# Pacific Garbage Patch

# Final Proposal

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# EXECUTIVE SUMMARY

The Pacific garbage patch team aims to simulate cleaning up the Great Pacific Garbage Patch. This will be accomplished with an autonomous solar powered boat, which uses a grabber to pick up ping pong balls and stores them in a container. The team used the customer requirements from the client to generate concepts. The team weighted to concepts based on importance to the design. The customer requirements were then used to create engineering requirements. The engineering requirements selected had targets and tolerances for those targets. The capstone team selected the testing procedures from 1-8. The group created a house of quality to organize the customer requirements with the engineering requirements. Thereafter, the team looked at existing designs to create new ideas. The team researched each sub component of the design of the existing designs. This included the Ocean CLEANUP, which is currently picking up plastic in the ocean. The team also looked at RC boat designs. We also looked at autonomous cars. The team then created a functional decomposition using a black box model and a functional model/work-process diagram/hierarchical task analysis to better organize the project. The team then broke down the project into subsystems for the existing designs. The team then selected the design with provided rational. The rational includes a decision matrix for the entire project in addition to pugh charts for some subsystems. The design is then described in detail. The team created a proposed design.

# ACKNOWLEDGEMENTS

The group tremendously appreciates the guidance of Dr. Trevas through design improvements. The team also has received great assistance in improving aspects of our design by Brandon Begay through his experience.

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# 1 BACKGROUND

## *1.1 Introduction*

In the pacific ocean, there are tons of plastic garbage floating throughout the water. This project requires the team to develop a model of a device that cleans up the Great Pacific Garbage Patch. The garbage patch damages the ecosystem in the Pacific ocean. The plastic is an issue for multiple reasons. The plastic when consumed, endangers the wildlife. This translates to affecting humans. When the wildlife is consumed, the "garbage" is then consumed as well. The objective of the project is to create an autonomous boat that collects ping pong balls in water to model a larger future device. This project sponsor, Dr. Trevas, wants the device to recognize where the ping pong balls are located and pick them up autonomously, with solar panels in order to negate the need for charging. This project is important to simulate the test concept in order to pick up plastic autonomously in the Pacific Garbage Patch. Through this project, we hope to model a device that may autonomously clean up the garbage, restoring the oceans ecosystem for the future.

## *1.2 Project Description*

The Pacific Garbage Patch Cleanup team is creating a device that simulates the cleanup of the Great Pacific Garbage Patch. The group will collect ping pong balls in a pool of water using a solar powered autonomous boat, with a camera to locate the plastic. The grabber will transfer the balls to on board the boat, into a container.

## *1.3 Original System*

This project involved the design of a completely new aquatic plastic collector. There was no original system when this project began.

# 2 REQUIREMENTS

The client for the Great Pacific Garbage Patch cleanup gave the team customer requirements. The team used this information to create engineering requirements. These requirements were combined to form the house of quality.

## 2.1 Customer Requirements (CRs)

The customer requirements are general requirements from the client. The sponsor gave the team 12 main requirements for the design. The complete system must meet these requirements as well as the individual subsystems of the boat, grabber, navigation, solar power, and camera detection. Each requirement is weighted on the importance of the requirement. The objective is to make a autonomous device to collect plastic in an effective and fast process using solar power. As the goal is to aid the oceans ecosystem in recovery, the requirement to not damage the ecosystem is weighted as a quarter of the requirements. The customer requirements are summarized in Table 1.

**Table 1:** Customer Requirements

| Customer Requirement | Weight |
|---|---|
| 1. Doesn't damage ecosystems | 25 |
| 2. Autonomous | 20 |
| 3. Solar Powered | 20 |
| 4. Collects 20 ping pong balls | 5 |
| 5. Sensors | 10 |
| 6. Effectiveness | 10 |
| 7. Fast | 5 |
| 8. Waterproof | 5 |

## 2.2 Engineering Requirements (ERs)

The customer requirements were used to create the engineering requirements. The team applied the qualitative customer requirements and turned them into quantitative engineering requirements. All of the customer requirements were taken into account, with the requirements receiving the most weight were the most influential in creating the targets and tolerances in the engineering requirements. The group selected each engineering requirement target and tolerance specifically, with the input from the client. The tolerances are roughly 1/10-1/5 of the target value. The engineering requirement relating to reliability and durability is the useful life in years. All engineering requirements use metric units. Each engineering requirement has certain targets and tolerances as seen in Table 2.

**Table 2:** Engineering requirements

| | Engineering Requirement | Mass (kg) | Plastic removal (%) | Power (W) | Velocity (m/s) | Plastic collection (pieces/day) | Useful life (years) |
|---|---|---|---|---|---|---|---|
| Target(s) | | 20 | 90 | 50 | 10 | 200 | 5 |
| Tolerances(s) | | 5 | 5 | 5 | 5 | 25 | 1 |

## 2.3 Testing Procedures (TPs)

Through measurements and/or trials, the team will test the engineering requirements ensuring we meet the client's requirements. With the decided upon subsystems products, necessary power and total weight of the system may be calculated (TP #1 and TP #2). As the velocity is dependent primarily on the motor, once a power efficient motor has been chosen, the speed of the decided motor may be tested (TP #3). Once the system is constructed, the plastic removal may be tested with the effectiveness of device (TP #4). Using the effectiveness of the detection as well as the speed of the boat, the plastic collect per day may be modelled (TP #5). Once the device is finalized, the lifetime of the device may be modelled factoring in the effectiveness of the solar cells (TP #6).

## 2.4 House of Quality (HoQ)

The house of quality combines the customer requirements and engineering requirements. Each customer requirement is weighted by importance. The intersection of the customer and engineering requirements are given a correlated score. A higher score indicates the requirements are more correlated. The numbers are tallied up in the absolute technical importance with a higher number indicating more importance. The relative technical importance gives the lowest score to the most important engineering requirement.

The weights range from 5-25. The most important customer requirement is that it doesn't damage the ecosystem with a weight of 25. The most important engineering requirement is the power with a absolute technical importance of 445 and relative technical importance of 1. This indicates that each subcompent of the design must focus directly or indirectly on energy efficiency. All of the data is shown in Table 3 below.

**Table 3**: House of Quality

| House of Quality (HoQ) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Customer Requirement** | **Weight** | **Engineering Requirement** | Mass (kg) | Plastic removal (%) | Power (W) | Velocity (m/s) | Plastic collection (pieces/day) | Useful life (years) |
| 1. Doesn't damage ecosystems | 25 | | | 9 | 1 | | 9 | |
| 2. Autonomous | 20 | | | | 9 | | | 3 |
| 3. Solar Powered | 20 | | 3 | | 9 | 3 | | 6 |
| 4. Collects 20 ping pong balls | 5 | | | 9 | 3 | | 9 | |
| 5. Sensors | 10 | | | 6 | 3 | | 9 | |
| 6. Effectiveness | 10 | | | 3 | | | 3 | 1 |
| 7. Fast | 5 | | | | 3 | 9 | 3 | |
| 8. Waterproof | 5 | | 9 | | | | | 6 |
| **Absolute Technical Importance (ATI)** | | | 105 | 360 | 445 | 105 | 405 | 220 |
| **Relative Technical Importance (RTI)** | | | 5 | 3 | 1 | 6 | 2 | 4 |
| **Target(s)** | | | 20 | 90 | 50 | 10 | 200 | 5 |
| **Tolerances(s)** | | | 5 | 5 | 5 | 5 | 25 | 1 |
| **Testing Procedure (TP#)** | | | 2 | 4 | 1 | 3 | 5 | 6 |

# 3 EXISTING DESIGNS

This section discusses existing designs that are applicable to this project. Each design has a component that is required to meet the needs in the house of quality. There are not any autonomous boats out on the market that clean up trash. However, RC boat can work autonomously when the team provide the other components that will be discussed further in the report. Meanwhile, this section will discuss design research and system level of our design.

