Pacific Garbage Patch

Preliminary Report

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Project Sponsor: Dr. Trevas

1 DISCLAIMER

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1 BACKGROUND

The background includes introduction, project description, and the original system that is relating to this project.

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 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 best way 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

Following is the original project description provided by the sponsor.

> "We would like a team of engineering students to research ways we can clean up the Pacific Garbage Patch https://www.usatoday.com/story/tech/science/2018/03/22/ great-pacific-garbage-patch-grows/446405002/ . There is a group in the Netherlands that propose converting all the non-recyclable plastic to low grade diesel fuel https://www.maritime-executive.com/article/port-of-amsterdam-gets-new-plastics-to-oil-plant . Is is possible to have a recycling plant on a barge near the plastic garbage patch? What other options are there to reduce the size of the patch?" [1]

1.3 Original System

The C3 Great Pacific Garbage Patch team is creating a completely new system with aspects that already exist.

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 group must meet these requirements to satisfy the client. This includes each component of the design meeting the requirements individually as well. Each requirement is weighted on the importance of the requirement. The objective is to make a durable, portable, waterproof, solar powered, easy to operate device, using sensors that cleans up ping pong balls in a pool that does not damage the ecosystem in a cheap, fast, safe and effective manner. 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, depicted in Table 1, are as follows:

Table 1: Customer Requirements

Customer Requirement	Weight
1. Doesn't damage ecosystems	25
2. Durable	5
3. Portable	5
4. Picks up trash down to 5 mm in length	5
5. Waterproof	10
6. Solar powered	10
7. Sensors	10
8. Cheap	5
9. Fast	5
10. Safety	5
11. Effectiveness	10
12. Easy operation	5

2.2 Engineering Requirements (ERs)

The customer requirements were used to create 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	Length (m)	Mass (kg)	Plastic removal (%)	Power (W)	Sorts plastic by type (% accuracy)	Velocity (m/s)	Plastic collection (kg/day)	Useful life (years)
Target(s)	1	20	90	200	90	10	150	5
Tolerances(s)	0.2	5	5	25	5	2	10	1

2.3 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 plastic collection with a absolute technical importance of 370 and relative technical importance of 1. All of the data is shown in Table 3 below.

Table 3: House of Quality

Customer Requirement	Weight	Engineering Requirement	Length (m)	Weight (kg)	Plastic removal (%)	Power (W)	Sorts plastic by type (% accuracy)	Velocity (m/s)	Plastic collection (kg/day)	Useful life (years)
1. Doesn't damage ecosystems	25				9	1	3		9	
2. Durable	5									9
3. Portable	5		9	9						
4. Picks up trash down to 5 mm in length	5				9		3		3	
5. Waterproof	10									9
6. Solar powered	10					9		3		
7. Sensors	10			1	3	3	9		9	
8. Cheap	5		1	1		3		1		
9. Fast	5			1	1	3	1	9	1	
10. Safety	5				1					
11. Effectiveness	10				3		9		3	1
12. Easy operation	5					1	3	1	1	
Absolute Technical Importance (ATI)			50	55	340	180	290	85	370	145
Relative Technical Importance (RTI)			8	7	2	4	3	6	1	5
Target(s)			1	20	90	200	90	10	150	5
Tolerances(s)			0.2	5	5	25	5	2	10	1
Testing Procedure (TP#)			1	2	5	3	6	4	8	7

3 EXISTING DESIGNS

There are not any autonomous boats out on the market that clean up trash. However, there are products that clean up trash, RC boats, and pre production autonomous cars.

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 best design today that is cleaning 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 [2]

3.2.2 Existing Design #2: RC Boat

There are numerous RC boats available to purchase today. They come in many shapes and sizes. Each model draws different amounts of power and travels at different speeds. The RC allows the boat to change speed and direction. The team needs to choose a boat that has a dedicated place to store th 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. 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 [4]. Some have claimed that this software is safer than human drivers.

