposes a great shock for those who find the bodies, as the Dutch inland waters have a major recreational value.

How is it solved ?

To carry out one of these operations it's needed to report the missing. This is usually done at the local police office that will examine the report and decide if they will start up a survey to find the person suspected to have become a victim of drowning. If the police finds enough reason to believe the missing person should be located underwater, normally they will start up the investigation for the period they think is sufficient.

Chapter 2.- Functional Specification

What equipment is actually used for drowning detection ?

Nowadays there are different underwater detection equipment, they tend to be really sophisticated, and therefore expensive. Their possibilities are huge and the range is variable depending on what the user is looking for.

Side Scan Sonar

Side-scan sonar (sometimes called side scan sonar, sidescan sonar, side imaging sonar, side-imaging sonar and bottom classification sonar) is a category of sonar system that is used to efficiently create an image of large areas of the sea floor. It may be used to conduct surveys for maritime archaeology; in conjunction with seafloor samples it is able to provide an understanding of the differences in material and texture type of the seabed. Side-scan sonar imagery is also a commonly used tool to detect debris items and other obstructions on the seafloor that may be hazardous to shipping or to seafloor installations by the oil and gas industry. In addition, the status of pipelines and cables on the seafloor can be investigated using side-scan sonar. Side-scan data are frequently acquired along with bathymetric soundings and sub-bottom profiler data, thus providing a glimpse of the shallow structure of the seabed. Side-scan sonar is also used for fisheries research, dredging operations and environmental studies. It also has military applications including mine detection.

Side-scan uses a sonar device that emits conical or fan-shaped pulses down toward the seafloor across a wide angle perpendicular to the path of the sensor through the water, which may be towed from a surface vessel or submarine, or mounted on the ship's hull. The intensity of the acoustic reflections from the seafloor of this fan-shaped beam is recorded in a series of cross-track slices. When stitched together along the direction of motion, these slices form an image of the sea bottom within the swath (coverage width) of the beam. The sound frequencies used in side-scan sonar usually range from 100 to 500 kHz; higher frequencies yield better resolution but less range. Here there's a graphic explanation of what is a side scan sonar and the image created by the software.

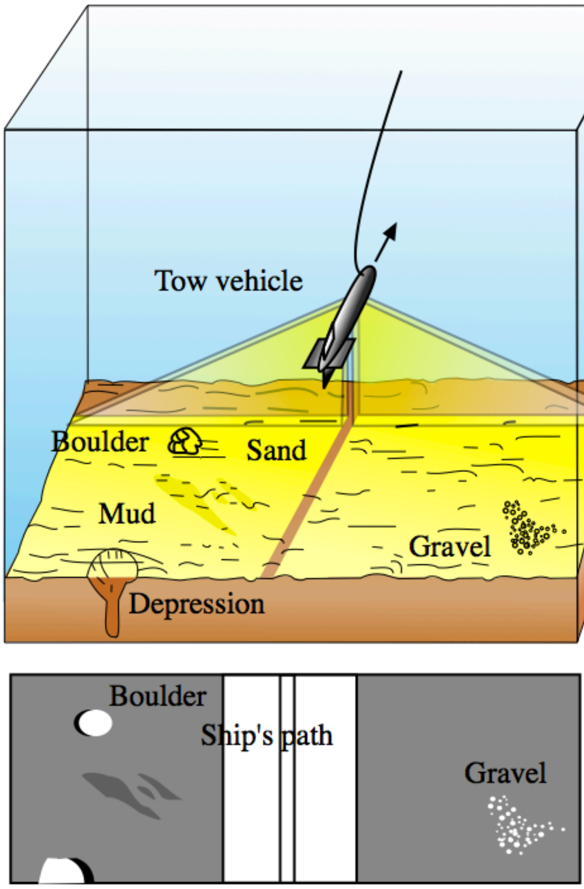

Figure 1: Side-Scan Sonar simulation.

In the picture we can see how the Side Scan Sonar gives a really good image of what the seafloor looks like, but if the interests are focused on finding persons, the Side Scan Sonar is not as useful as people think. This method is most suited for examinate and investigate objects on the seafloor and although it is also useful to find bodies, it's easy that the body goes unnoticed because of the different elements of the seafloor.

Non-underwater detection System

If a comparison between the Drowning problem and winter sports environment, is made, it's easily seen that the problem is more or less the same. When an avalanche occurs and a skier gets trapped under the snow there is a system which works perfectly in the snow in a really efficient way.

Recco

The Recco system is a cheap way to detect buried persons in the snow due to an avalanche. It consists of two parts, the reflector which is integrated in the skier clothes, boots or helmet, and the transmitter/receiver (detector) used by the rescue teams.

The operation of this system is simple: The detector transmits ultrasonic signals at one specific frequency, when a clothe reflector is hit by this signal it is reflected so the detector emits an acoustic signal. As this detector is being used by a rescue team, with the help of this sound it's easy to locate the buried body, it allows to the operators of the rescue team to go straight to the reflector position.

One of the interesting aspects of this method of person detection is that the reflector needs no batteries, it's small (50mm x 13mm) and it does not weigh more than a few grams. This charachteristics make the Recco system perfect for including the device in the skier clothes with no discomfort and without increasing excessively the price of the ski equipment.

Figure 2: Recco reflector, real scale.

Chapter 3: Technical Specifications

As seen in the two systems described before, the conclusion is that the first one is a complex and already existing method for underwater exploration and the second one is a really smart economic system for surface body detection.

The idea of this project is to develop a system that allows the rescue team to know the position of the body quickly, using the concept of the Recco system adapted to water. The Recco system doesn't work on water because the frequency used only travels in the air, snow or ice, but in a liquid medium it doesn't work.

On the other hand, the casing body will be built in plastic material using 3D printing technology, its lightness and mechanical properties make this kind of material the most suitable for the design and testing. Furthermore, the wide possibilities that offers this new technology allows to change and test the model in a really simple and economic and quick way compared to otherless modern method.

How is it going to work ?

The device is going to have three independent piezo speakers that are able to emit sound up to 6.5 kHz frequency. To start this acoustic signals, the CHRRB will have two microphones on the casing, as soon as a microphone detects a previous assigned frequency (this frequency has to be emitted by other device) the CHRRB will start giving acoustic signals for a predefined period of time. What is intended to get with this is the maximum life for the battery. In some way the working is like the Recco system but there isn't a real reflection, only a sound is transmitted to the the device and the device starts emitting an acoustic signal.

Main Specifications:

- CHRRB has to be small enough to fit in the pocket of a normal jacket.

- Water resistance. It's going to work underwater, the batteries and electronic circuitry need not to have direct contact with water.

- Good battery duration. System has to be optimized to make the battery last as much as possible.

- Economic. There's no necessity to obtain high sound quality, reliability is most important fact of the CHRRB.

- Good propagation of sound has to be guaranteed however the position of the device is.

- The construction of the body will be made with 3D printing technology.

3D printing technology

3D printing technology is a process of creating a three-dimensional object or shape designed with the help of digital software. This is achieved using an additive process, where successive layers of material are laid down in different shapes. This is possible thanks to the existing 3D printers which are computer controlled machines able to print layers of ink according to the designed model.