## 3.1 Design Research

The team used The Ocean CLEANUP to get ideas for our project. The benchmark study will help create an autonomous prototype that could be used to help clean up the Pacific Garbage Patch. The Ocean

CLEANUP uses ocean currents to passively clean the plastic, while the prototype is an active system. The active system might be better for certain areas of the garbage patch.

## *3.2 System Level*

There are several designs that satisfy different requirements for the design. This include The Ocean CLEANUP, RC Boats, and Autonomous cars. Each design satisfies different parts of the requirements. The Ocean CLEANUP is the most applicable design on the market, that will help us to clean up the Great Pacific Garbage Patch. The team is using this design as inspiration on how to make our product better. It is the main component cleaning up the plastic. The RC boat will probably be used as the vehicle on the water to find the trash. The features in the autonomous car will be used to modify the RC boat in order to change it to a fully autonomous boat. The autonomous features must identify the location of the ping pong balls, go over to them, pick them up in the boat, and then dump it in a specific location.

### 3.2.1 Existing Design #1: The Ocean CLEANUP

The Ocean CLEANUP was just launched into the Pacific Ocean to clean up plastic. This system uses ocean currents to passively pick up trash in the ocean. The device is a 600m long floater that goes 3m underwater [2]. The goal is to capture 50% of the plastic in just 5 years and 90% by 2040 [2]. The four steps are capture, accumulation, extraction, and landing. This design has minimal negative impact on the ecosystem. A picture of the design is displayed in Figure 1.


**Figure 1**: The Ocean CLEANUP [1]

### 3.2.2 Existing Design #2: RC Boat

There are numerous RC boats purchasable today. The models vary in designs and dimensions. The popular designs are speed boats and catamarans. Though the catamaran is better balanced and often larger than the speed boat design. Each model draws different amounts of power and travels at different speeds. The power and speed is determined primarily by the motor and thus independent of the boat design. The RC allows the boat to change speed and direction. The team needs to choose a boat that has a dedicated place to store the plastic. There also needs to be a set location for the solar panels. Some examples are shown in Figure 2 below.

**Figure 2**: RC Boats

### 3.2.3 Existing Design #3: Autonomous Car

Autonomous cars are being tested on the road. None of them have received approval to be fully autonomous. The cars uses sensors throughout the vehicle. It senses the road conditions, speed of the car, the distance and speed of other cars, traffic signals, and much more. The Tesla autopilot system is the most famous in Figure 3. The features include eight surround cameras provide 360 degrees of visibility around the car at up to 250 meters of range. Twelve updated ultrasonic sensors complement this vision [3]. Some have claimed that this software is safer than human drivers.

**Figure 3**: Tesla Model 3 with Autopilot [3]

## *3.3 Functional Decomposition*

The functional decomposition helps the team organize the design into different functions based on inputs and outputs. The functional decomposition aids the team to develop all the necessary parts to create boat the picks up ping pong balls autonomously. This includes the black box and functional models shown 3.3.1 and 3.3.2.

### 3.3.1 Black Box Model

The black box model depicts the inputs and outputs needed for this project depicted in Figure 4. In this case it is used for the autonomous garbage clean up boat. The inputs are the trough grabber and ping pong balls, solar energy and camera. These inputs correspond to the storage, electrical and mechanical energy, and navigation respectively. For example, the trough grabber is used to pick up the ping pong balls and dispense them into the storage. Solar energy powers the boats electrical and mechanical energy. The camera helps the autonomous clean up boat identify the ping pong balls through navigation

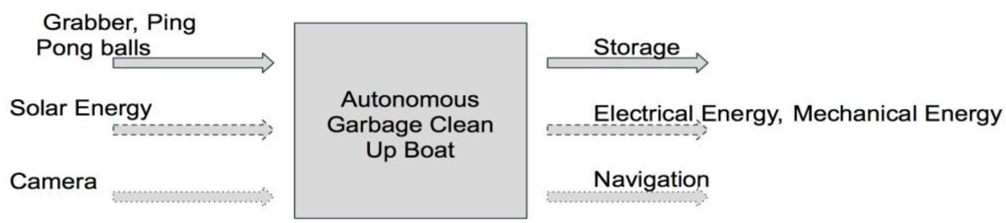


**Figure 4**: Black Box Model

### 3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

The functional model breaks down the black box in step by step method. Functional model shows the process of the design and how it should works based on the tasks that the team needs to accomplish in Figure 5. The figure above shows that the solar panel plays a significant role in this design by providing energy to the device and is stored in a battery. The energy is transformed to mechanical energy, which powers the plastic grabber. Some of the energy in the battery turns into electrical energy powering the sensor to locate the ball. Thermal camera helps the device to identify the ping pong ball so the grabber can collect it. Meanwhile, since the solar energy generates mechanical energy, the boat moves due to the mechanical energy.

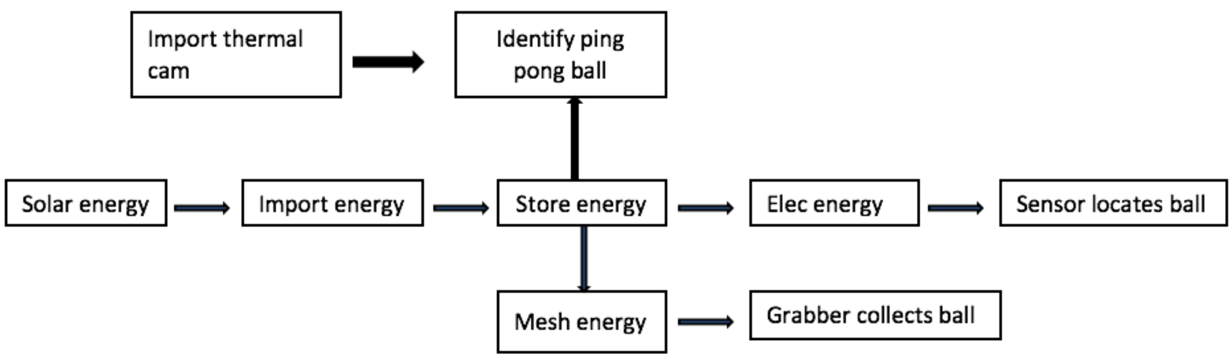


**Figure 5**: Functional Model

## 3.4 Subsystem Level

The total design consists of multiple subsystems in order to complete specific tasks. These include a grabber to collect the ping pong ball from the water, a sensor to identify the ping pong balls, and navigation to accurately move the boat to the ping pong ball.

