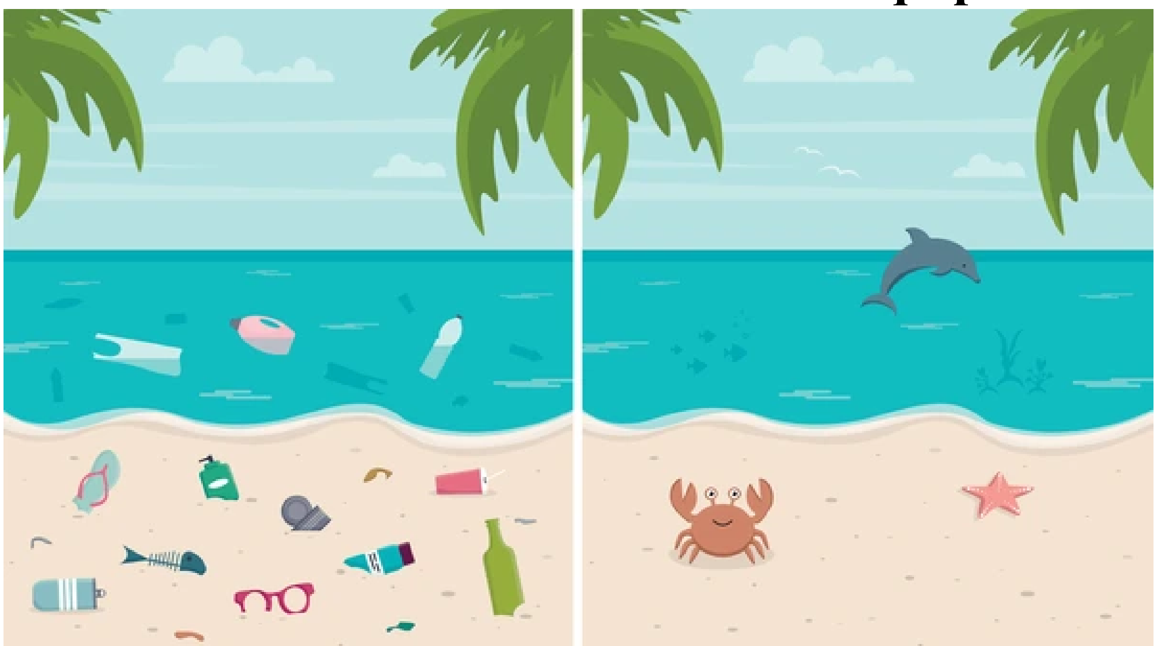
ALiCE

Autonomous Litter Collection Equipment



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Chapter 2 Project Description

2.1 Project Background and Motivation

In today's society, it has become more common for people to leave trash in places it does not belong, places such as parks, rivers, and more importantly beaches. Our group has decided to focus and provide a solution to combat marine debris. Marine debris; man-made objects that enter the marine environment through careless handling or disposal, intentional or unintentional release, or as a result of natural disasters and storms - is one of the ocean's most pervasive, yet potentially solvable, pollution problems. The presence of marine debris, coupled with its physical, ecological and socio-economic complexities, poses a severe threat to the sustainability of the world's natural resources.

Beachgoers find it convenient to leave trash behind, and they are unaware of the detrimental effects that these actions can cause to the environment, specifically sea-life. Litter and debris along the beach, including on sea turtle nesting beaches, soon makes its way to the sea where turtles and other marine life may consume or be trapped by these items. Clean, debris-free beaches will be beneficial to not only tourists and visitors but most importantly sea turtles and other marine life.

What if there was a way to reduce the amount of trash on these beaches? That's the question our group has decided to dedicate our senior design project to. We as a group will come together to solve one of the greatest problems of our generation by designing and developing a promising project. This project will feature a handful of subsystems containing both software and hardware that coincide with each other. The decision to choose this project will not only be a demanding project that will push us to the limits of our capabilities, but it will also make a positive impact on the environment and protect the 8,436 miles of shore line here in the State of Florida.

The motivation for this project is to take this challenge and use it to build something that can help benefit the environment. Using our design complete with convolutive hardware and software and using it to help marine wildlife would be extremely beneficial. We hope that with our design, we will be able to inspire companies, communities, or others to seek action on restoring and bettering the environment for the sake of those who are not able to, such as animals and plants.

