Project Plastic Abatement
End of Project Documentation

EEE193B / CPE191

Senior Product Design Project

Team 11

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Table of Contents

List of Figures

List of Table

Elevator Pitch

A fully autonomous rover will be designed in order to reduce the amount of plastic present in our local lakes and rivers.

Executive Summary

This document will walk through our group's attempt at providing part of a solution for the societal problem of increasing marine debris. We will explore the design idea approach, project timeline, risk assessment, plan for testing the prototype, review the marketability of the prototype, and analyze the test results.

Abstract

Increasing amounts of water debris is a societal problem our group intends on tackling over the course of two semesters. Humans have produced millions of metric tonnes of plastic and other materials that have been dumped into lakes, rivers, and oceans. As time progresses, further damage will be inflicted upon our local water bodies as well as its respective marine life. There have been past attempts to prevent further harm however manpower has been the main bottleneck. Our technical solution to this societal problem is an autonomous water rover capable of collecting small plastic debris at sea-level. Deploying rovers can require large amounts of manpower. For our design we will implement a fully autonomous rover in order to mitigate this problem. A fully autonomous rover will become a more modern version of past methods attempting to solve increasing plastic pollution in water bodies. Our aim is to design and build a project capable of cleaning our local water bodies without human operators. The brain for our operation will be a Durandal H7 PX4. This will control our two thrusters as well as the GPS modules. To communicate with our rover we will be using an open source software named ArduPilot. Our rover will be constructed out of PVC pipes and will use a mesh container to collect the waste. The rover will make its way around with a pre-determined mapped zone. Our team broke down our rover into its major sections. The sections were broken up into propulsion, rover communication, GPS mapping, central power, rover structure, and plastic collection. Once we had the overview set up, we were able to see which group members had strengths in these sections and got to work planning for each requirement. Each section has an estimate for the work required to get it operational, as well as a plan for being able to test the function once it is completed. As a team we mapped out the steps needed to complete our project by the due date. In order to do so we created a PERT Diagram and Gant chart. These tools will be useful to hold everyone accountable and properly assign team members to a specific task. We will also be able to monitor where everyone is along the way and at what point we can expect a task to be completed. Similarly our team split up the risk assessments into four main categories. Environmental Risk such as unforeseen weather. Technical Risk such as nonworking parts or poor design. Logistical Risk such as failure to receive components on time due to limited resources. As well as Systematic Risk such as someone getting COVID-19 or into a bad accident. Some of these risks range from low to severe impact as well as the probability for them can range from probable to not very likely. For our Marketability Forecast we will conduct market research on how our target consumers are. What environment our Rover will be operating in. As well as our main competitors and a full SWOT Analysis. By doing so we can better understand our demographic and the type of market we are in. Overall we provide as much detail as possible to explain what our goals were and what we did in order to accomplish those set goals.

***Keyword Index** — Plastic**,** Waterbodies**,** Marine Debris, Flight Controller, Motor Drivers, ArduPilot, GPS Module, Differential Thrusting, Telemetry System, Telemetry.*

I. Introduction

Our team is evenly balanced in terms of skillset as our group consists of both computer engineering majors and electrical engineering majors. Despite this balance, our group recognizes it will take more than a certain skill set order to tackle our chosen societal problem. We have decided to address the increasing amount of plastic entering our local lakes, rivers, and oceans. Our design idea aims to minimize the amount of manpower required to clean our local water bodies of plastic debris. This will be achieved by building a fully autonomous rover that will be capable of collecting small plastic debris at sea-level. This report will carry you through our design process from start to finish over the course of two semesters. Below you will find introductory segments to the many facets of our design process.

A. Societal Problem

As production increases around the world, so will the waste generated by that production. Around 20 percent of coastal waste make their way to the ocean through rivers [2]. Our goal is to create a robot that can detect where surface debris is and remove it from the water in rivers before it makes its way to the ocean. Our proposed solution is also applicable to lake debris, as marine debris is not solely focused on oceans and rivers. There is a continually growing need to address the problems of mismanaged waste in our waterways.