### 3.4.1 Subsystem #1: Grabber

The grabber is the mechanism that collects the trash out of the ocean. This design picks up ping pong balls in a swimming pool for the simulation. One end of the grabber is attached to the boat. The other end goes into the water and grabs the ping pong balls and places them in the boat. All of the designs must use solar power. The three main designs are the trough, arcade claw, and ice cream scooper.

#### *3.4.1.1 Existing Design #1: Front Loader Bucket*

The front loader bucket is often used with construction equipment in order to scoop and transfer material. This design can carry various materials with different weight, density and volume. This design will be applied for a water draining trough. The water draining trough can collect plastic, while its mesh design allows for water drainage. This design allows microorganisms to move through the mesh, while the larger animals can swim away. This design has minimal effect on the aquatic ecosystem.

#### *3.4.1.2 Existing Design #2: Arcade Claw*

The arcade claw is used in arcades around the world. The most common is the three prong design. It can collect different materials including stuft animals, and jewelry. This tool is effective in collecting different material shapes with the prongs. The arcade claw picks up the ping pong balls just like it picks up items in a arcade game. Though to capture the ping pong balls, it needs to drop down at the right location and angle. The claw drops the ball into the boat faster than the trough. It does not damage the ecosystem provided that the tips of the claw are soft.

#### *3.4.1.3 Existing Design #3: Ice Cream Scooper*

An ice cream scooper function is to scoop spherical pieces of ice cream. The ice cream scoop shape and size is similar to ping pong balls. The scooper can collect ping pong balls in the same way ice cream is scooped. The spherical shape is perfect for capturing ping pong balls. However, there is no drainage for water or small microbial life. This design collects too much water and puts it into boat, possibly sinking it.

### 3.4.2 Subsystem #2: Sensor

A sensor is used to identify and locate the ping pong balls.

#### *3.4.2.1 Existing Design #1: Thermal Camera*

Using the temperature of the ping pong ball against the water to identify the object. plays an important role for our project. thermal camera will be used to detect the ball in the swimming pool and we are going to use it to find the signal of the ball and the the signal will show in the camera , so we find the exact location for the ball. by the thermal camera we can see what our eyes cannot, so we can find the spot of each ping pang ball in the swimming pool easily. by using the thermal camera we can save the time and find all the spots of each ball. one of the most important benefit that the group notices in the thermal camera, that the team can look for the ball even in the night because during that time the camera will truly shine, so based on the customer requirements the team decided to go with the thermal camera until they notice that there are a better camera can support the project more than the thermal camera.

#### *3.4.2.2 Existing Design #2: Capacitive Sensor*

Registers the type of plastic in order to identify the ping pong ball. Also it's designed for plastic detection and provides accurate level detection in the plastic industry. This type of sensor might be very useful to our design. Capacitive sensor works by measuring in an electrical called capacitance.

#### *3.4.2.3 Existing Design #3: POV Camera*

POV Camera is a shortcut of (Point of View Camera) it's one type of digital camera , this kind of camera designed to captured the scene in front of anyone use it. its small camera, so most of people who like sports use it , because it is can attach in the helmet and hat.

### 3.4.3 Subsystem #3: Boat

The boat subsystem contains and has each of the other subsystems mounted on it. It is the body of the device and acts as the storage of the plastic.

#### *3.4.3.1 Existing Design #1: Speed Boat*

The speed boat contains a sleeker body to allow for faster and more agile movement. These allow for quicker movements using a motor to navigate.

#### *3.4.3.2 Existing Design #2: Catamaran*

The catamaran is a wider and thus more balanced boat. The increased balance allows for better distribution of the other subsystems to ensure no submerging. The catamaran is also equipped with a motor to navigate.

#### *3.4.3.3 Existing Design #3: Sail Boat*

The sail boat has a sleeker body allowing for more agile movements in the water. The boat uses air currents with its sail to navigate.

# 4 DESIGNS CONSIDERED

Using the existing subsystem designs, the team used combinations of them to create total designs. These designs are considered for the final product. The four main designs are listed in section 4. The remaining six designs are listed in Appendix C: Alternative Designs.

## *4.1 Design #1: Trough Grabber with Electric Motor and Thermal Camera*

This design, shown in Figure 6, combines the best of each subsystem and puts it together. The solar powered electric motor powered the thermal camera. This camera identifies the location of the ping pong balls. The automated system tells the electric motor to drive the boat over to the balls. The trough grabber goes into the water and scoops up the balls and puts them in the plastic storage area of the boat.

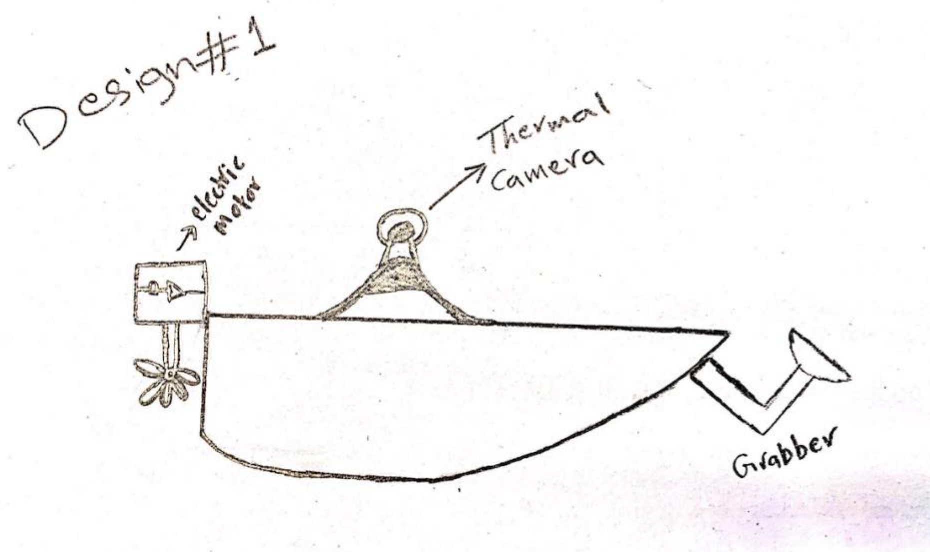


**Figure 6**: Design #1

Pros

- Collects more plastic
- Durable
- Effective
- Easy Operation

Cons

- Cost

## 4.2 Design #2: Arcade Claw with Capacitance Sensor and Rudder

The arcade claw with the capacitance sensor and rudder is one of the designs considered depicted in Figure 7. The rudder is a great way to steer the boat towards the trash. However, the arcade claw cannot collect the small pieces of trash. The plastic grabbed by the claw is easily dispensed into the boat.