In addition to protecting the environment with the creation of our project, our main motivation is to successfully complete the requirements of the senior design program. We wish to take this opportunity to show why we have made it this far and why we should be able to call ourselves engineers. We as a group would also be motivated to use this project as a stepping stone to helping us become better at communicating, collaborating, and planning as a team. These skills will become extremely important once we graduate and are making our way into the industry.

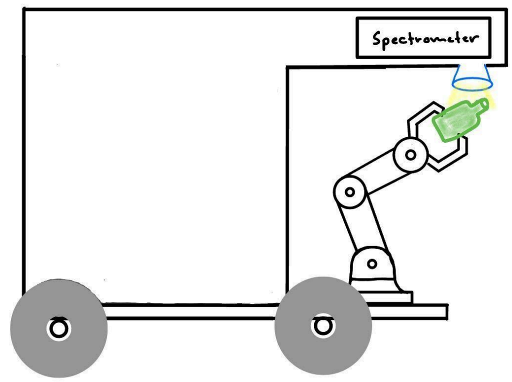


Figure 2.1.1: *Hand-sketch preliminary design*

2.2 Current Commercial Technologies and Existing Projects

2.2.1 BeBot

BeBot is a beach cleaning robot, essentially very similar to the project that we plan to create. BeBot utilizes a rake to pick up any waste from beaches, nature reserves, golf courses, etc. It contains a sifter that separates the trash from the sand. BeBot uses batteries and solar panels, which makes it 100% electric and does not use or produce any damaging gasses. It maneuvers using track-style propulsion and it is operated by a remote control that has a range of 150 meters. It contains a docking system to place the BeBot on before and after using it.

The BeBot should be stored in a temperature ranging from 41 to 86 degrees Fahrenheit. BeBot lasts up to 3 hours, and it takes up to 8 hours for it to charge. It has a maximum speed of 2.7 kilometers per hour and is able to carry weights up to 400 kilograms (about 881.85 pounds). The tray collection of BeBot has a capacity of 100 liters.

The BeBot has some similarities when compared to our design, the Autonomous Litter Collection Equipment (ALiCE). The idea and goals of ALiCE are the same, in which we aim to clean the beach environment using an autonomous robot. However, the difference is that while BeBot utilizes a rake style system that scoops up trash, we are using a robotic arm that detects and picks up trash on the beach. This will help keep sea-turtle nesting areas safe from being accidentally scooped up. Also, they use remote control with a range limit while we plan to have ALiCE to be autonomous that does not have a remote controlled limit or operator engagement. This will allow an operator to monitor and manage multiple systems rather than a single unit. Lastly, ALiCE will be equipped with a spectrometer to sort recyclables from trash and also leave seashells on the beach where they belong. ALiCE will also be 100% electric and have swappable battery capabilities.

2.2.2 iRobot Roomba

The iRobot Roomba has been a commercialized smart-home product that has had much success in the last decade. In September 2002, the company introduced the first Roomba model. Less than a year later, iRobot was selling a million units a year. Although early models were known for zigzagging randomly to achieve full room coverage, the semi-autonomous cleaning robot still had much success. In the last decade, the engineers behind the Roomba have fully transformed the mechanical maid to sweep, vacuum, and mop different types of flooring in homes and offices. iRobot's latest models feature a new visual simultaneous localization and mapping (vSLAM) navigation system, allowing it to clean more efficiently. Some of the other features Roomba include are cliff detect sensor, obstacle detection bumper, floor tracking sensor, acoustic and optical sensors (for detecting areas with excessive dirt and debris).

Our plan is to emulate this technology and apply it to a beach or waterfront environment. ALiCE will incorporate the same key technologies that are embedded in the Roomba design. While Roomba's are limited to indoor use only, ALiCE will be an industrial grade robot that can withstand extreme everyday environmental conditions. Although our design will be about 10x the size of a Roomba, we will have the ability to pick up items ranging from cigarette butts to 2-Liter Soda bottles.

