6 LiDAR Casing

(Jennifer Lee and Claire Chen)

6.1 Introduction

(Jennifer Lee and Claire Chen)

The LiDAR is a remote sensing device that sends out lasers to measure the distance between itself and possible objects. This is useful in ensuring that our sailboat is able to detect objects and maneuvers around them as needed. However, the LiDAR sensor may not be 100-percent water resistant/water proof, and the model implemented in our boat, the LightWare SF11, will probably be splashed and surrounded by water. Therefore, it needed a casing around it that would allow the connection to two servo motors to rotate the sensor in the YZ and XY directions while providing a water-tight barrier.

6.2 Preliminary Design

(Jennifer Lee)

6.2.1 Design Constraints

(Jennifer Lee) The most prominent design constraint of the LiDAR sensor box is the need for waterproofing. Stationed at the front of the boat, on deck, it is the component that experiences the most contact with the water after the ballast and the hull. Especially due to its need to be wired, the LiDAR sensor box should be 100% watertight. However, the need for visual feedback requires a transparent shelter for the sensor. This extra layer of material causes visual distortions which increases inaccuracies in measurements. Other design constraints include the dimensions of the LiDAR sensor as well as the manufacturability. The dimensions are important due to the location of the LiDAR sensor, the front and top of the boat. This means that there will be a slight imbalance of weight, thus compelling us to keep the box light. Additionally, the deck also tapers towards the ends, which requires the base of the LiDAR sensor box to be within those constraints. Addressing the manufacturability of the box, the necessity of wiring within the mechanism, requires quick installment and uninstallment for multiple testing, not only for the physical dimensions and workability, but also the software and calibration testing. This means that each of the two servos and the sensor should be easily adjustable and accessible.

6.2.2 Design Goals

(Jennifer Lee)

When creating this design, we referenced the previous design, a 3D-printed box, with an acrylic front that spun on a thrust ball bearing and tilted with a paperclip mechanism. This design also was heavily sealed with epoxy and tape. We found that this design was highly inefficient in its movement (did not coordinate well with the servos), but fairly cheap. The mechanism also had a tendency to jam and break.

To address these issues, the ultimate priority for designing the new sensor box was achieving easy and accurate movements when panning and tilting. Another high priority was waterproofing, as mentioned in the aforementioned section, as the component with the most exposure to water other than the hull and the ballast despite its use of electronics, waterproofing is a required design condition. Some other sub goals were durability and affordability. When creating and ideating these designs, we looked at some common designs as a reference.

6.2.3 Design Overview

(Jennifer Lee)

The initial designs were inspired by three different previously existing devices. The first was the security camera design, the second was the well-loved Star Wars character, R2D2, and the last device is the web camera. Some of the reasons why these were the one of the best designs to model off of was their known efficiency when panning and tilting.

6.2.4 Design 1: CCTV, Security Cameras

(Jennifer Lee)

Overview:

When looking at the movement of a classic security camera, we see that the joints are not contained. Both the panning and tilting were external. See Figure 61 for initial sketches of how the LiDAR sensor would be incorporated within this. Note that the sketches are not updated, see manufacturing plan for more details.

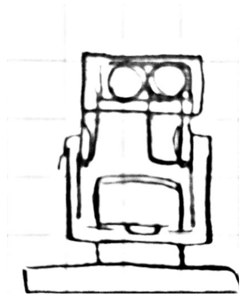

Figure 61: Sketch of security camera, CCTV design

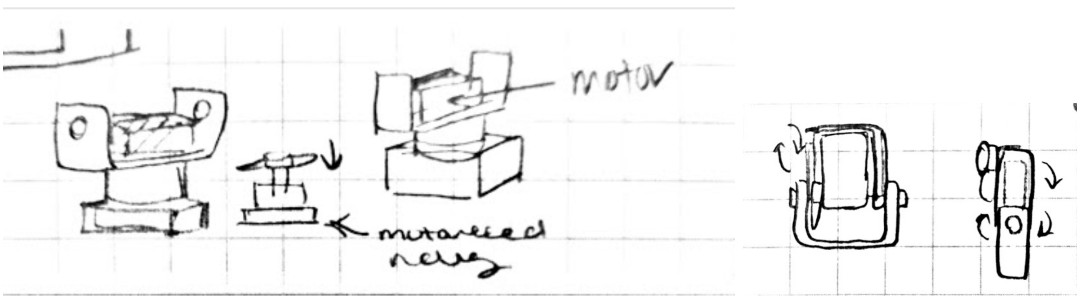

Figure 62: Sketch of internal mechanisms detailing rotation and wiring

Manufacturing Plan:

In order to manufacture this, it would mainly be composed of cut aluminum sheets and u channels (See Figure 62). There would be many sub components including screws which would require repeated testing and adjusting. Table 5 organizes potential purchases for this design.

Table 5: Hypothetical Table of Purchased Parts Design 1

Material	Approx. Quantity*	Approx. Total Cost**
Aluminum U-Channel	1/2 foot	$4
Aluminum Sheet	1 ft^2	$4
Vinyl/Plastic covering	1 roll	$20
Silicone Sealant	1	$8
Total	-	$36

*note that all of these dimensions are approximations

**note that all of these prices are approximations based on McMaster-CARR or Amazon

Problems:

Due to the exposed wiring and joints, waterproofing is the biggest issue. In order to waterproof, it would either be silicone sealant or a plastic covering, much like a raincoat. However there are several issues to this design. First and foremost, the amount of outward facing and exposed parts. Sealing the entire mechanism with a vinyl/plastic sheet with silicone sealant, does not allow easy accessibility nor installment/uninstallment. The amount of small parts and joints increases the difficulty of manufacturing. Furthermore, the wrapping of the wires around the exposed components can cause tangling and even more difficulty when replacing any electrical component.

6.2.5 Design 2: R2D2

(Jennifer Lee)

Overview:

Next is the R2D2 inspired design. Due to R2D2's rotating "head" in the XY plane and self-balancing body in the X-Z plane, it is easily applicable to the LiDAR sensor box (See Figure 63). This iteration showcases a Lazy-Susan like ball bearing system with the first servo which rotates in the XY plane. The YZ plane, much like R2D2, is through the legs of the mechanism (See Figure 64). Note that the sketches are not updated, see manufacturing plan for more details.

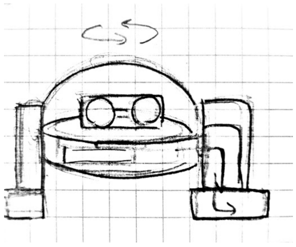

Figure 63: Sketch of R2D2 inspired design

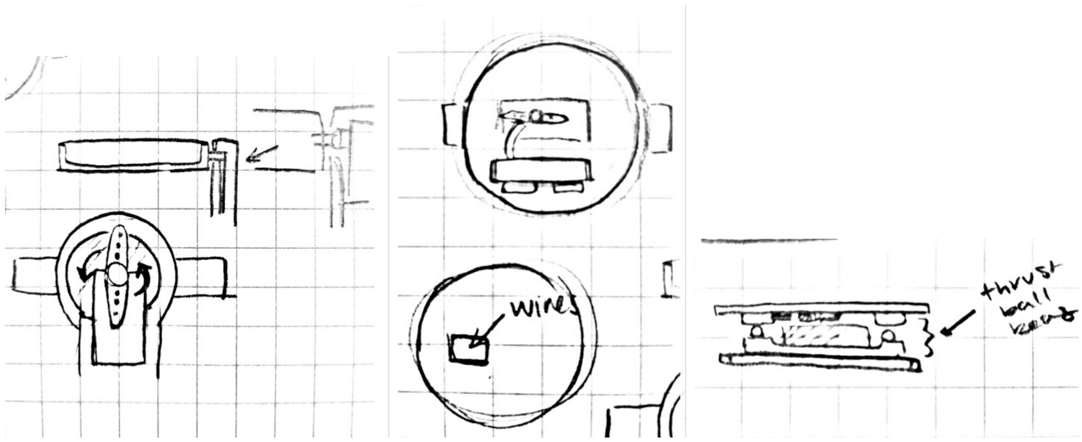

Figure 64: Sketch of internal mechanisms detailing rotations and wiring

Manufacturing Plan:

When manufacturing this, there is no easy way to create a clear plastic dome. However, getting a pre-manufactured, ready-made fishbowl as a top works. A sleeve ball bearing which has a rod threaded through that connects itself to the top plate and the micro servo would create the XY plane rotation. For the YZ planar rotation, there will be a hollow central axle (to allow the inner wires to run through it) that connects itself to the servo, through a skate bearing, under the plate (with adequate supports), and through another ball bearing on the other side. The wiring will be through the two hollowed-feet like structure. To further this design, it is possible to add a weight to the bottom of the head-like component so that the LiDAR itself can self balance. This iteration gets rid of any risk of any water infiltration with the use of ball bearings and tight axles. Table 6 organizes potential purchases for this design.

Table 6: Hypothetical Table of Purchased Parts Design 2

Material	Approx. Quantity*	Approx. Total Cost**
Fishbowl 4"	1	$5
Aluminum Sheet	1 ft^2	$4
Aluminum Circular Tube	1/2 ft	$5
Skate Ball Bearings	3	$15
Total	-	$29

*note that all of these dimensions are approximations

**note that all of these prices are approximations based on McMaster-CARR or Amazon

Problems:

Some issues to this design are the highly complex moving parts. With 3 skate ball bearings the amount of moving parts can become an issue in trouble shooting and manufacturing. Although much can be achieved through epoxying, there still can be easy slippage between the moving parts. Additionally within these issues, the parts to this design are highly customized. This often results in a reliance on 3D printing or machining difficulty and constant dimensional adjustments. Another issue that was brought up was the dome-like surface. With a transparent dome-like material, it may concentrate light through the refraction and create a fire hazard. If not a fire, it will cause overheating within the electrical parts which drastically reduces the lifespan of the parts and may cause unexpected errors.

6.2.6 Design 3: Web Cameras

(Jennifer Lee)

Overview:

Finally the web camera design. This design is fairly similar to the previous design however the rotation locations are switched (See Figure 65). This design focuses has the YZ planar rotation in the head of the device and the XY rotation on the bottom (See Figure 66. Note that the sketches are not updated, see manufacturing plan for more details.

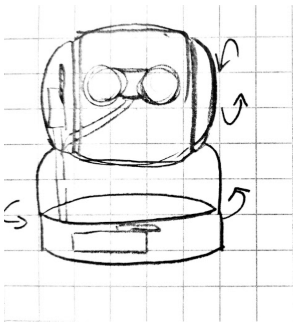

Figure 65: Sketch of R2D2 inspired design

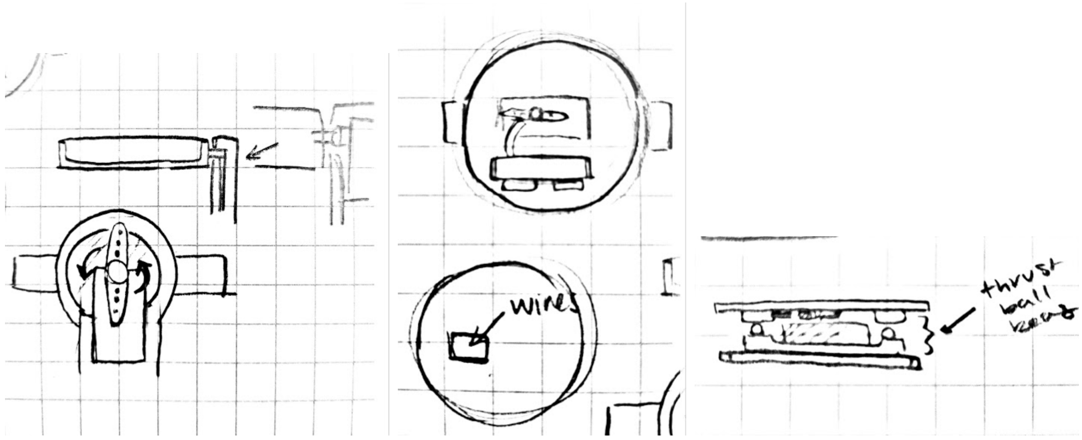

Figure 66: Sketch of internal mechanisms detailing rotations and wiring

Manufacturing Plan:

In order to manufacture this design, there would be an acrylic window for the LiDAR sensor which would be encased in a sort of cube hinged on a sleeve ball bearing on either side, with an hollowed central axle through the cube. Within this cube, there will be a weight on the bottom that would naturally balance the LiDAR sensor. Continuing on the aforementioned axle, the axle will be connected to the first servo which rotates in the YZ plane. The hollowed axle will allow the wiring of the LiDAR to be sent into and under the deck. The component that connects the head to the bottom bearing can be any sort of shape as long as it can hold the wires safely within it, such as a hollowed tube; this component is very flexible. This component would be attached to a disc of whatever shape, which would be centered and attached to another sleeve ball bearing where there would be a central rod attached to the second micro servo which would rotate in the XY plane. The use of sleeve ball bearings allow control from a further distance, allowing the electronic parts to be further from any crevices or weak points in the waterproofing. Unlike the last design, it is a flat acrylic window and thoroughly protected against any harmful refractions Table 7 organizes potential purchases for this design.

Table 7: Hypothetical Table of Purchased Parts Design 3

Material	Approx. Quantity*	Approx. Total Cost**
Acrylic Sheet	36 in^2	$5
Aluminum Sheet	1 ft^2	$4
Aluminum Circular Tube	1/2 ft	$5
Skate Ball Bearings	3	$15
Total	-	$29

*note that all of these dimensions are approximations

**note that all of these prices are approximations based on McMaster-CARR or Amazon

Problems:

Although the distancing allows water resistance to a certain degree, connecting and manufacturing all these smaller parts require great precision and a lot of customization. Once again this design requires a lot of smaller moving parts with the three sleeve ball bearings that are hidden. Due to workload, Jennifer Lee passed this to Claire Chen to work on it for the rest of the semester.

6.3 Current Design

(Claire Chen)

6.3.1 Current Iteration Overview

The design includes a round plate that connects to a servo underneath, allowing it to rotate in the XY direction. On the round plate, there is a rectangular hole to fit and secure another servo allowing the sensor to turn up and down as necessary. The thick bottom part is a hollow area that allows for any subsequent wiring to fit in cleanly. Lastly, the top frame is to be fitted with clear acrylic plates and sealed with silicone.