B. Design Idea

We started with the idea of creating a robot that could maneuver around low current water sources and pick up floating debris as a way of testing the viability of larger, more aggressive solutions that can be implemented in the future. Our main goal for the robot is to create a system that can act as independently as possible. The major topics we wanted to address in the independence of our robot were focused around limiting the amount of interaction and time needed to maintain its ability to pick up debris. We envision a system where someone can set the specific pathing of the robot, and then be alerted when the bin is full, or the batteries have been depleted. With a focus on convenience, our idea was to set a home location for the robot and when the batteries are low or the bin is full, it could make its way to that home location and send an alert when it has arrived.

There are many different ideas and products currently available whose sole purpose is collecting marine debris from sources of water. The ones that are available seem to be either prohibitively expensive, or provide a solution to specific locations, like the Baltimore Inner Harbor Water Wheel or . These solutions are great for marinas and higher flowing rivers, but we wanted to focus our efforts on an affordable solution that could be set up with relative ease and would require minimal human interaction.

C. Work Breakdown Structure

Due to Project Plastic Abatement having many unique features, each group member was assigned a specific portion of the project based on their experience and skill set. Our group considered this form of breakdown to be effective as it simplifies our project at the start of the design process for our group members but will allow us to easily integrate all of these specific portions into a single prototype.

To summarize our project and its features, our rover will be able to autonomously navigate through pre-mapped routes in a lake or river while collecting small plastic items in its path. In order to implement this design, there were many features and components needed. These features include the implementation of the following: a flight controller that will be able to flash specific software, a GPS module so we can monitor the rovers location, a radio telemetry module that will allow us to communicate with the rover from a ground station, underwater thrusters as a form of propulsion and steering, a LiPo power source, a structurally sound design for our rover, and an efficient bagging system for plastic debris.

As mentioned earlier, each of these features were assigned to specific group members in order to take advantage of our skill sets and minimize the need for constant group meetings due to COVID-19. The project overall costs approximately $700 and the money spent per member was determined by the hardware needed by each member to implement their assigned features.

Rodrigo predominantly focused on arranging the flight controller alongside its other hardware components. These other hardware components consisted of the GPS module, and the radio telemetry module. Rodrigo also was responsible for the software component named ArduPilot *Mission*

Planner which will allow us to monitor the rovers movement as well as other metrics. Due to many hardware components requiring direct communication with the flight controller, our group believed it would be best that a single individual be responsible for their implementation.

Jonathan worked on the electrical aspect of the project as his focus was on configuring our main power source. He was also responsible for testing and implementing the underwater thrusters as well as the implementation of an electronic speed controller. Jonathan decided that a 40A LiPo battery would allow us to have a runtime between 15 to 25 minutes meaning our rover would be able to navigate routes and collect plastic for this time.

Arnulfo was responsible for constructing the actual structure of our rover. He decided that using PVC pipe would be our best option due to its flexibility. This feature was important as we want to ensure the rover is compact enough to the point where it supports the weight of our hardware as well as avoids tipping over during turns. Since Arnulfo also has experience with electronics, he helped Jonathan configure the power source as well.

Robert held research on effective methods of collecting plastic and was also responsible for implementing these methods. He decided that a bagging method would be best as we can maximize our capacity for collecting plastic. Robert was also responsible for finding ways to waterproof our main hardware components as our rover will be tested on water. Due to his experience with software, Robert also helped Rodrigo with the configuration of ArduPilot *Mission Planner* and its parameters.

D. Project Timeline

With the usage of both the GANTT chart and PERT diagram, our group will be able to develop a full understanding of what needs to be completed by specific dates. Despite our group already recognizing tasks and work packages in our work breakdown structure, we will now be able to recognize firm deadlines and milestones needed for our project to be considered complete.

E. Risk Assessment

The risk assessment process is our group's way of trying to preempt issues related to our design, as well as acknowledge anything that will hinder our progress that is outside of our control. These risks include environmental risks, technical risks, logistical risks, and systemic risks. In determining the potential risk in each category, each member will outline the specific risks associated, as well as how we plan to mitigate the risk factors.

F. Problem Statement Revision

In order to tackle a societal problem as large as plastic pollution in oceans, a much more focused approach must be taken in order for this issue to be solved in the long run. Lakes and rivers tend to be the source of plastic due to them being near more populated areas and low level terrains. Therefore, our group will primarily focus on collecting plastic debris located in lakes and rivers to prevent further plastic from reaching oceans.

G. Device Test Plan

As we work towards our end goal, the main point of all this is to have a deployable prototype. There are many different factors that will go into this final prototype. With all our different components comes many different risks. As a team we will try to minimize these risks and run as many tests as possible so that in the end we as a group are sure that our Rover can withstand a list of different variables.