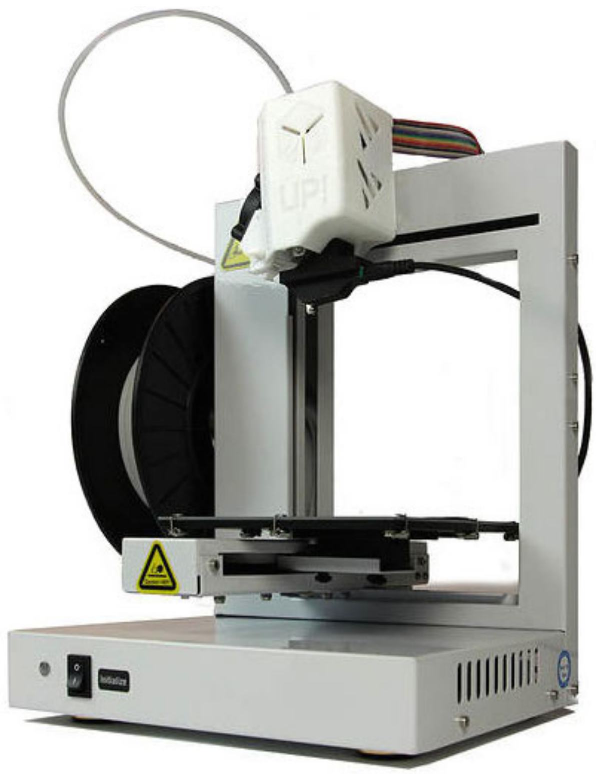

Figure 3: 3D printer used for prototyping. Model: Up! Plus.

While 3D printing technology has been around since the 1980s, it was not until the early 2010s that the printers became widely available commercially. Nowadays it is used for both prototyping and distributed manufacturing with applications in architecture, construction (AEC), industrial design, automotive, aerospace, military, engineering, dental and medical industries, biotech (human tissue replacement), fashion, footwear, jewelry, eyewear, education, geographic information systems, food, and many other fields. One study has found that open source 3D printing could become a mass market item because domestic 3D printers can offset their capital costs by enabling consumers to avoid costs associated with purchasing common household objects.

Figure 4: Examples of devices and gadgets printed using 3D printer technology.

What materials do 3D Printers use?

3D Printers can use a wide range of materials, including plastics, resins, metals, ceramics and more.

The most popular material is plastic, and most of the home or desktop style printers print objects using plastic, however some of the higher-end printers are capable of printing using many different materials.

Plastics

At the moment the majority of 3D Printers, especially the low cost systems, print using a technology called 'Fused filament fabrication (FFF)', these printers currently tend to print using one of the following materials:

- PLA (Polylactic Acid) - PLA is probably the easiest material to work with when you first start 3D printing. It is an environmentally friendly material that is very safe to use, as it is a biodegradable thermoplastic that has been derived from renewable resources such as corn starch and sugar canes.

- ABS (Acrylonitrile butadiene styrene) – ABS is considered to be the second easiest material to work with when you start 3D printing. It's very safe and strong, and widely used for things like car bumpers, or lego (the kids toy).

- PVA (Polyvinyl Alcohol Plastic) - It is used in papermaking, textiles, and a variety of coatings. It is white (colourless). It is sometimes supplied as beads or as solutions in water.

Powders

The higher end printers, can use various powder based materials to create 3D objects, these materials can include:

- Polyamide – Which is a strong and flexible material that allows a high level of detail to be achieved. Polyamide objects are constructed from a white, very fine, granular powder.

- Alumide – Is a Polyamide-like material with a distinctive sandy and granular look, that is a rigid and strong material. Alumide objects are constructed from a blend of gray aluminum powder and polyamide, a very fine granular powder.

- Multicolor – A full color material with a sandy and granular appearance. Models made out of multicolor are constructed from a fine granular powder.

Resins

Resins are also a material sometimes used in 3D Printing, although design freedom is limited due to the structure necessary to support the objects during the printing process. The following are examples of some resins that can be used:

- High detail resin - Objects made out of high detail resin are constructed from a photo polymeric liquid. This material is ideal for small and/or very finely-detailed visual models, where high detail is required.

- Paintable resin – Objects made out of paintable resin have a smooth surface and will look beautiful painted.

- Transparent resin - Objects made out of transparent resin are constructed from a hardened liquid. The material is strong, hard, stiff, water resistant by nature, and of course, transparent. Transparent resin is suited for models needing a good, smooth, quality surface with a transparent look.

Other Materials

Some metals and ceramics are also being used in 3D Printing, here are a few examples:

- Titanium – Is very light and the strongest 3D printing material available. Objects made from titanium are printed using titanium powder that is sintered together by a laser.

- Stainless steel – Object produced in stainless steel are 3D printed using a stainless steel powder that is infused with bronze material. Stainless steel is the cheapest form of metal printing, very strong and suitable for very large objects.

- Bronze – Objects produced in bronze are 3D printed in using a bronze powder that is infused with bronze. Bronze is an affordable and strong material for printing models in metal.

- Brass, Silver, Gold – Can also be used in 3D printing, although involves printing a wax mould which is then filled with the molten material.

- Ceramics – A 3D printing material that has a shiny appearance, is heat resistant, recyclable and food safe. Models made out of ceramics are constructed from alumina silica ceramic powder, then sealed with porcelain and silica and glazed. A perfect material for home decor items and tableware.

The prototypes are going to be made with plastic material, specifically ABS (Acrylonitrile butadiene styrene) because it is the material available at the Fablab which has the better end once printed. Experiences with other materials such as PLA (Polylactic Acid) are not as good as the choosen material, some small details of the prototypes are not accurate enough to have the desired finish.

Chapter 4: Protoypes.

Prototype 1

Main description:

The first prototype is focused on the sound propagation designed in a 2D plane, this means that each one of the three speakers is placed in a direction 120 º of the other. The size of the main body is the given by the measures of a 9 volt battery plus the electronic and circuitry elements, this makes an approach of the size of the device. The semisphere shown in the picture (Fig.3) is the sphere where the microphone is located, there's another one on the bottom side. These spheres what they create are standing waves inside of it, according to the formula:

$$f = \frac{c}{\lambda}$$

f = frequency [Hz]

c = medium propagation speed of sound (water = 1500 [m/s])

λ = wave length [meters]

Changing the frequency is possible to get different wave lenght, and therefore we can know the suitable size for the sphere to have standing waves inside and make the microphone detection easier.