2.2.3 Beach Metal Detectors

Some hobbyists take to the beach to search for hidden treasures buried in the sand, and as luck would have it, prove to be pretty successful in their searching. Metal detectors are commonly used to locate belongings left behind such as jewelry, old-coins, and relics. The two common techniques used today are Very Low Frequency and Pulse Induction, both techniques similarly use coils to transmit and receive electromagnetic fields. Depending on the type of metal below the sand line, the electromagnetic field responds differently, which will trigger the indicator and the operator will then dig to find their reward. While this helps keep metals out of the sea, this is more of a hobby and the drive behind this is for personal gain. ALiCE is a conscious effort to help the environment with almost no tangible reward. As a potential stretch goal, this technology could be incorporated later on and our system can begin to collect metals just below the surface.

2.2.4 Summary

The ALiCE (Autonomous Litter Collection Equipment) aims to address the issue with litter on beaches through the design of an autonomous robot and its purpose to collect debris and trash. Moving right into the core components of ALiCE, the robot rover is equipped with sensors, a robotic arm, a power supply system, spectrometer, and a PCB design that will act as a control center. This rover is designed to navigate on the beach in different environments while avoiding obstacles. The robotic arm is used to collect the debris that the camera vision will detect and is placed in an onboard recycle or trash pan.

ALiCE will be outfitted with a VIS-NIR Spectrometer used to analyze items recovered from the ground and determine whether the item is recyclable or not. The power system of ALiCE is built on sustainability and will include an efficient battery that can supply power to the entire system.

The enclosure will protect the system from the earth's elements and allow cooling to prevent any failures.

The motivation of ALiCE is mainly inspiring other communities and organizations to provide innovative results for a cleaner environment. This project explores current ideas and technologies we learn from and relate our project to. Learning about these existing solutions helps with understanding requirements and needs for the project as well as gain inspiration. We can use these ideas to creatively construct ALiCE.

2.3 Goals and Objectives

The function of ALiCE is for it to be able to successfully navigate its way through the sand while avoiding the water and large obstacles. It should also be able to successfully navigate over gravel as well since gravel could be found on some beaches. While ALiCE is making its way through the sand, it is scanning the floor in front of it using a camera to look for potential trash. When something has been found that is not sand, ALiCE will make its way towards the object so that it is close enough for the robotic arm to pick it up.

Goals:

- Collection - Collect debris that may cause harm to marine ecosystems.
- Navigation - effectively navigate and localize the area of the beach tasked with cleaning.
- Obstacle Avoidance - avoid large obstacles and bodies of water that may damage the rover.
- Identify - accurately identify recyclables, trash, and seashells in real time.
- Ease - deliver a system that will take minimal training and operate independently.

Objectives:

- Camera Vision and Machine learning to navigate around obstacles and approach debris on the beach.
- Measure across visible and near-infrared wavelengths to accurately identify items recovered with fast readout capabilities.
- Measure items ranging in size i.e. aluminum cans, soda bottles.
- Be able to use the camera and lidar puck to correctly determine what is obstacles that should be avoided by the rover
- Determine what is the most efficient and effective way for the robotic arm to pick up trash and avoid clashing with other components.
- Implement redundant safety systems like emergency stops and robot arm force limits.
- Design an enclosure that allows ventilation and protects the system from the elements such as sun, heat, rain, and sand.

Stretch Goals:

- Identify and avoid sea turtle crawlings, nesting, or hatchlings.
- Implement metal detection technology to recover metals below the sand line.
- Design swappable battery system, to change batteries on the go.

- Onsite docking station, with self-emptying capabilities.
- Add solar panels to help keep the system running while in the field.
- Remote viewer where operators can remote-in a troubleshoot system if necessary.
- Implement a self-recovery mechanism for AliCE.