Just as a brief summary we will look into testing the structure of our rover, the power of our rover, and even the trash collection part of our rover. Some of these tests are more definitive and have specific numbers, while others will be more pass or fail. However we will dive deep into the areas and hope that we can cover most if not all variables that need to be tested.

H. Market Review

In order to refine our current prototype, we needed to identify the market it would be entering including competitors, our consumers, and overall environment of our prototype. After conducting research, we have found our model to be the most affordable solution for local lakes and river departments to utilize to collect water waste. Although our model is extremely affordable in comparison, we will need to refine our collection method as other models are able to collect more waste.

I. Testing Results

After formulating an effective test plan, our group completed all tests needed to verify if our rover is functional or not. Some of our fundamental tests included testing the reliability of the rovers frame, the battery operating time, and also a variety of signals coming from the flight controller or the telemetry radios. These tests have proven and confirmed that our prototype is not only fully functional, but also deployable.

II. Societal Problem

A. Problem Statement

More and more waste is produced on the daily. At the moment humans produce approxima-tely 360 million metric tonnes of plastic per year [1]. According to the EPA, that is not slowing down anytime soon. We are projected to increase the global waste generation by seventy percent in the year 2050 [2]. All of this waste doesn't all end up in landfills.A portion of it goes into creeks and rivers which ultimately end up in our oceans. Specifically eight million tons of plastic end up in our oceans every year [4]. Not only does this cause a problem to marine life but it also affects ecosystems and with plastic washing on shores around the world it also affects tourism [4].The ocean is vast and it can be difficult to pinpoint the location of where the waist is. It is nearly impossible to track garbage unless it accumulates in large masses.

Another study done by the EPA states that nineteen percent of coastal plastic emissions travel by river [2]. We can mitigate the amount of waste in the ocean by not letting it get there in the first place. Knowing that the rivers are chokeholds we can prevent garbage from making it out to the ocean. At the moment, the amount of waste that is already in the ocean has had a huge impact on marine wildlife. over 690 different marine species have been affected by the plastic that accumulates in their habitat [3].

Due to the immense amount of plastic present in the ocean, it was clear that our approach to simply send out a rover to the ocean would be a shortsighted approach in potentially solving this societal problem. After further research, it is clear that we must take a more focused approach and extend our concern to local lakes and rivers rather than large bodies of water such as the ocean. As of today, there is plenty of information that indicates plastic pollution in oceans is just as big of an issue as plastic found in freshwater ecosystems, specifically lakes and rivers [7]. The reasoning behind this is because lakes and rivers serve as more than waterways for oceans but also as streams that carry plastic[8]. Majority of the plastic found in the ocean primarily comes from freshwater ecosystems due to them being closer to valleys and lower elevation terrains. Therefore, it is important that our design is able to navigate freshwater ecosystems and collect plastic before the current takes them closer to oceans.

A major point of concern also comes from how larger plastic waste degrades into microplastics once it gets into these environments. Once in terrestrial or aquatic environments, the plastics get fragmented and the resulting microplastics can make their way into our drinking water and into our bodies through the foods we eat [8]. The ramifications of this plastic is dire to marine life and can have harmful implications to their health. Overall, something must be done before it is too late. We need to come up with a possible solution in order to reduce the waste that makes its way into the habitat of marine wildlife and cleaning the rivers is a step in the right direction.

III. Design Idea

A. Project Plastic Abatement

Project Plastic Abatement is a fully autonomous rover that will allow us to minimize the number of plastic that is polluting our local water bodies. For short, we will refer to Project Plastic Abatement as PPA. To put it plainly, plastic has polluted our water bodies for a considerable amount of time to the point where marine life is being harmed. It is estimated that approximately 360 metric tons of plastic are being produced per year [1]. More often than not, a large portion of this plastic ends up in our rivers and lakes. PPA will be able to travel through low-current bodies of water and follow pre-mapped routes that are considered to be highly-polluted zones of a river or lake. These pre-mapped routes will be determined and laid out by the user via a user-friendly interface. Once the rover is placed on water, the rover will begin the route and propel itself using underwater thrusters. As the rover proceeds through the route, it will be able to steer in any direction needed using the underwater thrusters. The rover will collect any plastic in its path using a meshed container. This collection process will occur simultaneously with the rover navigating its predetermined route. Once the rover has completed the route, it will return to its initial starting position.