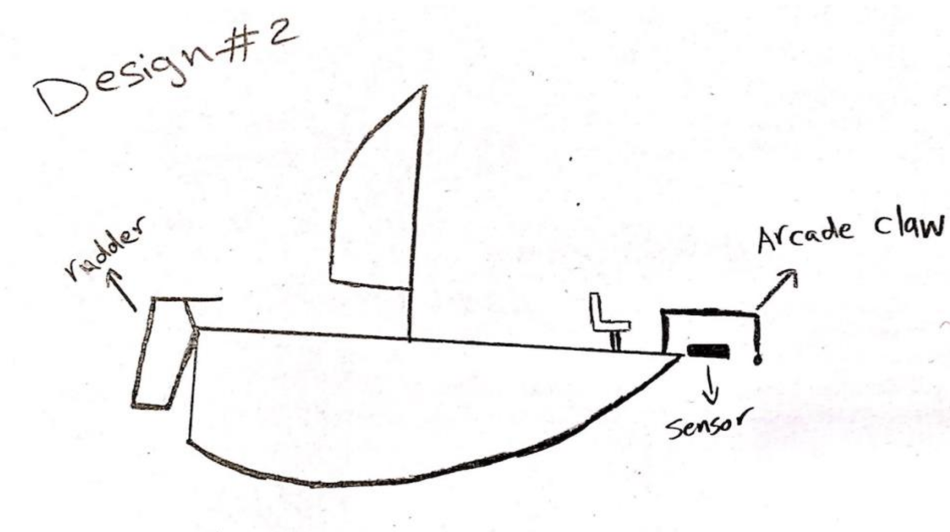


**Figure 7**: Design #2

Pros

- Easy to maneuver
- Releases plastic into the boat

Cons

- Arcade claw cannot collect small pieces of plastic

## 4.3 Design #3: Ice Cream Scooper with POV Camera and Oar

The ice cream scooper with POV camera and Oar is not as functional as other designs as seen in Figure 8. The ice cream scooper damages the ecosystem by killing small microorganisms. Yet, it does the best job collecting the smallest pieces of plastic.

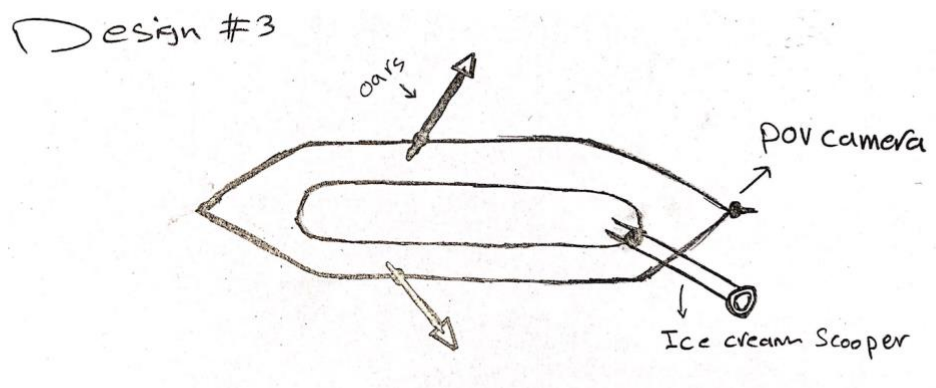


**Figure 8**: Design #3

Pros

- Collects the smallest pieces of plastic

Cons

- Ice cream scooper damages the ecosystem
- Grabber collects too much water
- Slow steering and movement

## *4.4 Design #4: Reach grabber with the Iphone camera and sail*

This design is the datum design in Figure 9. Overall it is a poor design. It is cheap to manufacture and run. It is easy to release the plastic into the boat. However, the Iphone camera is easy to scratch without protection

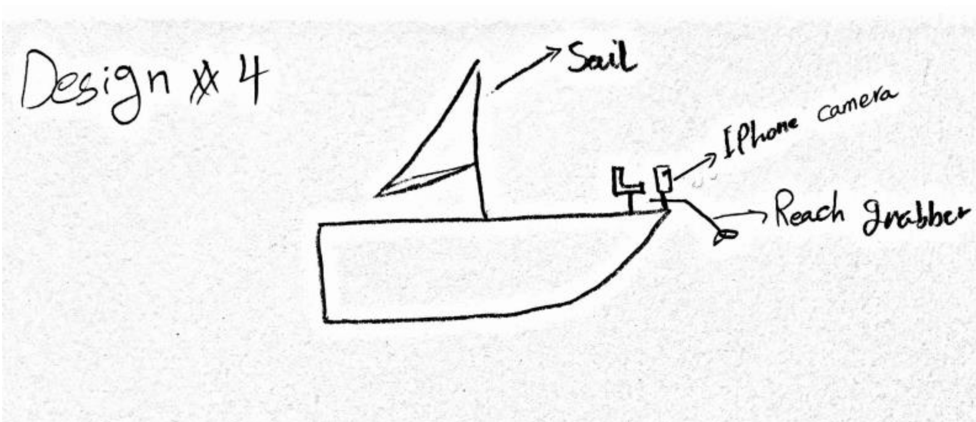


**Figure 9**: Design 4

Pros

- Cheap
- Fast release into the boat

Cons

- Camera can scratch
- Sail does not work in low winds

- Cannot grab small pieces of plastic

# 5 DESIGN SELECTED – First Semester

The team needed to choose a final design. The team used a decision matrix and multiple pugh charts to help with this process. This design needed to satisfy the customer needs, engineering requirements, and receive the best score for each component on the pugh charts.

## *5.1 Rationale for Design Selection*

The team selected Design #1: Trough grabber with electric motor and thermal camera. The group used a decision matrix to compare each subsystem to the customer requirement criteria to select this design as seen in Table 4. The team lowered the weights compared to the house of quality. The scores are shown on a 1-5 scale. The highest number is the most important subsystem. Furthermore, some subsystems have a pugh chart as a tool to help select the best design depicted in Tables 5-7. Design #1 scored the highest on the pugh charts.

**Table 4**: Decision Matrix

| | | Camera | | Solar Panels | | Grabber | | Boat | | Navagation | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Criteria | Weight | Score (1-5) | Weighted | Score (1-5) | Weighted | Score (1-5) | Weighted | Score (1-5) | Weighted | Score (1-5) | Weighted |
| Doesn't damage ecosystems | 5 | 1 | 5 | 1 | 5 | 5 | 25 | 5 | 25 | 3 | 15 |
| Durable | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Portable | 1 | 2 | 2 | 1 | 1 | 4 | 4 | 4 | 4 | 2 | 2 |
| Picks up trash down to 5 mm in length | 1 | 1 | 1 | 1 | 1 | 5 | 5 | 1 | 1 | 1 | 1 |
| Waterproof | 3 | 5 | 15 | 5 | 15 | 3 | 9 | 5 | 15 | 5 | 15 |
| Solar powered | 3 | 3 | 9 | 5 | 15 | 3 | 9 | 3 | 9 | 2 | 6 |
| Sensors | 3 | 5 | 15 | 4 | 12 | 2 | 6 | 1 | 3 | 5 | 15 |
| Cheap | 1 | 4 | 4 | 3 | 3 | 2 | 2 | 4 | 4 | 2 | 2 |
| Fast | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 | 2 | 2 |
| Safety | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 4 | 4 | 1 | 1 |
| Effectiveness | 3 | 5 | 15 | 4 | 12 | 5 | 15 | 2 | 6 | 3 | 9 |
| Easy operation | 1 | 2 | 2 | 1 | 1 | 5 | 5 | 1 | 1 | 2 | 2 |
| Total | | 35 | 75 | 32 | 72 | 45 | 91 | 38 | 80 | 33 | 75 |

The decision matrix compares the customer requirements, labeled criteria, with the different components of the design. The criteria is weighted on a scale of 1-5. The group determined that each component was very important. The weighted scores ranged from 72-95.