Figure 3: Tesla Model 3 with Autopilot [4]

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

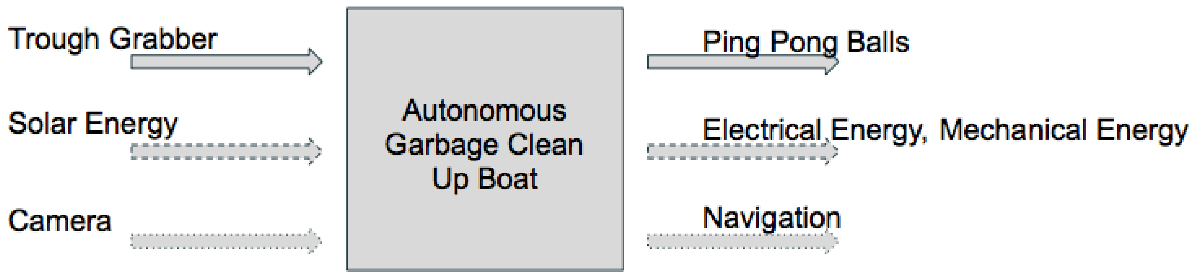

Figure 4: Black Box Model

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

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

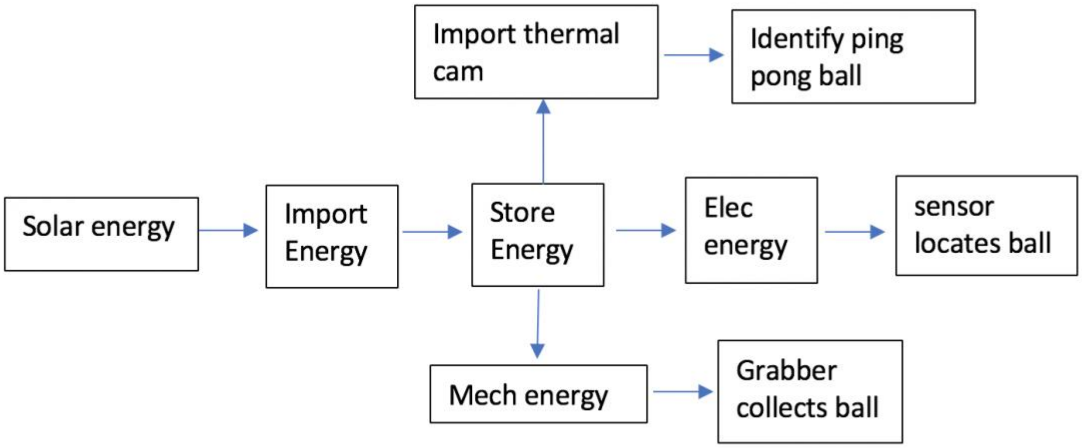

Figure 5: Functional Model

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. 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.

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. The sensor identifies the location of the plastic, and the grabber moves to that location. 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: Trough

The water draining trough is the best design based on the pugh chart. The trough can collect the most plastic, while its mesh design allows for superior 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 picks up the ping pong balls just like it picks up items in a arcade game. The problem with this design is similar to the arcade game. It has a hard time capturing the ping pong balls if it does not 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

The ice cream scooper can collect ping pong balls in the same way it scoops ice cream. 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. it plays an important role for our project. 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 and the Pugh Chart the team decided to go with the thermal camera until they notice that there are a better camera and 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.

3.4.2.3 Existing Design #3: POV Camera

In addition to programming, the feed from the camera will be read and identify objects in its view.

3.4.3 Subsystem #3: Navigation

Navigation is used in order to direct the boat towards the ping pong ball.

3.4.3.1 Existing Design #1: Rudder

There are different types of rudder. by researching about the types of the rudders we got the best two type which is Spade or Balanced Rudder and Unbalanced Rudders[7]. its depends on the size of the ship. Located at the rear of the boat, a thin plank directs the boat towards a ping pong ball.

3.4.3.2 Existing Design #2: Motor

We can use the solar power to make it work. It is better to use because it is faster to arrive to the ping pong located and it will not take the effort, and it is located in the rear.

3.4.3.3 Existing Design #3: Oars

By using the oars the team can head to the ping pong located but it will take more time and effort because we will use our hands to move the boat to the target. Placed on the sides of the boat, submerging and surfacing the planks will change the direction of the boat.