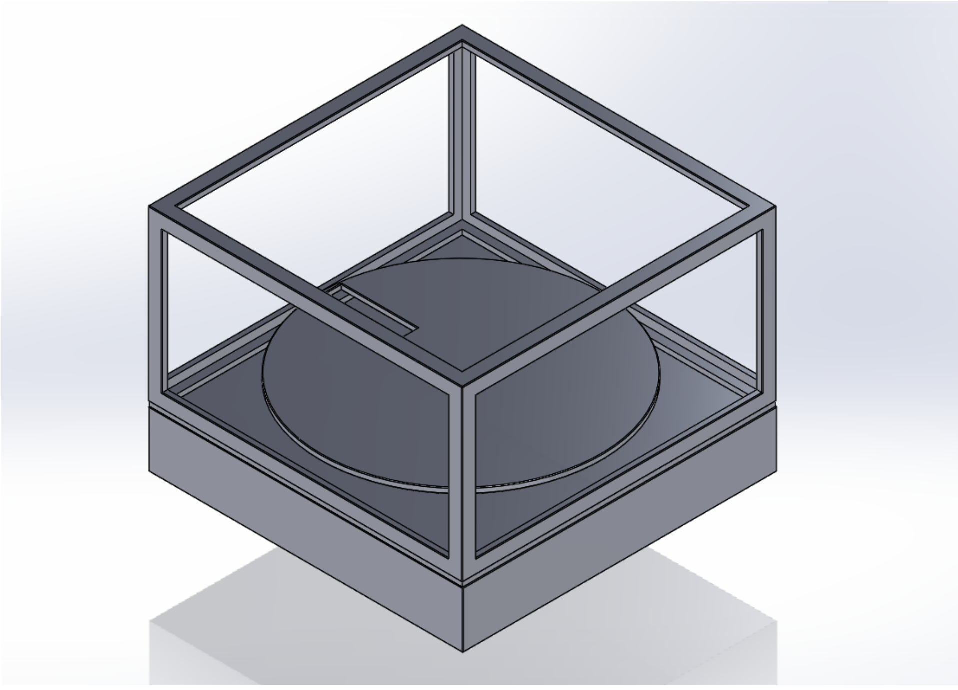

Figure 67: LiDAR Casing Design

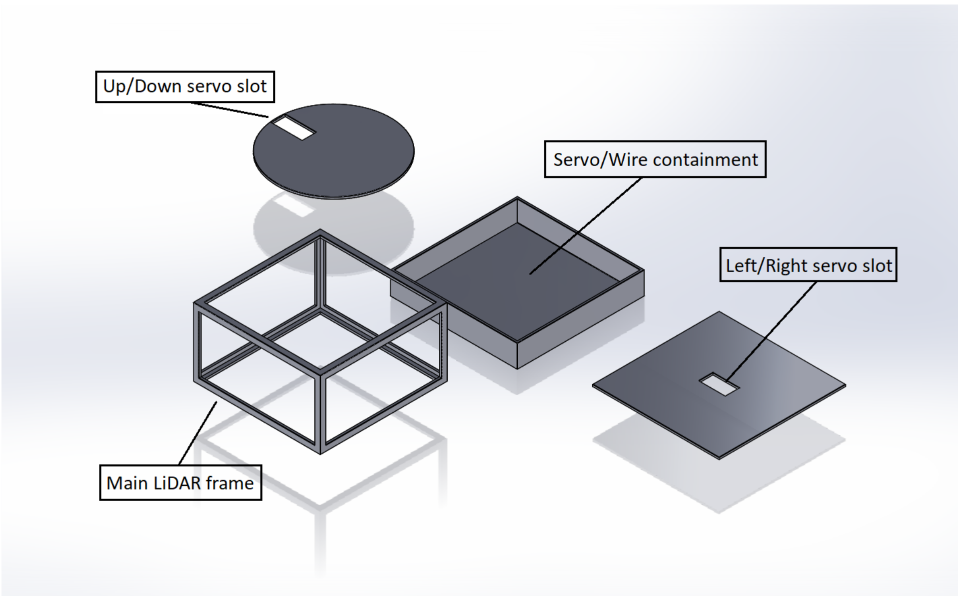

Figure 68: LiDAR Casing Exploded View

6.3.2 Parts

Part	Part Num	Quantity	Total Cost
Acrylic Sheets, 1/16" x 6" x 12"	8560K178	1	$2.75
Silicone Sealant	-	1	$8.00
Anti-Fogging Spray	-	1	$8.55
Micro Servos	169	2	$11.90

Total Estimated Cost: $31.20

6.3.3 Future Plans

(Claire Chen and Jennifer Lee)

Due to manufacturing and fabrication cut short, future plans include the fabrication, testing, and integration of this design. With those steps taken, the design will be appropriately altered to fit the function. Currently with this design, the sensor rotates inside the box frame. However, this design has to be tested to ensure that the frame does not cause any issues with object detection. Should it be an issue, one possible solution would be to have the whole frame rotate along with the sensor. Another issue that might arise is the fogging of the acrylic plates – in which case, either another material needs to be used or the plates need to be prepped with anti-fogging spray before assembly.

Overall, more testing needs to be conducted to determine the efficacy of the design.

Additional ideas for this mechanism that could be incorporated into future discussion is the use of self-stabilizing in the YZ planar rotation with the use of weights, much like a roly-poly toy or a camera stabilizer. The design can also incorporate a gyroscope for more accurate calibrations. Due to the importance of simplicity and functionality, we were not able to add complex structures.