**Table 5**: Grabber Pugh Chart

| | | Design Concepts | | | |
|---|---|---|---|---|---|
| Criteria | Weight | Trough grabber with holes | Arcade claw | Ice cream scooper | Reach grabber |
| Doesn't damage ecosystems | 5 | (+) | S | (-) | DATUM |
| Durable | 1 | (+) | S | (+) | DATUM |
| Portable | 1 | S | S | S | DATUM |
| Picks up trash down to 5 mm in length | 1 | (+) | (-) | (+) | DATUM |
| Waterproof | 3 | S | S | S | DATUM |
| Solar powered | 3 | S | S | S | DATUM |
| Sensors | 3 | S | S | S | DATUM |
| Cheap | 1 | (-) | (+) | S | DATUM |
| Fast | 1 | (-) | (+) | (-) | DATUM |
| Safety | 1 | S | S | S | DATUM |
| Effectiveness | 3 | (+) | (-) | S | DATUM |
| Easy operation | 1 | (+) | (-) | S | DATUM |
| Total + | | 5 | 2 | 2 | |
| Total S | | 5 | 7 | 8 | |
| Total - | | 2 | 3 | 2 | |
| Overall Score | | 3 | -1 | 0 | |
| Weighted Overall Score | | 9 | -3 | -4 | |
| Rank | | 1 | 2 | 3 | |

The grabber pugh chart compares and contrasts the grabber component of the design. The customer needs are labeled criteria, and given a weight of 1-5, just like the decision matrix. The design with the highest +, overall score, and weighted overall score s the best design. This is the trough grabber with water drainage holes.

**Table 6**: Sensor Pugh Chart

| | | Design Ideas | | | DATUM Design |
|---|---|---|---|---|---|
| **Criteria** | **Weight** | **Thermal camera** | **POV Camera** | **Capacitive Sensor** | **IPHONE Camera** |
| Doesn't damage ecosystems | 5 | S | S | S | DATUM |
| Durable | 1 | (+) | S | S | DATUM |
| Portable | 1 | S | S | S | DATUM |
| Easy to find garbage | 3 | S | S | S | DATUM |
| Waterproof | 3 | (+) | (+) | (+) | DATUM |
| Solar powered | 3 | S | S | S | DATUM |
| Sensors | 3 | S | S | S | DATUM |
| Cheap | 1 | (-) | (-) | (+) | DATUM |
| Fast | 1 | S | S | S | DATUM |
| Safety | 1 | S | S | S | DATUM |
| Effectiveness | 3 | (+) | (-) | (-) | DATUM |
| Easy operation | 1 | S | S | S | DATUM |
| **Total +** | | **3** | **1** | **2** | |
| **Total -** | | **1** | **2** | **1** | |
| **Total S** | | **8** | **9** | **9** | |
| **Overall Score** | | **2** | **-1** | **1** | |
| **Weighted Overall Score** | | **6** | **-1** | **1** | |
| **Rank** | | **1** | **3** | **2** | |

The sensor pugh chart weights the criteria on a 1-5 scale to judge the design ideas. The thermal camera gets the best scare for total +, overall score, and weighted overall score. The worst design is the POV camera which receives the most - score.

## *5.2 Design Description*

The pacific garbage patch cleanup team is creating a device that simulates the cleanup of the Great Pacific Garbage Patch. Our device breaks down to 5 main components; RC boat, solar panels, grabber, thermal camera, and motors. The main goal is to collect 20 ping pong ball from a pool of water using these components. The device should indicates the balls by using thermal camera and collect them by the grabber. The boat is powered by the solar cells, which they are located on the top of the boat to gain power from the sun and store and generate it to the boat. Furthermore, the balls that are collected will be stored in a container in the boat. For the motor, we would replace the RC boat motor with a slower motor to let the solar cells gain enough power and to collect the ping pong ball. Since the team is working with the thermal camera, we removed the navigation from the design since it would not be as efficient as the thermal camera. The assumptions and calculations are listed in Appendix E: Assumptions and Calculations. The ping pong ball has a diameter of 4cm and a mass of 2.7grams. The volume is 33.51cm^3 for one ping pong ball.

# 6 PROPOSED DESIGN – First Semester

The team bought the RC boat, thermal camera, hinges, and solar panels. The team will create an initial prototype of the trough grabber and beam using MakerBot in the Cline Library at Northern Arizona University. The team will fabricate the final trough grabber and beam using ABS plastic from the 3D printers at Northern Arizona University. The autonomous features will first be simulated with arduino. After that, we will write the software. The software will direct the boat to detect when a ping pong ball is near the boat. The boat then drives over the ball using the solar powered motor. The grabber then lifts up the ball and drops it into the storage container using an additional smaller electric motor. The goal is to collect 20 ping pong balls. The team will make physical and operational changes when the design fails to meet the requirements. The team will test each component to make sure it meets the customer and engineering requirements. A bill of materials lists the quantity, description, function material, dimensions, cost, and link to cost estimate in Appendix D: Bill of Materials.  The current budget is $1500. The actual expenses is low because there will be unanticipated expenses in the future. The team created a detailed schedule listing the week, start date, agenda item, and assignments due for next semester depicted in Table 7.

**Table 7**: Detailed Schedule

| ME 486C - ME Capstone Spring 2019 Tenative Schedule | | | |
|---|---|---|---|
| Week | Start Date | Agenda Item | Assignment Due |
| 1 | 1/14 | Team/Staff Meeting | Final Proposal Rewrite and Individual Post Mortem |
| 2 | 1/21 | Team/Staff Meeting | |
| 3 | 1/28 | Team/Staff Meeting | Website Check 1 |
| 4 | 2/4 | Progress Presentation | |
| 5 | 2/11 | Team/Staff Meeting | |
| 6 | 2/18 | Hardware Review 1 | HR1 Summary and Peer Eval 1 |
| 7 | 2/25 | Team/Staff Meeting | Individual Analysis II |
| 8 | 3/4 | Team/Staff Meeting | Midpoint Report |
| 9 | 3/11 | Midpoint Presentation and HR2 combined | HR2 Summary and Peer Eval 2 |
| 10 | 3/25 | Team/Staff Meeting | Website Check 2 |
| 11 | 4/1 | Team/Staff Meeting | Drafts of Poster and Operation Manual |
| 12 | 4/8 | Final Product Testing Proof | |
| 13 | 4/15 | Team/Staff Meeting | |
| 14 | 4/22 | Final Presentation and Poster | Final Poster and Operation Manual |
| 15 | 4/29 | Team/Staff Meeting | Final Report and CAD package |
| Finals | 5/6 | | Website and Peer Eval 3 |

The assembly view exploded view of the CAD model shows each component of the design. Both show the trough grabber, solar panels, camera, and boat, The main motor is hidden on the backside below the solar panels. The components are put together in their proper size and location in the assembly view in Figure 10. The exploded view shows the different components separately, in Figure 11, in order to get a better view of the individual components as there are multiple hidden surfaces in the assembly view.