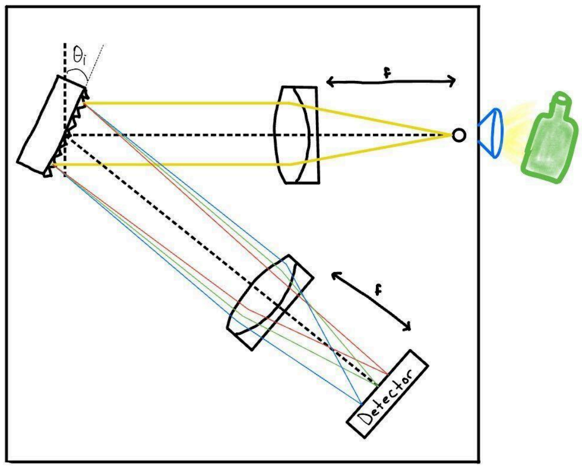


Figure 2.3: *Hand-sketch Spectrometer*

2.3.1 Hardware

2.3.1.1 Rover - Objective

The Rover is the subsystem responsible for traversing the beach for debris collection. It will be a fully automated self-driving platform outfitted with sensors, motors, and durable beach style wheels. The rover will include an enclosure that will protect PCB, power supply, and electronics from the beach environment. The rover will provide stability to successfully transport the robot arm without falling over or getting stuck on one side while it is picking up trash or traveling in heavy winds. The rover will need a basic motor and will be connected to our microcontroller. To move around on the beach and keep stability we will be using beach balloon wheels on the rover.

2.3.1.2 Robot Arm - Objective

The Robot arm is the biggest and boldest part of our project. We have access to an industrial grade robot arm and plan to utilize it in our design. The star of the show will be fitted with a claw like gripper that will be able to pick up objects ranging in size.

2.3.1.3 Spectrometer - Objective

The spectrometer will determine whether the item collected is recyclable, trash, or possibly a seashell. The spectrometer will measure across the VIS-NIR spectrum for analysis of the material. Measuring in this spectrum will give accurate results in real time. The basic function of a spectrometer is to receive light, break it into its spectral components, digitize the signal as a function of wavelength, and read out its analysis. We will be designing and developing the spectrometer so that it is capable of measuring items ranging in size while maintaining accuracy of what type of material is being measured.

2.3.1.4 Power Supply - Objective

The power supply will be protected by the rover enclosure and will power our motors, spectrometer, the PCB, and the robot arm. We would like to have an efficiency on the power supply of at least 80% minimum but will shoot for more around ~90% for the final product. The power supply will also either be able to be plugged straight into the wall to recharge or easily accessible to be taken out and recharged then put back in between charges. We would also like to shoot for a minimum of an hour battery life.

2.3.1.4 PCB - Objective

The printed circuit board will be the brains of the operation. The PCB will have all the programming to control ALiCE to the fullest extent. The PCB will be able to interface with the motor of the rover to control driving. It will use sensors to detect where trash is and drive to the trash to pick it up. Then the PCB will control the robot arm to pick up the trash. The PCB will have a good microcontroller on it with enough memory to be able to run all the specified goals. It will also be able to easily interface with all other parts of the project.

2.3.1.5 Charging Station - Stretch goal

Our robot will be almost fully self-sufficient. The goal is to provide a turnkey solution where an operator can power up the system after it's charged and watch it go. Implementing an automated charging station will allow the system to truly be fully autonomous. That’s where we design a landing pad for our rover to come home to. These charging stations would either work through wireless charging or precise programming to connect it to a charge port. The charging station would need to be mounted to a flat area on the beach such as the bottom of a boardwalk to make sure the bot can get there with no issues and without any changes to the charging station.

2.3.2 Software

2.3.2.1 Rover - Objective

The first objective is for the rover part of the project to be able to drive on its own while also making sure it is still on the sand. For this to be achieved, ALiCE must be able to communicate with the equipment that allows the rover to move and also the partial objective so that it can make sure it stays on sand. The partial objective is making sure that the camera and the lidar puck are able to contribute info to both the robotic arm as well as the rover. The reason it is needed for the rover is to make sure that it stays on the sand and if there are any obstacles in the way it should avoid it. The rover should also be able to drive close enough to trash so that the robotic arm can pick it up

2.3.2.2 Robot Arm - Objective

The second main objective of ALiCE's software is the robotic arm. The arm should be capable of receiving commands from the software, and then position itself to where the trash is, and then pick it up without an issue. Once it picks up the trash, the spectrometer will then determine what type of trash it is and it is up to the robot arm to place it in the correct bin. The arm will be limited from rotating 360 degrees because the arm is placed in front and it could potentially collide with the enclosure behind it causing damage to both the enclosure and robot arm.