B. Design Philosophy

As stated earlier in the report, a large struggle when constructing and deploying rovers to collect water debris is the need for manpower. Most solutions to this societal problem require a crew or staff to control an aspect of the device whether it be steering, power control, and actually controlling a crane or claw that collects trash. While having a crew may be beneficial in some instances, the amount of debris in our local water bodies will always outnumber the number of staff members needed to operate such devices. Therefore, our water rover was designed with the focus on autonomy. This means our goal from the start was to design and develop a vehicle that was capable of navigating specific areas of water bodies without the need for human input or interference and collecting trash along the way. Our overarching philosophy within our design process was that a crisis as large as plastic pollution in water will require hundreds if not thousands of devices similar to ours in order to help alleviate the amount of damage that has been done to marine life.

In order to build a fully autonomous rover, it was important that we had a centerpiece capable of playing the role of the "brain" of the rover. A more specific name would be a flight controller which would control every aspect of our rover. We found the Durandal H7 PX4 to be an ideal candidate as it would allow us to flash specific software and it would enable us to control aspects of our rover that would otherwise require a human. The flight controller will be responsible for directing the motors of essential components such as our 2 RC Boat underwater thrusters and our GPS Modules. The flight controller will also collect data necessary to verify specific metrics needed to verify our prototype's utility. Examples of these metrics are speed, distance traveled, and current used. This is by far the most essential component of our water rover.

From a software perspective, it was vital that we would be able to communicate with our rover. This communication will take place through an open source software suite named ArduPilot. ArduPilot is a software suite that will allow us to communicate with the device in the form of direction. Utilizing both the Durandal H7 PX4 and the GPS Modules, ArduPilot will enable us to plan out missions and lay out specific routes we want the rover to travel. This eliminates the need for human steering control which is a facet of our rover that separates it from past solutions to this societal problem. ArduPilot will be our user-friendly interface allowing the user to both lay out specific routes and also monitor the rover's progress. ArduPilot will also receive data from our flight controller such as speed, distance traveled, and current. Although ArduPilot will be key in communication, this mainly applies to when we have a finished prototype.

In order to ensure our RC Boat thrusters, rover structure, and power system are reliable, we will be utilizing two 915 MHz radio telemetry modules to communicate with the rover. This telemetry radio will allow us to communicate with the rover and transmit important data such as routes, current voltage of LiPo batteries, and distance of rover. This will be vital to our design as it will allow us to see how the rover is doing on long distance missions.

Our method of collecting debris was designed with the intention of being efficient and capable of collecting considerable amounts. Therefore, we decided to avoid the usage of any claws or cranes within our design process. Past solutions to this societal problem often included these methods of collection but struggled due to its need for manpower but also its effectiveness. Our group agreed that the usage of a simple mesh container or bagging system attached to the rover will allow us to collect an abundance of plastic without the need of slowing down in order to pick out the plastic. This mesh will allow our rover to collect trash as it navigates through pre-mapped zones.

C. Design Uniqueness

Although there have been many rovers designed to complete the same task, we consider our design to be very unique in many aspects. As stated earlier, the main aspect of our rover that makes it unique is that its final prototype will be fully autonomous. Most designs usually require a person to direct the device usually from a ground station. Although this has its benefits, there is too much plastic polluting our waters to the point where manpower becomes a bottleneck. There have also been designs that have been autonomous but often fail in two aspects. The first one being that it harms marine life. Many rovers are often too large and collect plastic from 5-10ft below sea level to the point where some marine life may get caught in the collection process. Our rover avoids this issue by simply collecting debris at sea level rather than digging deeper into a waterbody and potentially harming marine creatures. The second failure of many rovers is their cost. Many rovers such as *FRED* cost upwards of $35,000 to obtain. *FRED* is a solar-powered device that is capable of collecting marine plastic pollution. *FRED* is simply an acronym for Floating Robot for Eliminating Debris.[4] Although this device is autonomous, it is extremely expensive and often out of budget for utility companies to deploy in lakes or rivers. Therefore, we find our model to be unique due its fully autonomous feature, being harmless to marine life, and being inexpensive in comparison to other autonomous rovers.