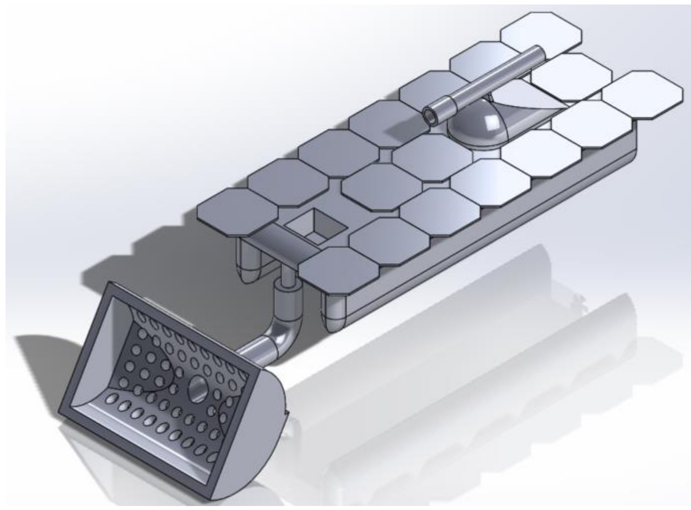

**Figure 10**: Assembly View of CAD Model

Figure 11 shows the exploded CAD model view. The front solar panels are lifted up to show the front end and trough grabber connection. The thermal camera is lifted to expose the cockpit in the boat and the connection. The main motor is extruded backwards as it is completely hidden in the assembly view.

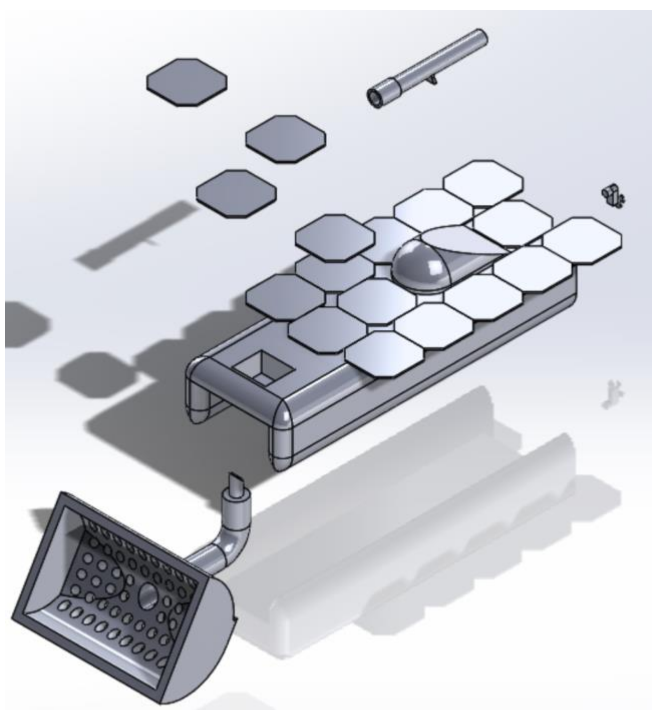

**Figure 11**: Exploded View of CAD model

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# 7 APPENDICES

## 7.1 Appendix A: Gantt Chart

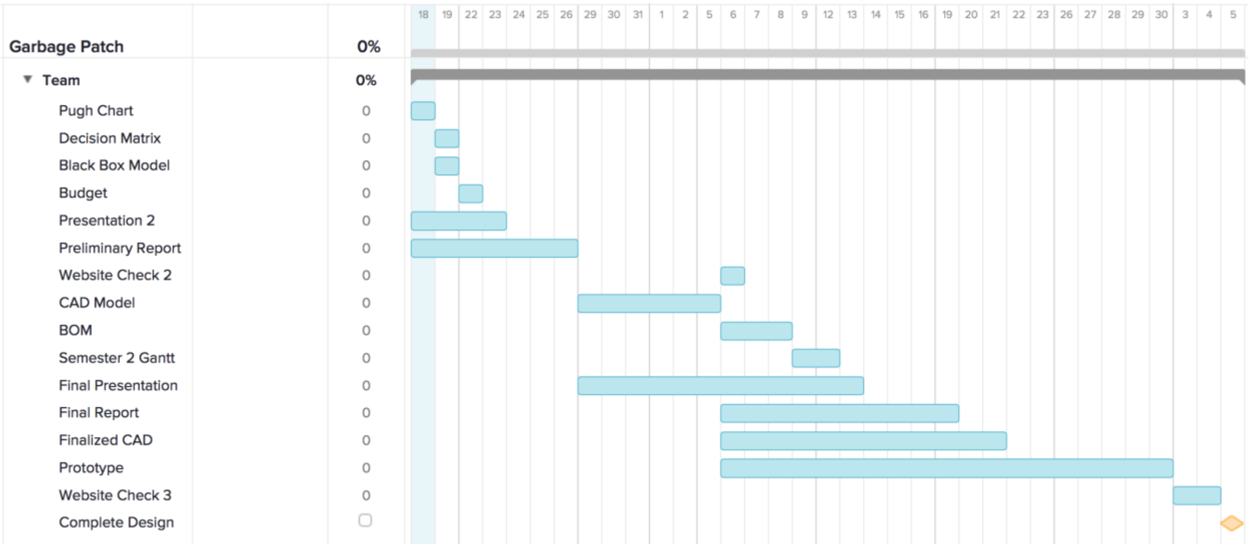
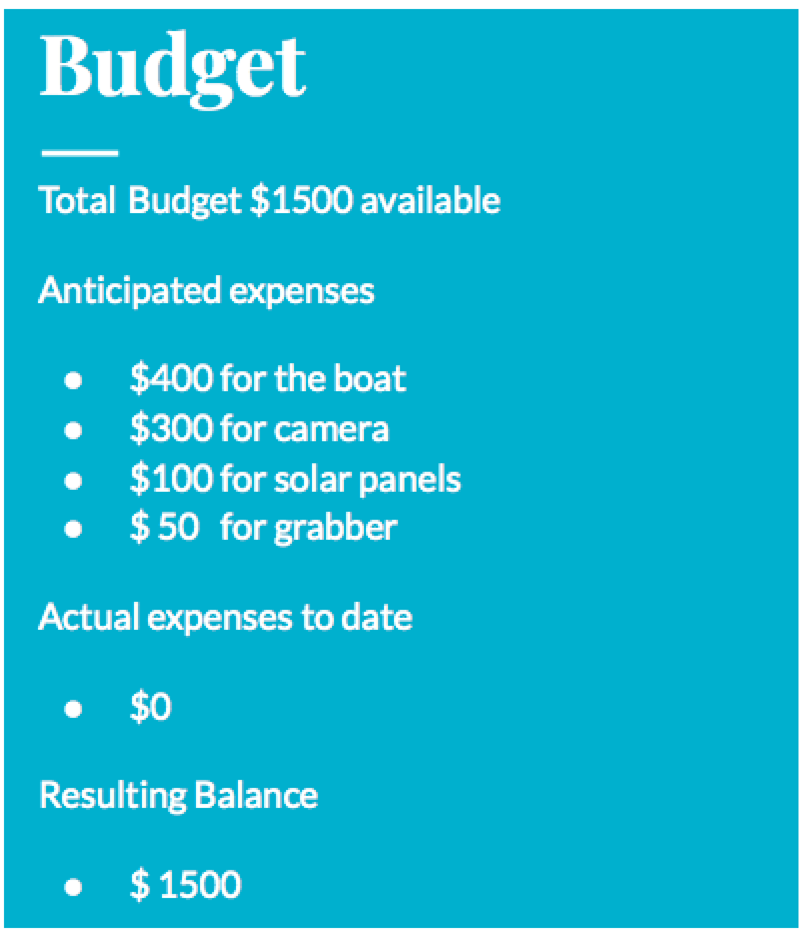