4 DESIGNS CONSIDERED

4.1 Design #1: Trough grabber with electric motor and thermal

camera

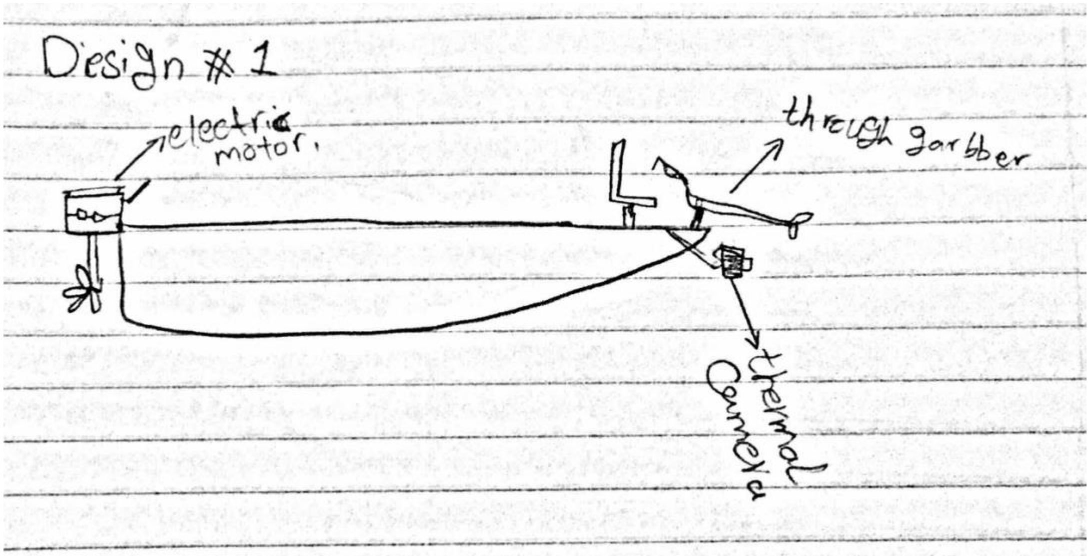

Figure 6: Design #1

This design 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.

Pros

- Collects more plastic
- Durable
- Effective
- Easy Operation

Cons

- Cost

4.2 Design #2: Arcade claw with capacitance sensor and rudder

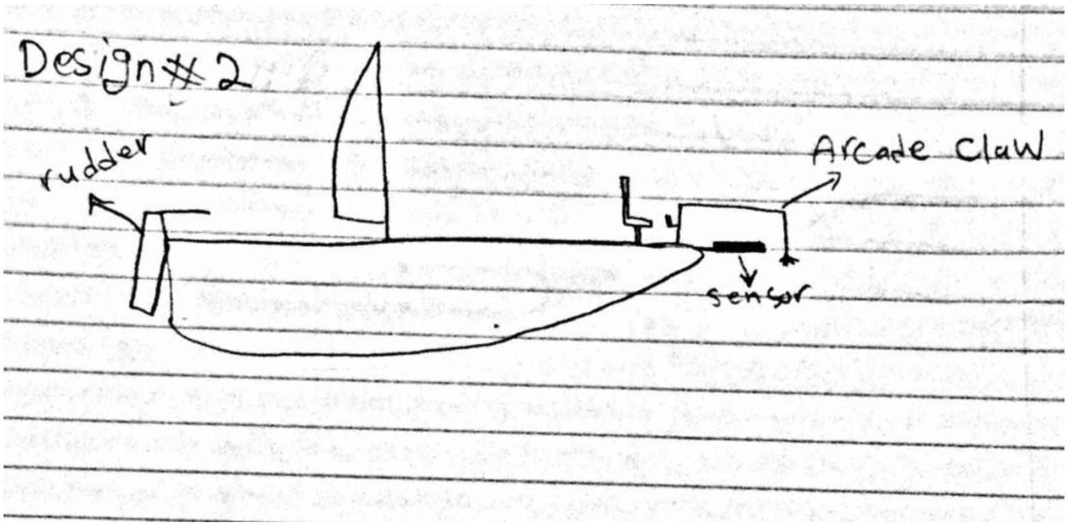

Figure 7: Design #2

The arcade claw with the capacitance sensor and rudder is an ok design. The rudder is a great way to steer the boat towards the trash. However, the arcade claw cannot collect the small pieces of trash