From a design perspective, there is no other design out there similar to ours. Though there may be designs that accomplish similar goals in terms of collecting plastic, no other design is similar to ours. Our design utilizes very different hardware components in comparison to other designs. No other design currently uses a single microcontroller as the main component of the rover. Technologies such as *The Interceptor* do not utilize a microcontroller located within the rover but more so depend on a computer located on land [6]. So although *The Interceptor* is autonomous, it lacks the microcontroller technology that we will be utilizing. In our case, the Durandal H7 PX4 is the centerpiece and controls all aspects of the rover. This piece will be wired to other components such as the thrusters, GPS Module, and a radio telemetry module. Another unique aspect of our rover is the method of movement. Majority of designs that tackle plastic pollution use large wheels or a form of cycling to allow for movement. These same designs also lack mobility as they are either very blocky or have poor steering in general due to the large wheels. An example of this design is called *Mr Trash Wheel. Mr Trash Wheel* consists of 2 large wooden wheels on each end of the design [6] This vessel is powered by current therefore makes it dependent on current for propulsion. Our design will utilize underwater thrusters to propel our rover and enable us to keep our design much more compact in comparison to other models. These same thrusters will be used to implement differential thrusting to allow for quick and tight turning. This form of steering in combination with our overall compact design separates our design tremendously from others.

The final aspect of our design that makes it unique from other models is the form of communication between the user and the rover itself. Many designs completely lack a form of communication between the user and the device. An example of this is *The Interceptor* designed by The Ocean Cleanup[6]. This design completely lacks a form of communication between the user and device. *The Interceptor's only* form of communication is when it sends signals to a system to alert the user that its trash container is full. However, this is only a one way form of communication as it's the device that communicates with the user's computer system. The reason why communication going both ways is so important is because many problems can be avoided. For example, using these telemetry radios we will be able to establish a safe and long distance point to point communication signal with our rover. We will be able to receive and transmit a variety of data effortlessly. This data is then presented to us in our user interface which is called ArduPilot *Mission Planner.* Overall, we consider our design highly unique due to its cost, propulsion methods, and communication methods.

Table 1: Punch List

Feature	***Measurable Metric***
Propulsion System for Rover	RC Boat underwater thrusters will be able to provide enough propulsion for the rover to navigate in low current streams at a speed ranging from 0.6 m/s to 1m/s .
Rover will use differential thrusting to turn efficiently.	With the implementation of differential thrusting, the underwater thrusters should enable the rover to keep its turning radius under 10m.
Communication system between the user and the rover.	With the usage of two 915 MHz telemetry radios, we will be able to wirelessly communicate with the rover with a maximum range of 300 meters.
GPS Mapping	Utilizing a GPS/Compass module, the rover will be able to update its location at a rate of 5Hz (5 cycles per second) so long as it is within a 300m distance from the starting point.
Operating Voltage and Run Time	Powered by LiPo batteries, the robot will be able to run on between 12 and 24 volts DC. The rover will have an estimated operating time between 15 and 25 minutes.
Rover will be able to complete routes in an autonomous fashion.	Through the usage of a flight controller and ArduPilot software, our rover will be able to complete routes with a maximum distance of 300m at a speed ranging from 0.6 m/s to 1 m/s.
Rover will be structured to reliably navigate through routes without loss of balance or sinkage.	Using PVC pipes the Rover will be capable of holding up to 25lb. The dimensions of the structure will be 4 feet in length, 3 feet in width, and 7 inch in height.
Rover will be capable of collecting numerous plastic items at sea level.	Using a wired collection system we will be able to collect a maximum of 20 16oz water bottles.

D. Specific Design Components

The entire design will be centered around a flight controller, specifically the Durandal H7 PX4. This piece of hardware will be responsible for running the ArduPilot Rover Firmware. Additionally, it will be responsible for controlling other components such as our GPS module and any motors that will be implemented. The communication between the Durandal H7 PX4 and other hardware components or motors will be achieved through PWM commands. The Durandal will also be partially responsible for data-logging many of our metrics such as battery voltage, speed, and distance traveled. This flight controller is essentially the brain of the rover.

Figure 1: Durandal H7 PX4 Flight Controller [12]

As mentioned above, our main software component will be ArduPilot. ArduPilot is an open source software system that allows for data-logging as well as mission planning. The mission planner feature will be the software used to flash, setup, and tune our hardware components. Mission planners will also be responsible for zone mapping areas of a lake and will allow us to retrieve any data needed to determine the success of our rover like speed or distance traveled.