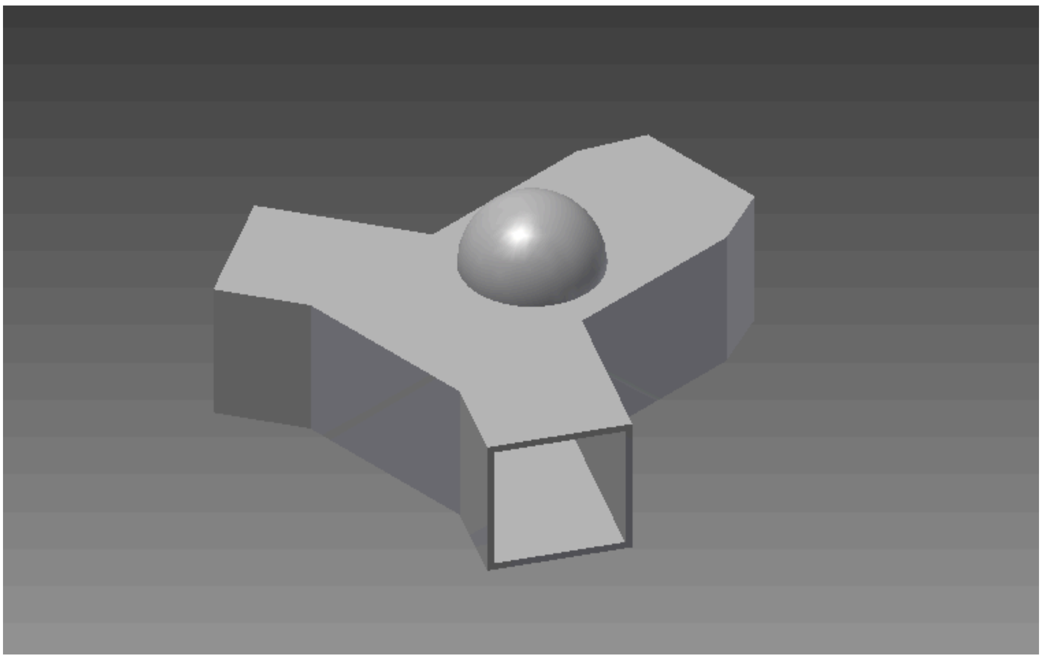

Figure 5: Prototype 1 , general view.

Specifications:

- Speakers: 3 units of 20 mm diameter piezo ceramic speakers 6400 ± 500 Hz
- Microphones: 2 units of 6 mm diameter 1,5 -10 Volt power.

Conclusions:

The idea of using the semisphere as a sound chamber is the strong point of this design, but the plane sound propagation is not suitable for this kind of application because if the device falls underwater in a bad position the sound will not be able to be trasmitted as good as wanted. This prototype needs no printing because it's not going to be used and it's only an hypotesis.

Prototype 2

Main description: This prototype is the first that is going to be printed using 3D printing technology. The design is a longitudinal body where all the items are placed along the casing with a hole on one of the sides to attach a carabiner. Batteries and electronic circuitry will be placed in a water proof chamber designed immediately below an internal semisphere which will work as a sound chamber. To have access to the battery chamber there's a one millimeter thick cover which is attached using 8 screws to the main body. The semisphere has direct contact with water thanks to two parallel conductions which go from the bottom part to the upper part (Fig.7), and it means it's full of water because it's designed to trap the sound waves and make them becoming standing waves. About sound propagation, the idea is the same that in Prototype 1, one transmitter each 120º but not in a 2D plane, this prototype introduces improvements due to a pyramidal form on the top of the casing, this is where the piezo ceramic speakers are placed, and also where the semisphere is built. The wires of the speakers go until the battery chamber passing through small holes which are sealed with special water proof sealant.

Figure 6: general view with parts.

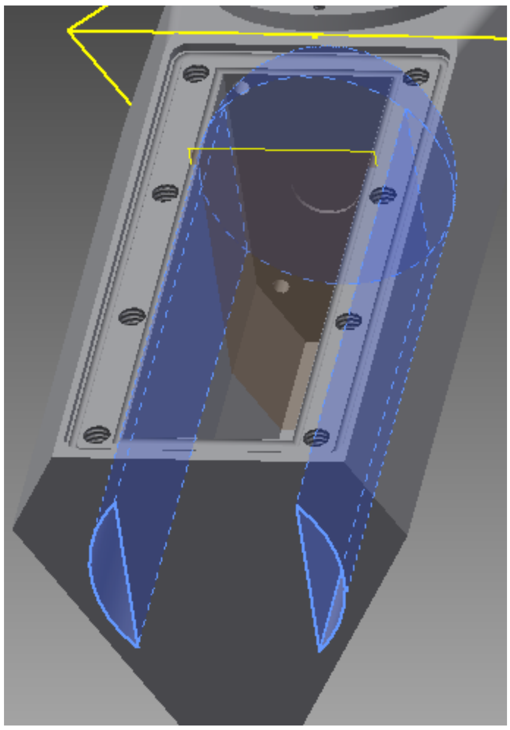

Figure 7: Parallel conductions detail.

As said on the prototype 1, the semisphere size comes given by the formula:

$$f = \frac{c}{\lambda}$$

f = frequency [Hz]

c = medium propagation speed of sound (water = 1500 [m/s])

λ = wave length [meters]

The size choosen is 30 milimeters, this means that the frequency of the waves to become standing waves are 50 KHz.

$$f = \frac{1500}{0{,}03} = 50\ KHz$$

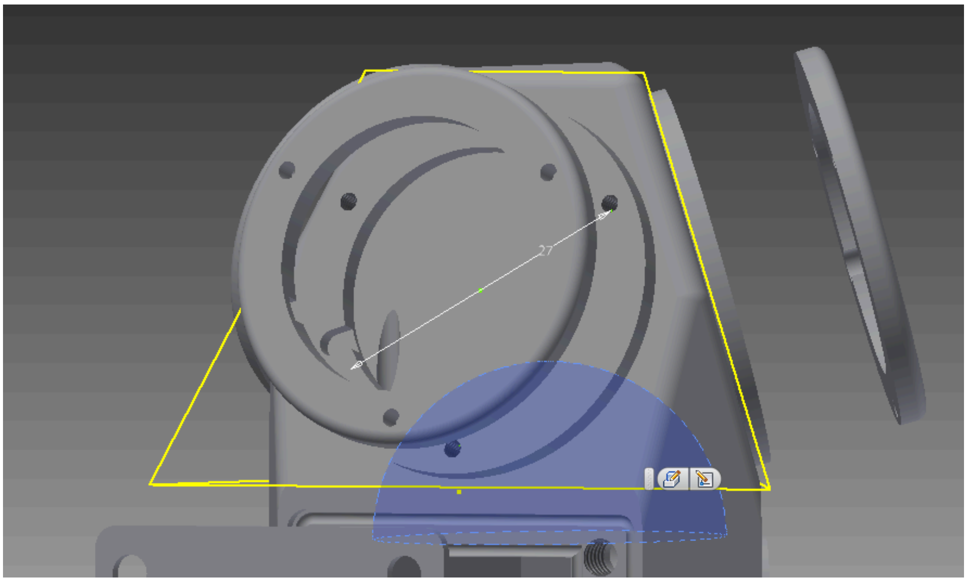

Figure 8: sphere detail.

Specifications:

- 3 units of 27 mm diameter piezo ceramic speakers 6400 ± 500 Hz.

- Microphones: 1 unit of 8 mm diameter 1,5 -10 Volt power.