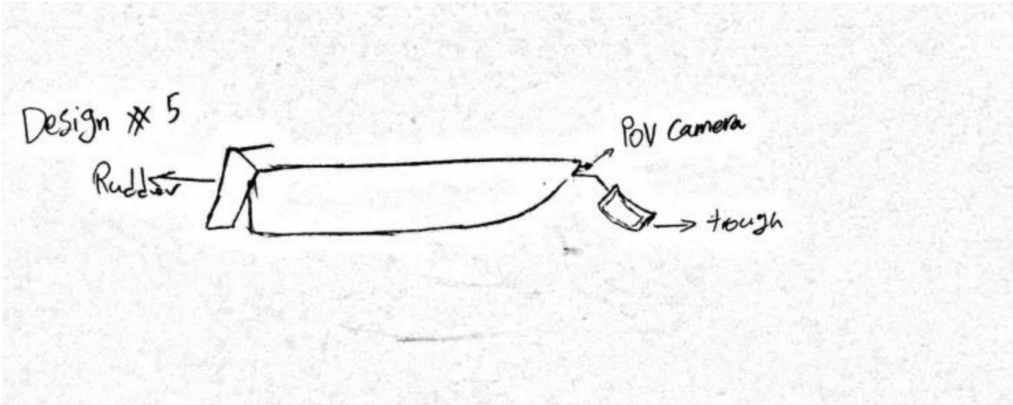

**Figure 10**: Gantt Chart

## 7.2 Appendix B: Budget

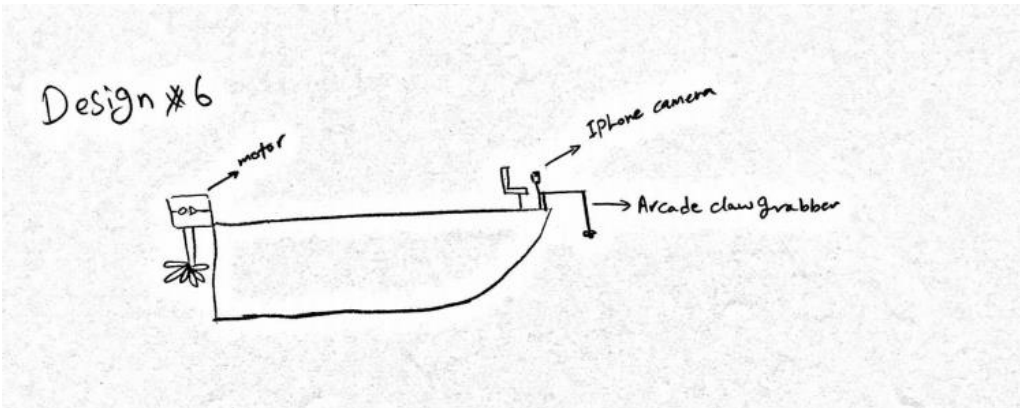


## 7.3 Appendix C: Alternative Designs

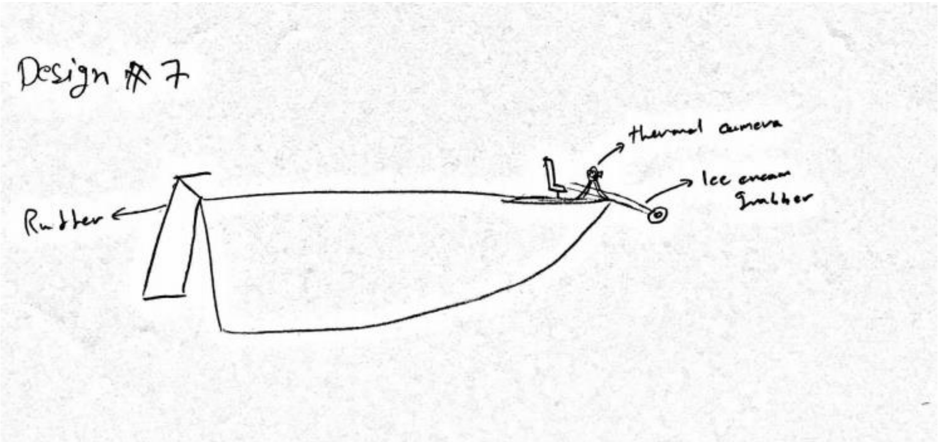
### 7.3.1 Design #5: Trough with the POV camera and rudder