Figure 2: ArduPilot Logo [14]

In order to successfully map out zones for our rover, we will need to implement a GPS and Compass module. This module will enable our rover to acknowledge its position, speed, and orientation. This component will be key in allowing our rover to follow routes and also return to its starting point.

Figure 3: GPS + Compass Module [13]

In order to establish connection between us and the rover, we will be using two 915 MHz Radio Telemetry modules. These two modules will be our method of communicating with the rover from our ground station. This form of communication will allow us to upload ArduPilot parameters, upload mission routes, and command the rover to return to its starting position. We estimate that this communication will be functional within a range of 0 to 300 meters.

Figure 4: 915 MHz Telemetry Radios [15]

Our rover will be able to navigate low current streams of water through the usage of RC Boat underwater thrusters. These thrusters will provide our method of propulsion as well as steering. Steering will be implemented using differential thrusting. Differential thrusting occurs when two motors turn in opposite directions therefore allowing the rover to turn in a specific direction. It will be important for us to monitor the motors as our rover could continuously drive in circles if one of them fails.

Figure 5: RC Boat Underwater Thrusters [16]

Our current design is to have a netting style type of trash collection. We would essentially make one big net out of landscaping fence material. We made it slightly wider than the rover by a few inches, just as long as the rover and about a foot deep. With it we will be able to collect a decent amount of trash and because of the material of the fencing it should be fairly sturdy. With the size of the bag being about 12 inches wide and 30 inches long we should be able to hold quite a bit of trash with our trash collection system. It should be able to store and carry around about 50 bottles, so we will be in very good shape. Then with our open mouth style collection system at the front of our rover we will be able to collect a variety of sizes of plastics and trash. I think our only thing we have left is to decide how we know when to stop collecting because a. the bag is full or b. we caught something we shouldn't have.

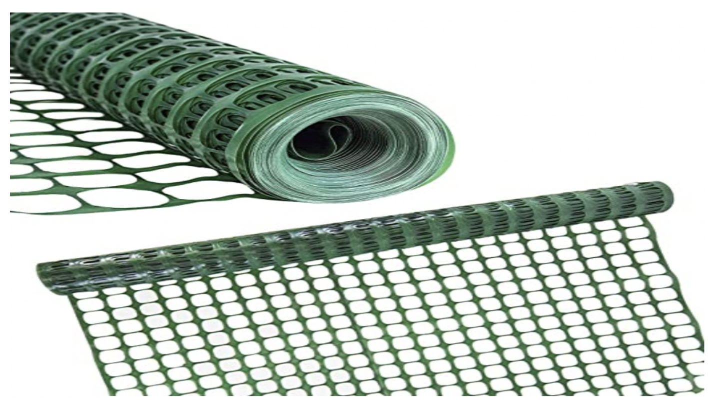

Figure 6: Landscape Fencing Trash Bag [17]

For our structure we will be using a PVC pipe that is 4 inch in diameter. The structure will resemble a trapezoid where it will be wider in the base for better stability but big enough at the top to be able to carry the box that will have all of our electronic components. This design is our best option because it provides good balance all around and with the base being larger there should not be a point in when the structure loses its center of gravity and tips over. Below is a sketch of our proposed design. It illustrates our intended dimensions such as width, height, and length. It also labels the location of our hardware as well as other materials.