- Screws: 8 units of M4x5 socket screws.

9 units of M2x10 socket screws.

-Batteries: 1 unit of 9V battery or 2 units of AA 1,5 Volt batteries.

Conclusions:

The result is quite good once printed, but the weak point and this is the one which is going to be solved in the next prototype are the protrusions. This design doesn't keep in mind the ergonomy once the device is placed in the pocket, and the upper part where the piezos are placed stand out some millimeters which is enough to tangle up with other elements. The same happens to the top cover, which is designed to be attached with eight screws but without leaving place for the heads, this issue makes that the metallic screws also tangle up with the pocket, jacket, trousers...etc.

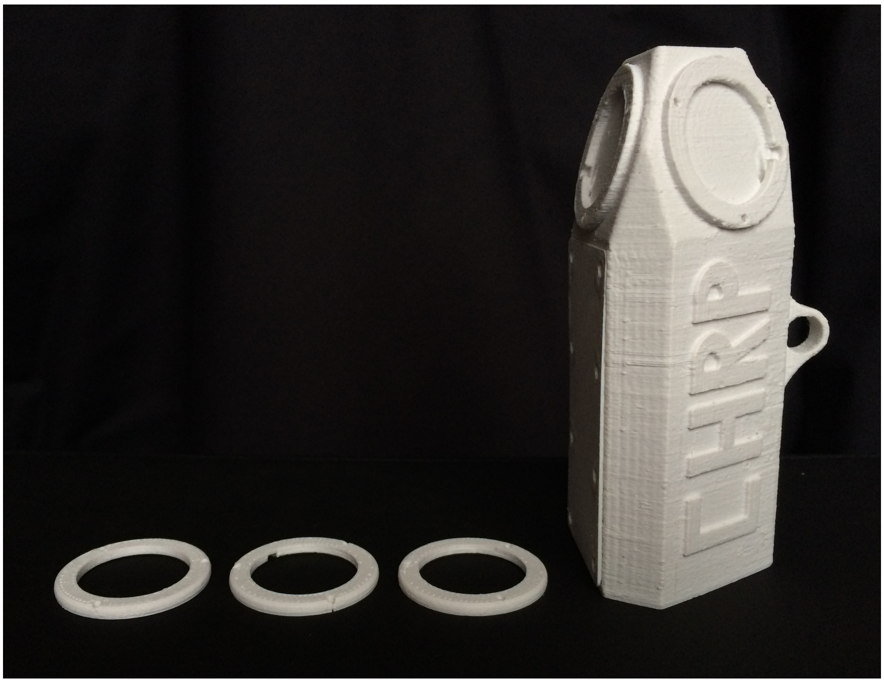

Figure 9 : General view with separate pieces.

Prototype 3

Main descripition: Prototype 3 is the second which is going to be printed. The distribution of the items along the casing is mostly the same of Prototype 2 with some modifications which improve the design, functions and ergonomy. The main changes are in the upper pyramid where the piezo ceramic elements are placed, the angle of the three sides now is smaller so the sound has a better propagation in a 3D environment such as underwater is. This also fact gives the possibility of enlarging the water proof chamber where batteries and electronic circuitry are placed, and also makes the building simpler.

Looking into the ergonomy design the changes are noticeable, the piezos places now are not standing out thanks to the smaller angle of the pyramid, the internal sphere now isn't as close to the sides of the pyramid so it exists more space between the pyramid outer sides and the semisphere (Fig.11) and it's possible to attach the piezo speaker to the casing without any protrusion as it was in Prototype 1. The hole to attach the carabiner now it's placed in one of the sides of the pyramid which is enlarged to make the water proof chamber bigger, this makes that the hole stays completely integrated in the device body. The top cover has also been modified, now it's two millimeter thicker than before (one millimiter). This increase of the thickness comes because of the addition of new countersunk screws which need a conical finish (Fig.12), so according to the choosen screw size the cone is bigger or smaller. In this case it's needed 2,3 millimiter deep of conical finish.

As said on the other prototypes, the semisphere size comes given by the formula:

$$f = \frac{c}{\lambda}$$

f = frequency [Hz]

c = medium propagation speed of sound (water = 1500 [m/s])

λ = wave length [meters]

The size choosen is 30 milimeters, this means that the frequency of the waves to become standing waves are 50 KHz

$$f = \frac{1500}{0{,}03} = 50\ KHz$$

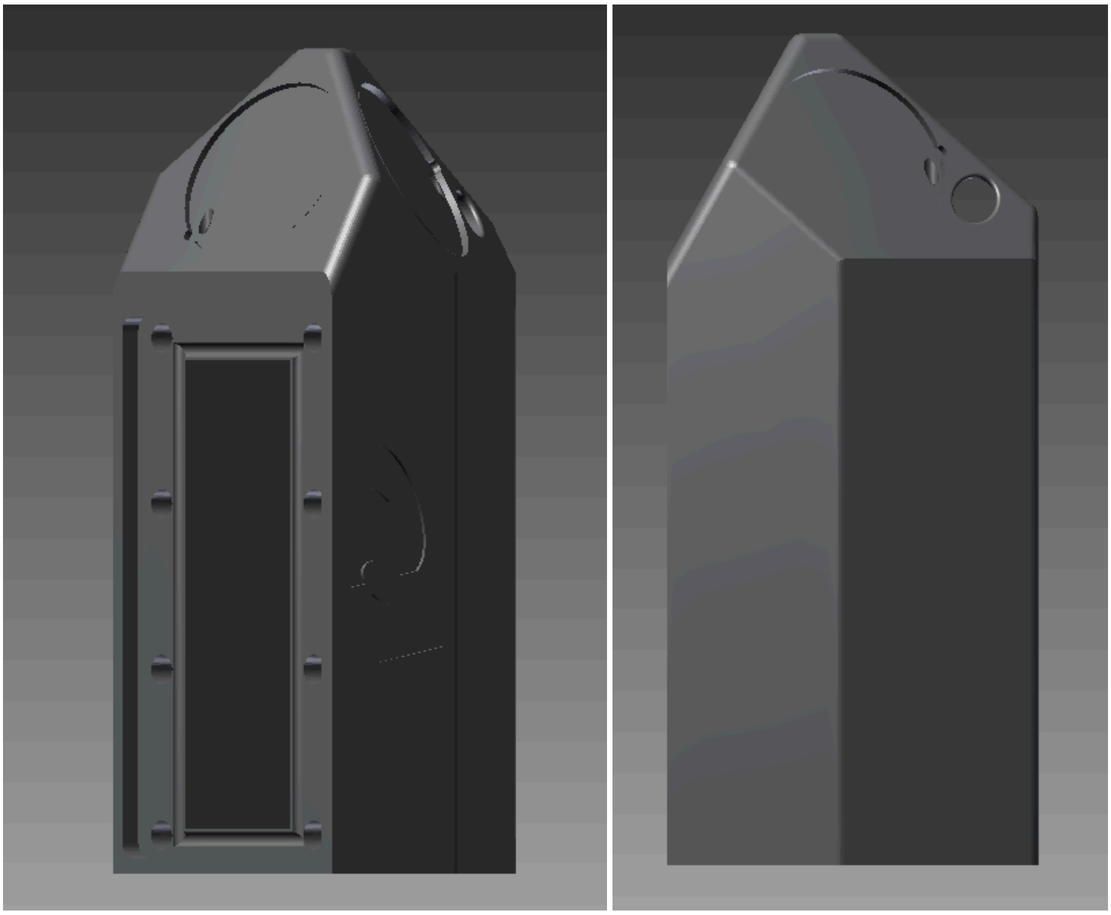

Figure 10: General view and left side view.