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

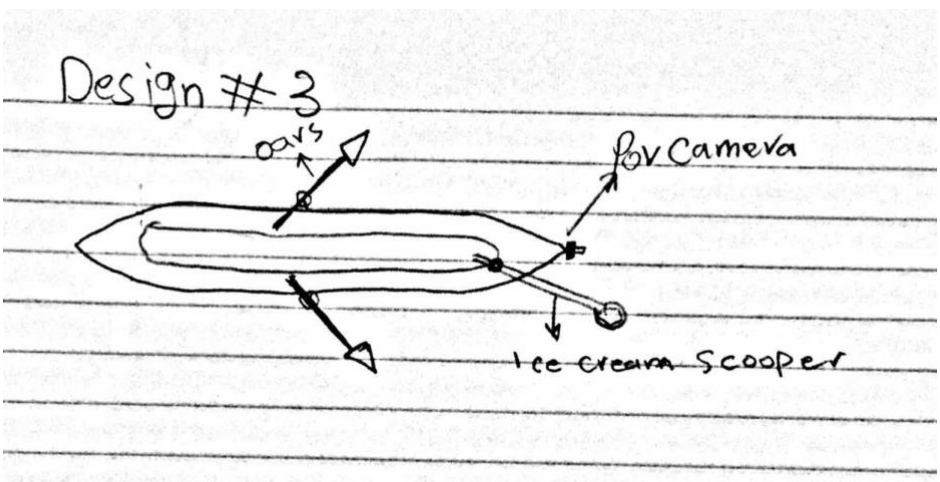

Figure 8: Design #3

The ice cream scooper with POV camera and Oar is one of the worst designs. The ice cream scooper damages the ecosystem by killing small microorganisms. Yet, it does the best job collecting the smallest pieces of plastic.

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

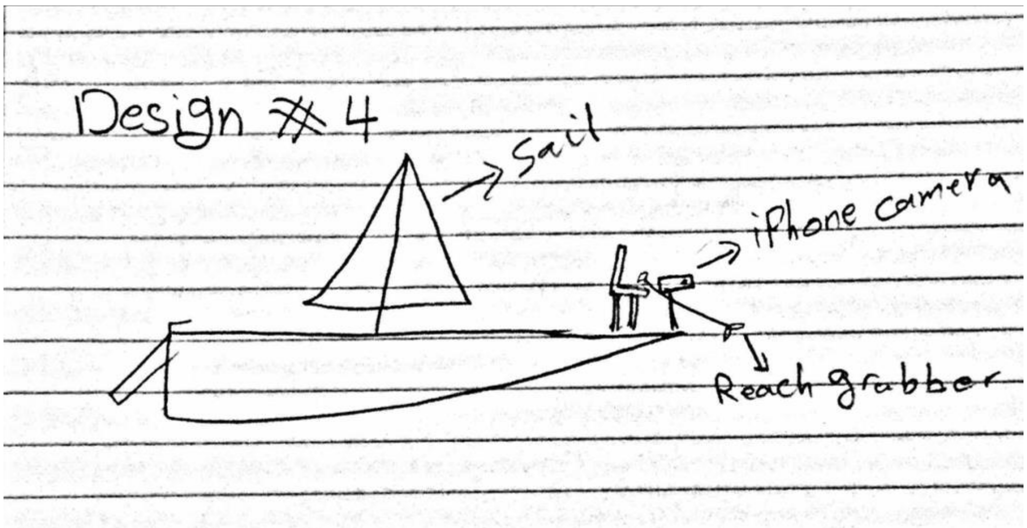

Figure 9: Design 4

This design is the datum design. 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

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 chose 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.