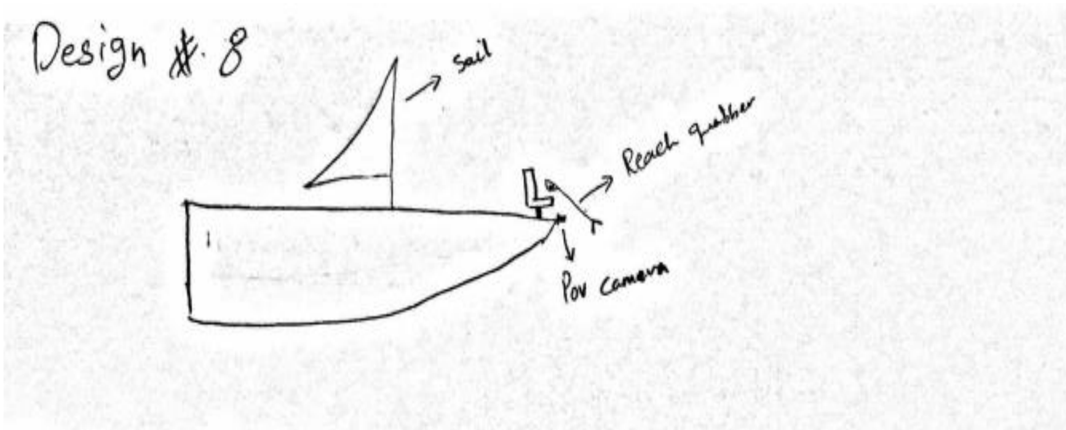

### 7.3.2 Design #6: Arcade claw grabber with the Iphone camera and motor



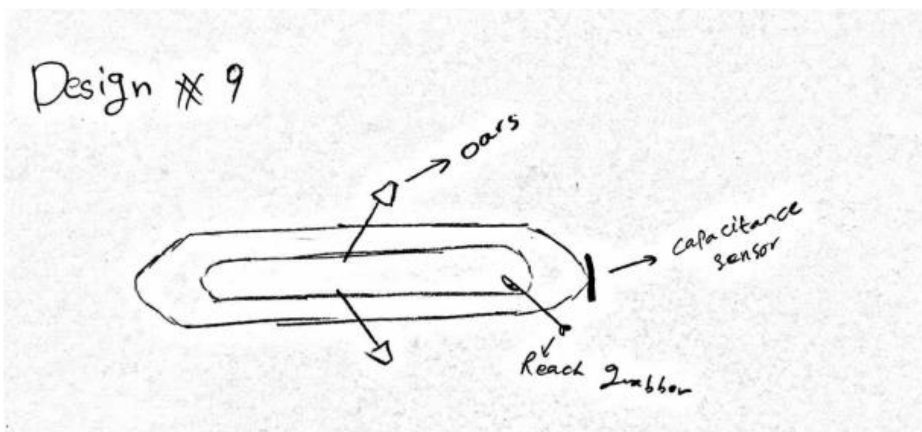

### 7.3.3 Design #7: Ice Cream grabber with the thermal camera and rudder



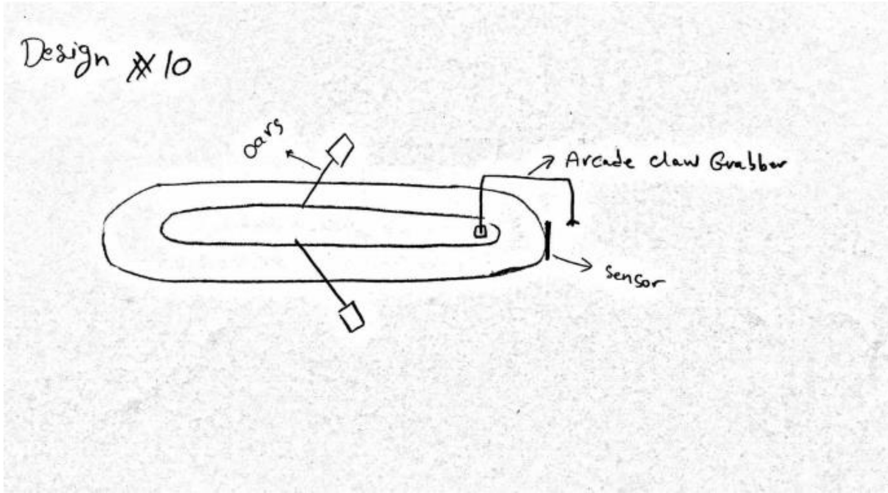
### *7.3.4 Design #8: Reach grabber with the POV camera and sail*




### *7.3.5 Design #9: Reach grabber with the capacitance sensor and oars*




### *7.3.6 Design #10: Arcade claw grabber with the capacitance sensor and oars*




## 7.4 Appendix D: Bill of Materials

| Bill of Materials | | | | | | | |
|---|---|---|---|---|---|---|---|
| Team: C3 | | | | | | | |
| Qty | Description | Functions | Material | Dimensions | Cost | Link to Cost Estimate | Manufacturer |
| 1 | Boat | move | fiber glass | 1.02m x 0.30m x 0.25m | $399.99 | https://www.horizonhobby.com/AQUB2101?KPID=AQUB2101&CAWELAID=320011980001437484&CAGPSPN=pla&CAAGID=37619207031&CATCI=pla-550124742228&gclid=Cj0KCQiA3IPgBRCAARIsABb-iGJR9dAkOykRdNKKDh2qSB3L8EdfYypU8UGch-n3T_amHkso_NxodX8aAndIEALw_wcB | Aqua Craft Motley Crew FE Brushless Catamaran |
| 1 | Camera | detect | fiber glass | HT-02D -20-300C +-2C 274mm x 185mm x 109mm .898kg | $199.99 | https://www.amazon.com/Handheld-Resolution-1024Pixels-Temperature-20-300°C/dp/B07D5CKT2J/ref=asc_df_B07D5CKT2J/?tag=hyprod-20&linkCode=df0&hvadid=242022044358&hvpos=1o4&hvnetw=g&hvrand=4347983675219588209&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9030289&hvtargid=pla-539141451732&psc=1 | Akozon |
| 1 | Trough | collect | ABS plastic | 15cmx10cm | $30.00 | | |
| 2 | Trough Beam | hold trough | ABS plastic | 2cm dia | $10.00 | | |
| 15 | Hinges | trough movement | Nylon | 15.875mm x 28.575mm | $6.25 | https://www.towerhobbies.com/cgi-bin/wti0001p?&I=DUBQ2025&P=FR&gclid=Cj0KCQiAuf7fBRD7ARIsACqb8w6JJ7Ijtt77OuITJjtDObTCc7TWaDMtlYX9nZuGGrJiO8sqdUJfOSwaAv1QEALw_wcB | Dubro |
| 20 | Solar Panel | power | Silicon | 125mmx125 mm | $100.00 | https://www.amazon.com/Sunpower-Flexible-Monocrystalline-Tabbing-Efficiency-x/dp/B078KCCY4T/ref=sr_1_2_sspa?ie=UTF8&qid=1543298742&sr=8-2-spons&keywords=sunpower%2Bsolar%2Bcell%2Bc60&th=1 | SunPower |
| Total | | | | | $746.23 | | |

## 7.5 Appendix E: Assumptions and Calculations

- average diameter of a pingpong ball 4cm

    - volume of a ping pong ball = (4/3)pi(r^3 ) = 33.51cm^3
        - 20 ping pong balls 20 x 33.51cm^3 = 670.2cm^3
- average mass of a ping pong ball 2.7g
    - 20 ping pong balls x 2.7grams = 54grams
- gravity 9.81m/s^2
    - weight of one ping pong ball 9.81m/s^2 x 2.7g = 26.487N
        - 20 ping pong balls 26.487N x 20 = 529.74N
- air pressure is 1bar
- density of air 1.225kg/m^3
- density of water 997kg/m^3
- Rbar = 8.314kJ/kmol*K
- Molar mass of water 18.02kg/kmol*K
- Molar mass of air 28.97 kg/kmol*K
- Air is an ideal gas
- Specific weight of water 9.807kN/m^3
- specific weight of air 12.01N/m^3