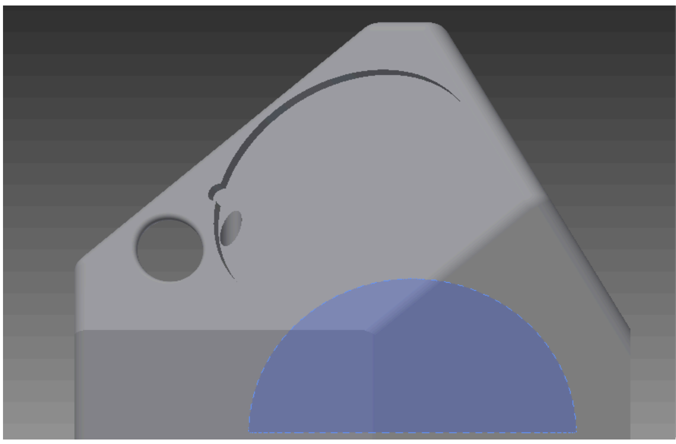

Figure 11: Sphere detail.

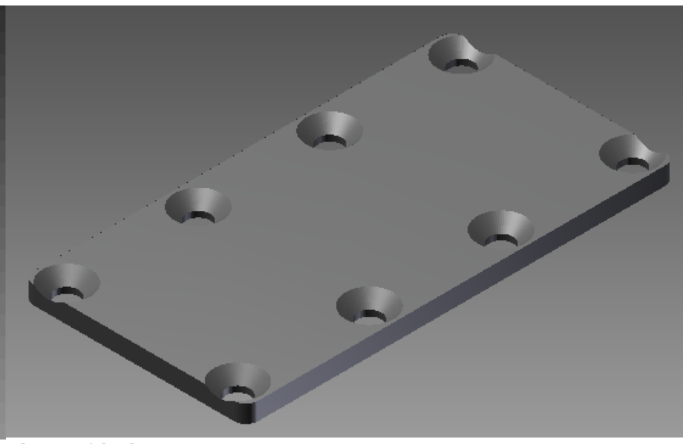

Figure 12: Capper.

Specifications:

- 3 units of 27 mm diameter piezo ceramic speakers 6400 ± 500 Hz.

- Microphones: 1 unit of 8 mm diameter 1,5 -10 Volt power.

- Screws: 8 units of M4x10 countersunk screws din 7991.

-Batteries: 1 unit of 9V battery or 2 units of AA 1,5 Volt batteries.

Conclusions:

Once printed the result was good, but the decision of optimize the water resistance and protection of electronic elements was taken, so a new internal element was designed to avoid the water better than before.

Modifications:

The modifying consists in a small case opened in one side which is placed in the battery chamber. It's slightly smaller in all dimensions and has one millimeter wall thickness to make it fit perfectly inside the small device and to allow to introduce without problems a 9 Volt battery. Although it's still necessary using rubber seals, the water would have to go through two different rubber seals to achieve contact with the protected elements. On the other hand it's also added structural resistance to the body of the case.

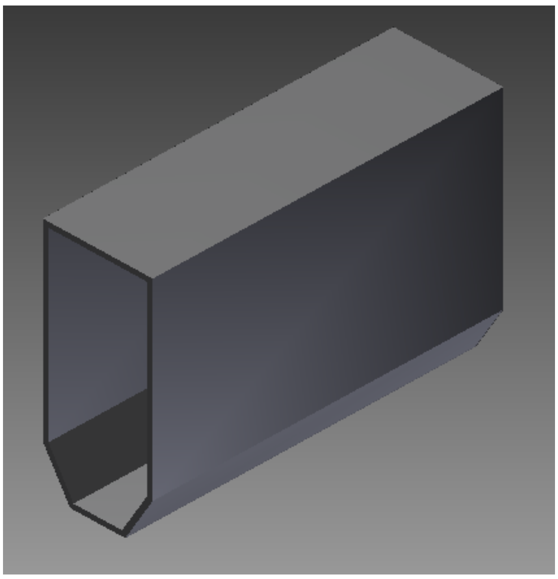

Figure 13: Internal case.

Conclusions:

With this Prototype has been achieved what was intended when Prototype 2 was printed, now there are no protrusions and no elements which can cause problems once the device is placed in a pocket or attached using a carabiner. Another remarkable aspect is the accuracy of the 3D printer with simple designs such as the internal casing of the introduced modification. This element fits perfectly in the chamber, there was no necessity of reprinting it or modify the dimensions, just design it with CAD software, print and fitted correctly, with this is meant that if the possibilities and settings and options of the 3D printer are known and the user is familiarized with them the accuracy can be really high.

Figure 14: Prototype view with the internal casing.

Prototype 4

Main description:

Prototype 4 is the last one of iterations. This design presents big changes according to the previous prototypes due to the possibility of using button cell batteries. This fact gives the chance of reducing considerably the size of the water proof chamber and therefore the total dimensions. Other aspect to comment is the suppresion of one of the three piezo elements, this allows not to use the upper pyramidal shape to transmit sound in 360 degrees and the upper part of the casing is only the outer part of the sphere used as a sound chamber.

Pyramid shaped upper part is the best choice to have a combination of optimum sound propagation and internal useful space (semispherical chamber), but using three 27 millimeter diameter piezos, the pyramid becomes too big to be used with the button cell batteries, so one piezo has been removed and the two left are now placed in both sides of the main body.

The capper has been placed in the bottom part of the body because of construction facilities. This is the best place to situate it because other four sides of the body are occupied by the CHRP logos and the two piezo speakers. Reducing the size doesn't allow to use screws like where used before, this means that to close and seal the device it will be needed to glue it, so once it's closed it's not possible to open it.