2.3.2.3 Trash Detection - Objective

The third objective of AliCE's software is to be able to detect trash. The software will detect trash from the sand and be able to tell the rover to go and pick it up. The software needs to be able to make use of the camera to detect what is trash and how big is the trash. We want to make sure it doesn't pick up anything like shells or rocks that would waste trash space. We will start out with a goal of being able to pick up anything to the size of an aluminum can. We can then hope to grow this to be able to pick up something a little bigger and heavy like a beer bottle later on in the project. After picking up the trash, the spectrometer should also be able to scan the trash to figure out what type of trash it was

2.3.2.4 Unstuck feature - Stretch Goal

One idea that we thought would be very challenging, but useful, is to implement a self-recovery mechanism for AliCE. The arm should be able to reach the ground and exert enough force to push or pull the robot.

2.4 Product Specifications

Table 2.4: *Distribution of Worktable*

Component(s)	Parameter	Specification
Meca500 Industrial Robot Arm	Payload, Reach Speed	0.5kg 0.33m 150 deg/sec
Power Supply	Discharge Time, Efficiency	TBD >80%
Spectrometer	Readout Rate Sensitivity Optical Bandwidth	60Hz 1000 counts/(ms μW) 2.0-5.0μm

Camera	Resolution Framerate FOV	1080p TBD 75 deg
Lidar Puck	Range Field of View Power Scan Rate	12m 360° 5v 2-10Hz
PCB	Memory, Peripherals	TBD
Motor (Drive)	 Power Torque	TBD
Motor (Steering)	 Torque	TBD
Control System	Processor	TBD
Proximity Sensors	Range	4 - 30cm