Table 7: Navigation Pugh Chart

		Design Ideas			DATUM Design
Criteria	**Weight**	**motor**	**oars**	**rudder**	**Autonomous Sail**
Doesn't damage ecosystems	5	S	S	S	DATUM
Durable	1	(+)	(-)	S	DATUM
Portable	1	(-)	(+)	(-)	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	(+)	(-)	(-)	DATUM
Safety	1	S	S	S	DATUM
Effectiveness	3	(+)	(-)	(-)	DATUM
Easy operation	1	(+)	(-)	S	DATUM
Total +		**4**	**3**	**2**	
Total -		**3**	**4**	**3**	
Total S		**5**	**5**	**6**	
Overall Score		**1**	**-1**	**-1**	
Weighted Overall Score		**1**	**-1**	**-1**	
Rank		**1**	**2**	**2**	

The navigation pugh chart weights the criteria on a 1-5 scale. The motor has the best score with 4 +, 3- and 5S. The overall score and the weighted overall score is 1.

REFERENCES

[Include here all references cited, following the reference style described in the syllabus. There should only be one Reference list in this report, so all individual section or subsection reference lists must be compiled here with the main report references. If you wish to include a bibliography, which lists not only references cited but other relevant literature, include it as an Appendix.]

[1] St. Louis Earth Day. (2018). great-pacific-garbage-patch | St. Louis Earth Day. [online] Available at: https://stlouisearthday.org/plastic-soup-anyone/great-pacific-garbage-patch/ [Accessed 21 Sep. 2018].

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6 APPENDICES

6.1 Appendix A: Gantt Chart

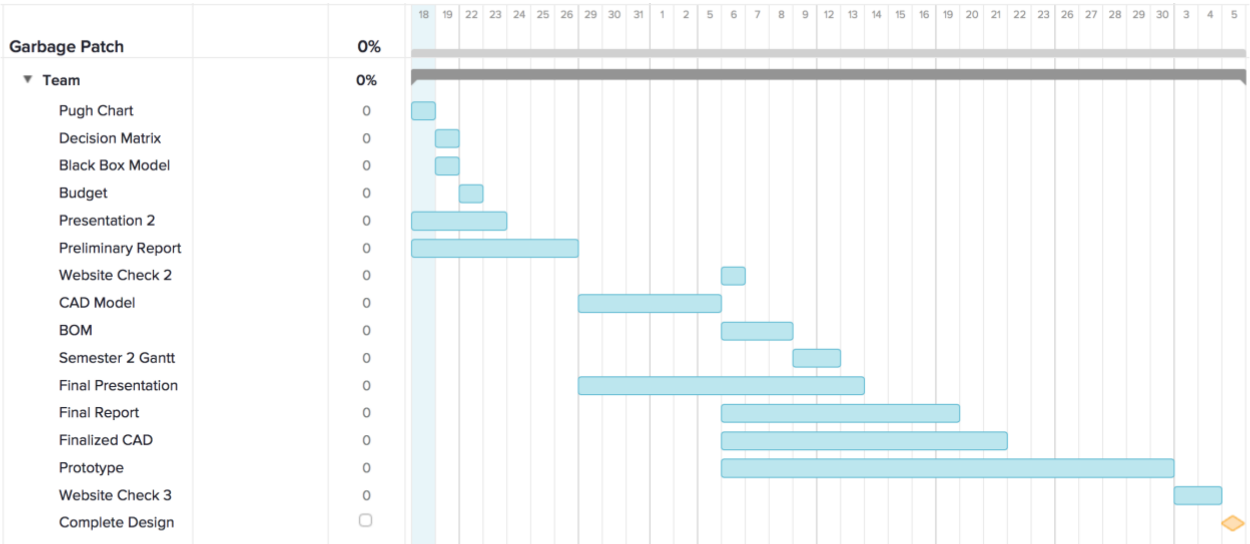

Figure 10: Gantt Chart

6.2 Appendix B: Budget

- Budget
  - $1500 available
- Anticipated Expenses
  - Boat
    - $150
  - Solar Panels
    - $250
  - Grabber
    - $200
  - Camera
    - $350
  - Navigation
    - $100
- Expenses to date
  - $0
  - $1050 - 1100 (Expected)
- Resulting Budget
  - $1500

6.3 Appendix C: Alternative Designs

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

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

motor

6.3.3 Design #7: Icecream grabber with the thermal camera and rudder

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

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

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