As said on the other prototypes, the semisphere size comes given by the formula:

$$f = \frac{c}{\lambda}$$

f = frequency [Hz]

c = medium propagation speed of sound (water = 1500 [m/s])

λ = wave length [meters]

The size choosen is 30 milimeters, this means that the frequency of the waves to become standing waves are 50 KHz

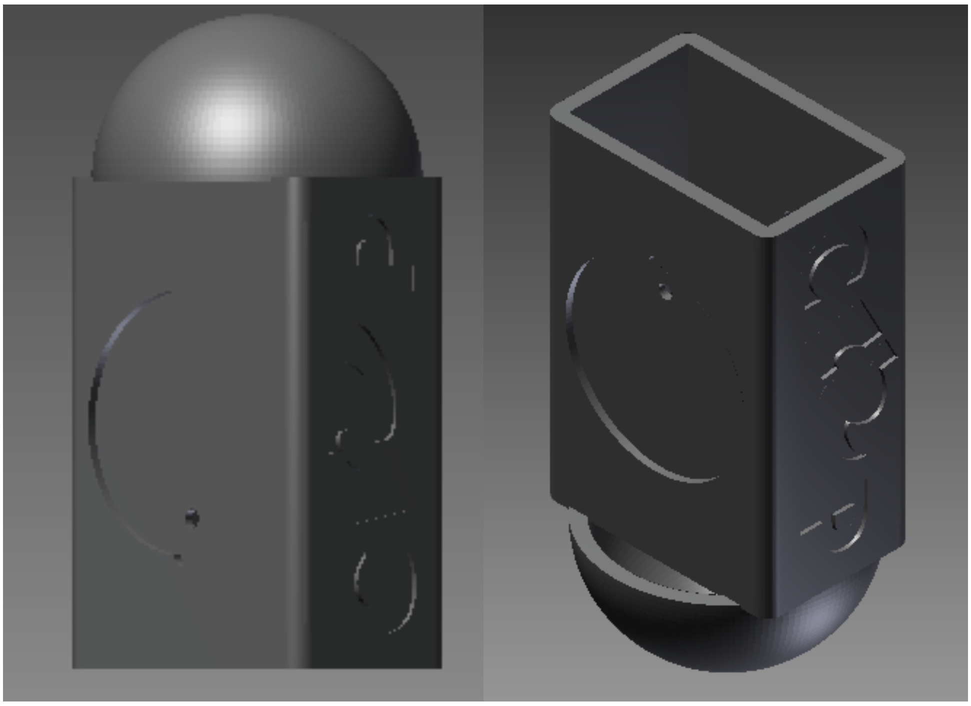

Figure 15: General view, up and bottom.

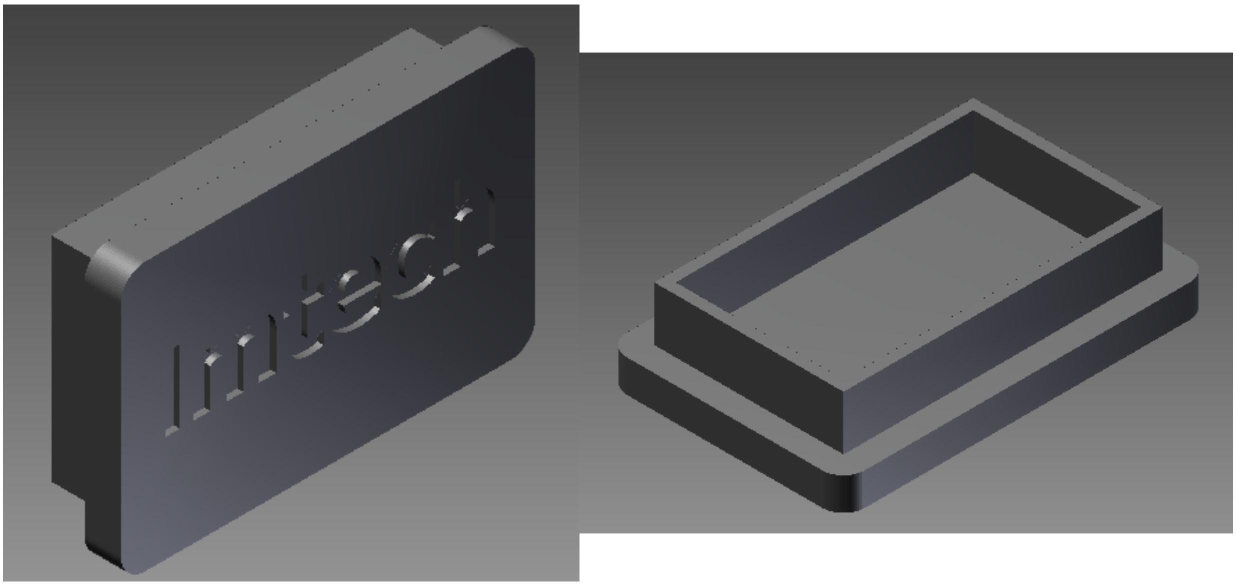

Figure 16: Capper gneral view.

Specifications:

- 2 units of 27 mm diameter piezo ceramic speakers 6400 ± 500 Hz.

- Microphones: 1 unit of 8 mm diameter 1,5 -10 Volt power.

- Batteries: 2 units of Panasonic CR 2477 button cell batteries.

Conclusions:

The size is correct, it's much smaller than the other two prototypes and it fits better in the pocket than the previous. Everyhing is simplier in this design but the principle is the same that the other ones. The weak point is the two dimension sound propagation (which is going to be modified), but to make it thinner it's necessary to take one piezo out and avoid the uncomfortable pyramidal shape. Also the non-removable capper could be a weak point, but if you take into account this is a single use device this is not a real problem.

Figure 17: Prototype view.

Modifications:

The modifying consists in the creation of a protection lattice designed to fit along the main body of the casing (Fig. 21). What this offers is strong protection for the piezo ceramic elements but without disturbing the sound propagation, furthermore to make possible the integration of this new lattice it's necessary to redesign the capper (Fig. 18). Taking advantage of this, a new piezo transmitter has been introduced to fit in this capper so now there are three sound propagation elements and the 2D sound propagation issue has been fixed (Fig.19). Also to protect this new piezo it's necessary a new protection structure, so it has also been designed a new protection lattice wich is attached to the new capper (Fig. 20). All these modifications don't really impact on the size of the device because the biggest item is the upper semisphere, and all the designs are based in the outer diameter of this.

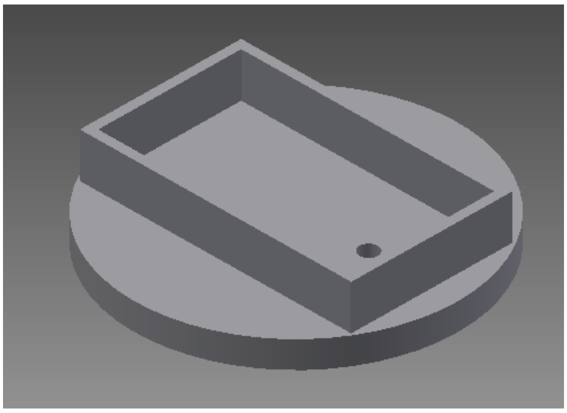

Figure 18: Modified capper, inner view.

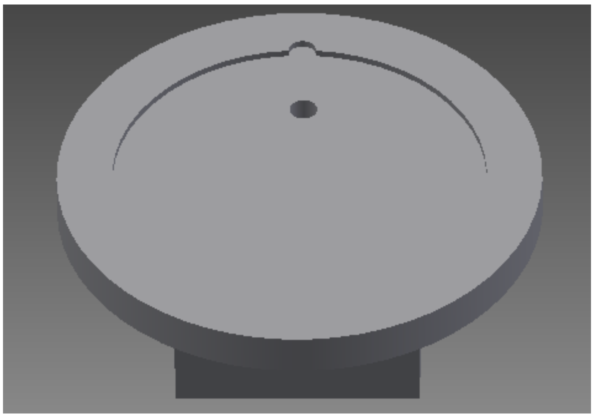

Figure 19: Modified Capper with piezo spot.