Figure 2.4.2: *Hardware Diagram*

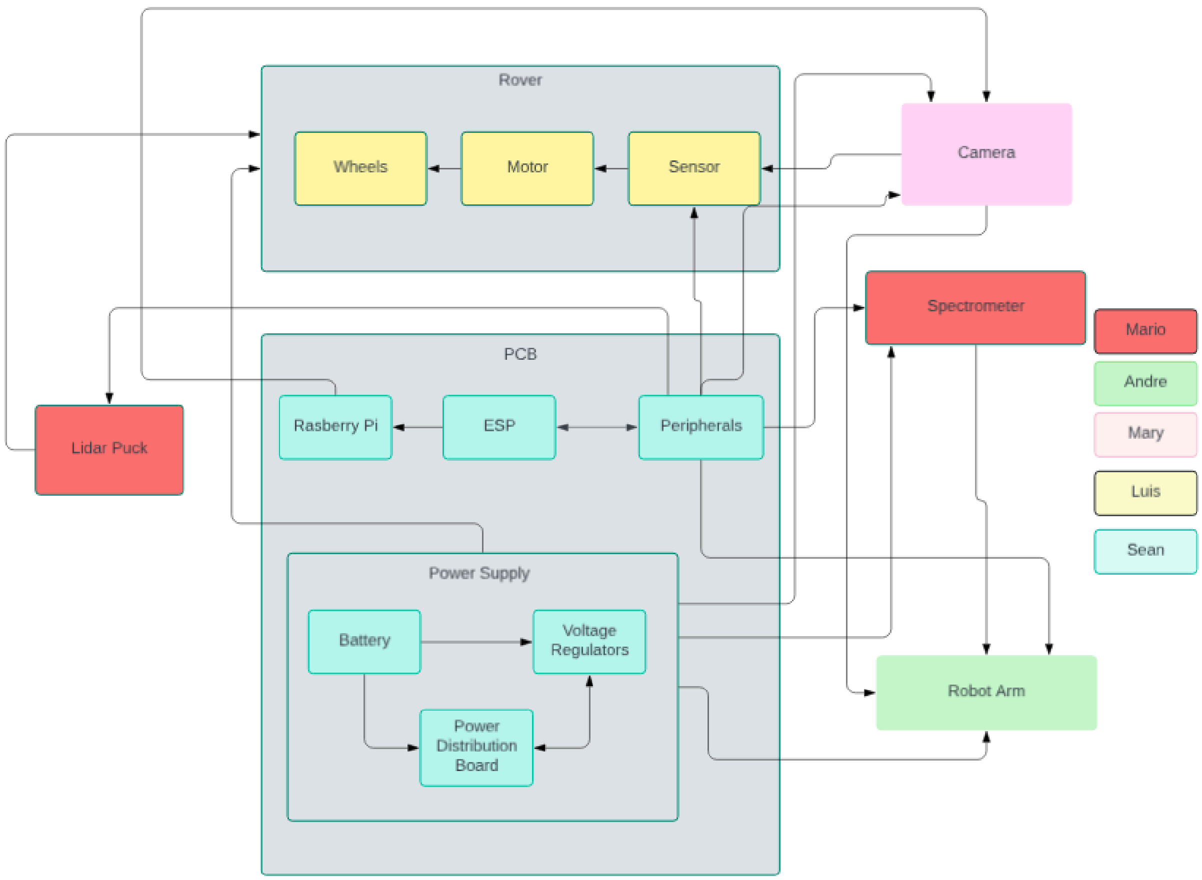
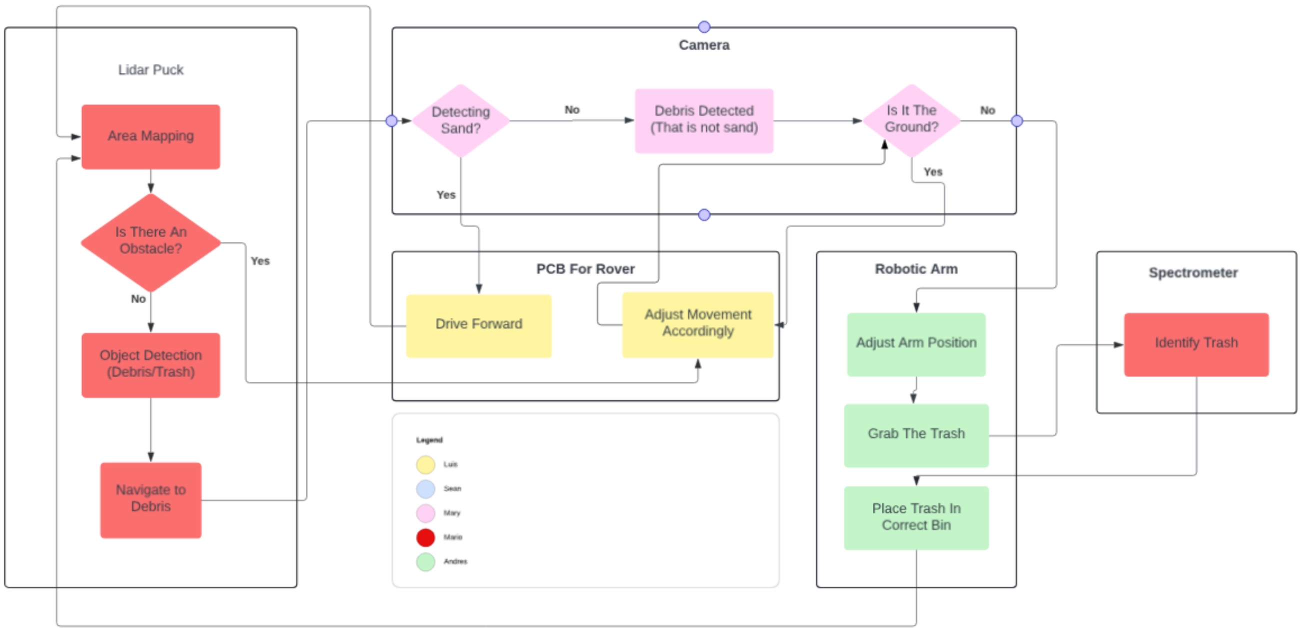


Figure 2.4.3: *Software Diagram*



Chapter 10 Administrative Content

10.1 Budget

Although there are no external sponsors for this project, the group was able to source a substantial amount of supplies for the design build through donations and “on loan” from one of the team members’ employers. The Mecademic Meca500 Industrial Robot Arm was an essential component that will allow the team to retain capital and focus on sourcing less expensive parts. In addition, the team will have access to 3D printing and a small machine shop for custom brackets/fixtures. The table below details the critical components necessary to have a successful design. For the remainder of the items that aren’t donated, the group will be dividing the cost of parts between the 5 members. This will help gain experience in finding cost-effective, off the shelf solutions throughout the design process. The group has agreed to set the budget to $500, this will cover the supplies listed below with some cash flow to cover unforeseen expenses.

Table 10.1.1: *Preliminary Design Budget*

Sub-System	Budget	On Loan
Robotic Arm	$15,000	Yes
Motors/wheels (Donor)	Donation	No
PCB/Electrical	$200	No
LiDAR Puck	$77	No
Raspberry Pi Camera	$84	No
Prox Sensors	$15	No
Enclosure	Donation	No
Battery/Power Supply	Donation	No
Misc wiring/connectors	Donation	No
Spectrometer Build	$150	No
	Sub Total =	$526

10.3 Distribution of Worktable

Below is a table that outlines each specific task that is expected from each group member in which it ensures a clear division of responsibilities. There are integration meetings to ensure that each section flows seemingly together and test the system as a whole.

Table 10.3.1: *Distribution of Worktable*

Computer Engineering	Responsibility	Tasks
Mary Bartlinski & Andre Reveles	Program Robot Arm	Program the robotic Arm: write a programming algorithm that will allow the arm to pick up trash and move
		Integrate the Camera: Collaborate with Mario so that the arm's movements align with the camera detections
		Simulate and Test: Simulate the program in a controlled environment and test on the beach

CREOL: Photonics	Responsibility	Tasks
Mario Puesan	Camera Vision and LiDAR and Spectrometer	Image Processing Algorithm: Develop and implement an algorithm that processes camera images and object detection
		Integrate the Arm: Work with Andre and Mary to ensure that the camera works simultaneously with the robotic arm
		Test: Test the camera in various lighting and different beach conditions
		Trash differentiation algorithm: create and test an algorithm that is able to use the spectrometer to split up the trash into different types
Computer Engineering	**Responsibility**	**Tasks**
Luiz Hernandez	Program the Self-Driving Car	Car Selection: Research and select parts for the base of the robot.
		Navigation System: Develop an algorithm that will allow the car to self drive on different surfaces and detect objects, making sure that it interacts with the camera and arm
		Testing: Test the car in different beach conditions making sure it’s well structured
Electrical Engineering	**Responsibility**	**Tasks**
Sean Waddell	Supply Power to Robot and PCB design	Power System Design: Design a system that will allow power to flow throughout the whole robot selecting batteries and circuits that provides sufficient and efficient power to provide the most efficient battery life and performance
		PCB design: Design a PCB that will match our test microcontroller and have all the peripheral, memory, and other specified requirements.

		Safety and Testing: Implement safety features to prevent overheating and exhaustion as well as ensuring no water damage to the system. Test in different temperatures.

10.4 Milestones

Below are two tables that tell the meeting and event times that are required to create good time management between our group members and give us plenty of time for each step of the process. These milestones will lead us down the right path to success for our project. The first table will describe the time spread out for making the project idea and paper. The second table will describe making the prototype for the project.

Table 10.4.1: *Project Initialization Milestone*

Project Design				
Start Date	**Planned Date**	**End Date**	**Task**	**Description**
5/14/24	5/14/24	5/16/24	Recruitment	Members recruited: Mario Puesan (PSE)**,**Mary Bartlinski (CPE), Andre Reveles (CPE), Luiz Hernandez (CPE), Sean Waddell (EE)
5/16/24	5/25/24	5/27/24	Brainstorming and Decision	Talking over zoom and deciding from everyone presented projects which one to do
5/16/24	5/30/24	5/31/24	Divide and Conquer Paper	First 10 pages of our final document
5/16/24	7/4/24	7/5/24	60-Page Paper	60 pages made for our final draft of the paper
5/16/24	7/22/24	7/23/24	Final Paper	150 pages for the final draft of our project in Senior Design 1

Table 10.4.2: *Project Prototyping Milestone*

Project Prototyping				
Start Date	**Planned Date**	**End Date**	**Task**	**Description**

8/21/24	TBD	TBD	BOM	Making a BOM based of the parts we need with room to grow incase we need more or less for the project
8/21/24	TBD	TBD	System Design	Designing the system together with all the parts connected and first look at what the final design will accurately look like
TBD	TBD	TBD	PCB Design	Design a PCB to fulfill the requirements of our test PCB with all the required specifications needed to run our project
TBD	TBD	TBD	PCB Testing	Testing the PCB out to make sure it works as well or better than our test Microcontroller for our project
TBD	TBD	TBD	Prototype Completion	The completion of our Prototype and the end of Senior Design 2

Various tasks overlap as expected due to how the project is done with previous work being important to future work and some tasks are TBD. These milestone tables are a guideline for reference to make a successful project.