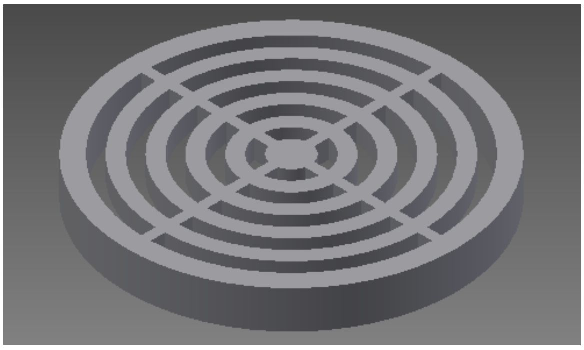

Figure 20: Bottom protection lattice.

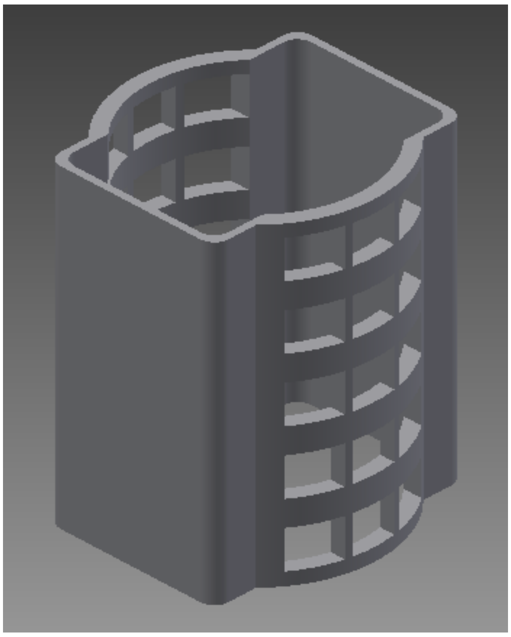

Figure 21: Main body protection lattice.

Conclusions:

The changes introduced to the prototype make this device much better than it was, the extra protection added enhances the mechanical properties of the body, such as resistance to shock and pressure. The lattice placed along the body has a 2 millimiter thickness in its circular construction, this gives the prototype more strenght to put up with some extra pressure. What we achieve introducing the third piezo is sound propagation in the direction of a perpendicular axis to the other already existing sound propagation axis.

Figure 22: General view, separate pieces.

Figure 23: Front view, complete assembled device.

Prototype 5

Main description:

The fifth prototype is a modification of the fourth one, but it's considered another prototype because the changes introduced affect directly to the shape of the body. What it is intended in this design is to create a more stylish shape.

The idea of this iteration is getting a cylindrical form with the objective of hiding the outgoing small corners of Prototype 4. To make everything fits, it's needed to oversize the semisphere. The principle is the same as before: main body with the sound chamber and battery water proof emplacement, protector lattice along all the body and the capper in the bottom with its respective protector lattice. The piezo elements are placed exactly in the same position, two in the main body and one in the bottom capper.

When the semisphere is enlarged, it happens that the frequency of the waves to become standing waves decreases, this means that this 6 millimeters difference makes a change that must be taken in account.

The semisphere size comes given by the formula:

$$f = \frac{c}{\lambda}$$

f = frequency [Hz]

c = medium propagation speed of sound (water = 1500 [m/s])

λ = wave length [meters]

The size choosen is 36 milimeters, this means that the frequency of the waves to become standing waves are 41,6 KHz

It's experienced a 8,4 KHz decrease respect the original 30 millimeters sound chamber.

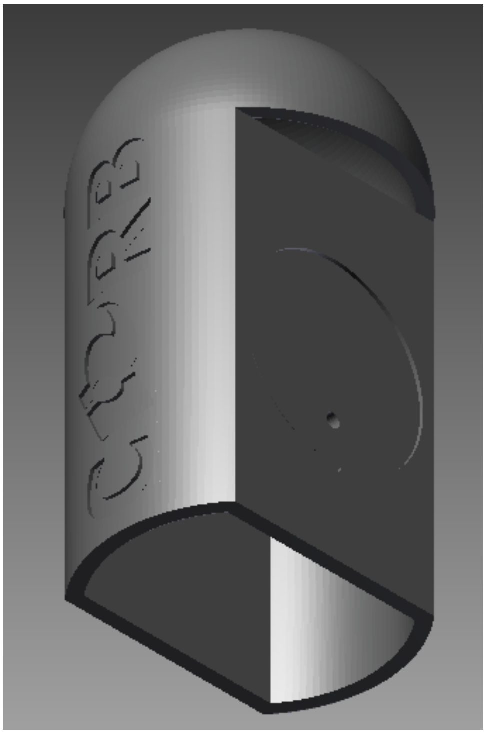

Figure 24: Prototype 5, general view

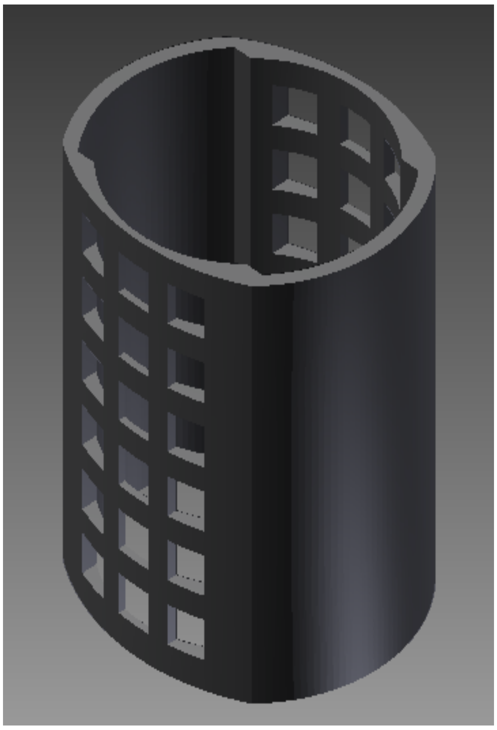

Figure 25: Protection lattice

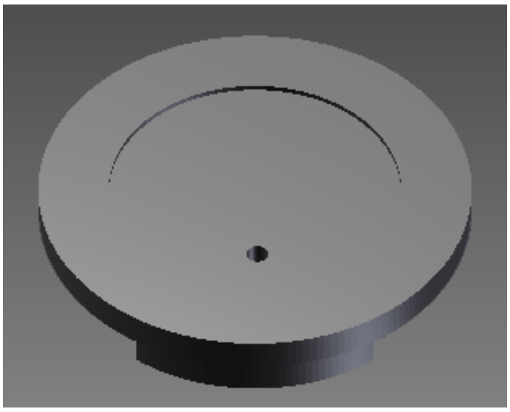

Figure 26: Capper

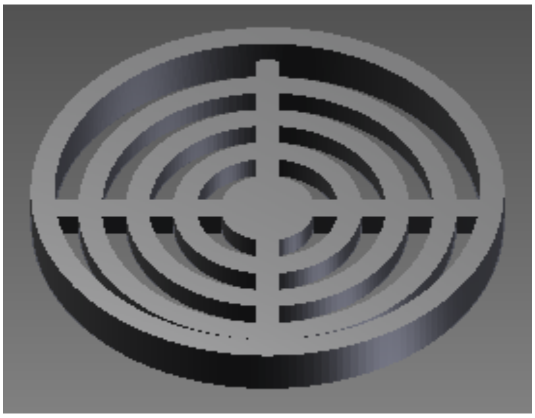

Figure 27: Bottom Protection lattice

Conclusions:

This design is a few millimeters larger than the orginal one but the shape is more elaborated. This iteration was made because of the good result of the fifth one due to the big size difference of between the first prototypes, so it was decided to improve the ergonomy trying to take out the standing out borders. The problem with this kind of modifications always result in the enlargement of the total size, this is like the eternal problem between design and practicality.

Chapter 6: Personal Experiences, Reflection and Resources.

Personal Experiences.

What I have learnt about 3D printers doing this assignment is quite a lot. First of all I would start saying the big differences existing between different materials, at the beggining I thought the result was the same doesn't matter which material was being used, but when I started to be more involved with the printers at the Stadslab I realised there are important differences between materials. Step by step I was getting a few more exigent with the final result, so I decided using ABS when possible because in my opinion this plastic gives the better product and the hardest one. I also have noticed that the same material can have better or worse quality, as seen on the prototypes, although being two of them white ABS and printed in the same printer (Fig. 3), the white colour is not exactly the same. The same happens with the final result, the one which is a bit harder has not as good finish as the other one.

But not all is about the material, the printer also has an important paper on this. At the Stadslab there are different printers to use, I always tried to use the Up Plus 2 (Fig. 3) which was the most accurate of the available devices. During the prototypes printing I also experienced problems for several times with the different plastic materials. Using the hardest ABS, I had to reprint the protector lattice (Fig. 21) four times because the machine stopped extruding ink because the continuous obstructions produced by the lower quality ink, this is what I mean when I say better or worse quality. One of the parts of prototype 3 is printed using a different material (PLA) and a different printer, it's easy to see the differences of the ended product, even having the machine set for printing at the maximum quality with the 100 % of inner parts material, which means that the printing is slower and the product is harder(Fig. 28).

And finally I would like to add the difficulty of printing an empty inner space using a 3D printer. When an empty space is left in the product design, the 3D printer software creates a really thin structural layer to support the layers that are going to be added. Once you take the product out of the printer machine, you have to manually take this small layers out, but when it exists an internal chamber, such as the semispheres which are inaccessible, it's necessary to open it and remove the structural layers, or print it in two pieces and then glue it. This are prototypes and they have this structural elements inside, but they are so thin that maybe they could work.

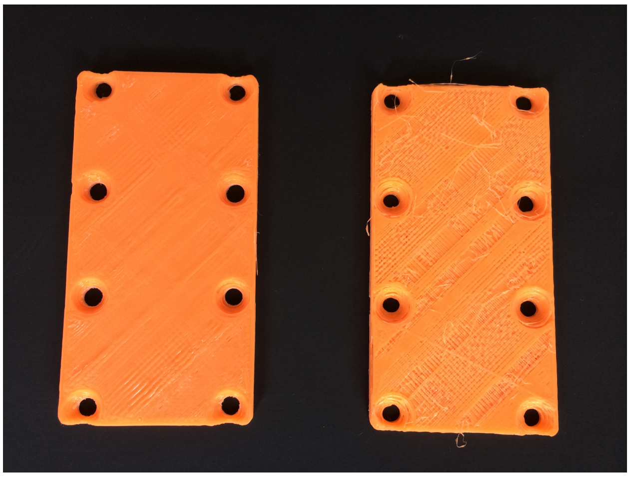

Figure 28: Prototype 3 cappers. Left : Printed with 100 % inner material and maximum quality.Right:Printed with 60% inner material and low quality.

Figure 29: Printed prototypes.

Personal Reflection.

When I arrived at the Netherlands I had never experienced contact with a 3D printer before, I knew it was happening kind of revolution with all these new technologies which were really expensive at the beginning and little by little, like happens with all the electronic and digital devices was becoming more affordable and consequently it was getting closer to the usual life and different field application such as medical, engineering or architecture use.

One of the advantages that I consider one of the main reasons for the success of this technology is the possibilty that offers us of making real something that it was only digital reality. This fact can help enormously the designing work of everybody who can handle with minimum knowledge of Computer Assisted Design (CAD). With this we achieve the privilege of being able to obtain a device/prototype and see its weaknesses and how it looks and works once it's in our hands, which is completely different to see it in your computer screen. A few years ago, this wouldn't have been possible without spending a large amount of money in the machinery set up and of course, without prototyping as easily as it is possible nowadays.

The inconvenience if we think about 3D printing technology as a possibility of mass production option is the printing elapsed time. Each prototype in this project has used an average of five hours and thirty minutes just for being printed, then you need taking out the structural plastic and the final polish to have an acceptable quality product, that gives us an approach of the printing speed, but I think this is not the aim of this technology, as said before there is no other option that allows us customizing in such a quick and easy way.

Other specific downside of this project could be the small differences between the plastic layers, if we think about the sound chamber the best result for sound would be a really smooth superficial finish, but with this process that's not possible without post treatments.

In my opinion the best option for a good mass production would be a combination of 3D printing technology and traditional plastic injection procedures. This injection with molds is defintely way faster than 3D printing technology but the introduced changes once the molds are done involve a several investment compared to 3D printer technology. It's important knowing the strong points of each technology and how to get the maximum profit of both of them putting them together, for example prototyping with the 3D printer as many times as wanted until the desired result is obtained, once it's obtained the procedure to create the machinery set up should be started.

On the other hand, and leaving apart the mass production environment, it's extremely remarkable how medical advances are becoming everyday more surprising. There's a case here in Holland that I find specially interesting: **3-D Printed Skull Successfully Implanted in Woman.** This means a huge step for medical applications and for 3D printing technology, being able to help people with this serious issues with this innovative devices gives us the point of view that this field is in constant development and it seems that it's going in the good direction, unless nothing strange like different laws for the interest of a few people are imposed.

Finally I would like to give special thanks to my project manager and advisor Kees Pieters who has helped me and given ideas about possible designs and changes to be introduced in the prototypes.

Resources.

Wikipedia, Side Scan Sonar - http://en.wikipedia.org/wiki/Side_scan_sonar

Wikipedia, 3D printing technology - http://en.wikipedia.org/wiki/3D_printing

Drowning persons in the netherlands - http://www.metaldec.nl/eng/drowning_victims.html

Stratasys, materials - http://www.stratasys.com/materials

What materials do 3d printers use ? - http://www.3dprinterhelp.co.uk/what-materials-do-3d-printers-use/

Recco - http://www.recco.com/