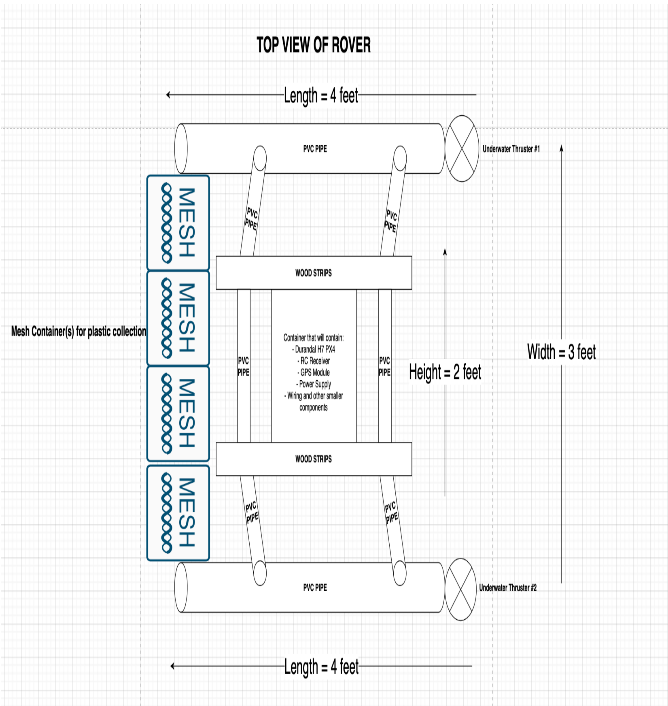

Figure 7: Rover Structure [18]

IV. Funding

A. Funding Source

Our project will be fully funded by our group members. Therefore, there will be no sponsors or any form of outside funding for our project. Our group has decided on a budget of $700-$800 that will be spread among our 4 members and concluded that it will be sufficient enough to build our design idea.

B. Cost Estimate

Table 2: Itemized List and Total Item Cost

Item	**Source**	**Cost**
Durandal H7 PX4 + Power Distribution Board	Amazon	$275
GPS Module	Amazon	$28.99
RC Transmitter	Amazon	$54.99
Wires	Amazon	$23.99
RC Receiver	Amazon	$38.49
PVC Pipes	Home Depot	$76.84
RC Boat Underwater Thrusters	Amazon	$59.99
Mesh Collection	Amazon	$24.48
	Current Total:	$582.77

V. Work Breakdown Structure

Project Plastic Abatement was split up into four different parts. These parts are based on the many components needed to construct our rover. These parts are the following: microcontrollers/modules, power sources/thrusters, rover structure, and plastic collection. Each part was assigned to a specific group member based on their skills and experience.

To be specific, Rodrigo was responsible for the microcontrollers/modules section which consisted not only of the main microcontroller board, Durandal H7 PX4, but also other hardware modules such as the GPS unit, and radio telemetry module. In order to test these units, a software named ArduPilot *Mission Planner* was also part of Rodrigo's section.

Jonathan was in charge of the power source/thrusters section due to his experience with circuits and power. This section consisted of configuring our main source power in terms of runtime, safety, and its ability to function with the rest of our hardware components. Configuring the thrusters is also part of this section due the thrusters being directly wired to the components such as ESCs, batteries, and power distribution boards which all fall into Jonathan's area of experience.

The design and construction of the rover itself was assigned to Arnulfo. This section is essential due to the hardware and electrical components relying on this structure to sustain them during water navigation. This part was specifically assigned to Arnulfo as he has experience with configuring circuits so he will ensure the rover will be able to host wires of various lengths without coming in direct contact with water. Arnulfo was also assigned to provide assistance to Jonathan in regards to configuring our power source and its components.

In terms of plastic debris collection, Robert was responsible for holding a vast amount of research that consisted of collection methods of current designs and finding which method will be most effective. In addition, Robert also coordinated these methods with Arnulfo in order to ensure the rover will be able to support certain methods of collection. Robert also provided technical support to Rodrigo in regards to the main software component ArduPilot *Mission Planner*.

In order to complete each individual section and integrate them into our final prototype, it was vital that our group further broke down these sections into subsections. These subsections consist of smaller tasks that will allow each member to efficiently complete their initial part. Both the 4 unique sections and their corresponding subsections can be easily seen on a tree-like diagram that makes it easier for us to monitor the progress of our project.

Work Breakdown Structure Overview

1.1 Propulsion and Steering System

Our rover will be able to propel itself across low current streams of water as well as effortlessly turning as needed throughout its route.

1.1.1 Underwater Thrusters

RC boat underwater thrusters with brushless motors will be our sole method of propulsion due to their compact design, power, and ability to mesh well with our design.

1.1.1.1 Voltage Supply Calculations

We wanted our boat to run on LiPo batteries because they meet a good price and performance to size for our projected footprint. The thrusters were chosen based on their operating voltage over 12-24 volts DC and the batteries were chosen with the understanding that more could be added in parallel for a higher capacity if we don't meet our initial run time estimates.

1.1.1.2 RC Communication with Microcontroller

In order to implement the thrusters, an RC transmission controller will be used to simply verify functionality of thrusters.

1.1.2 Differential Thrusting

By changing parameters within ArduPilot, we will be able to give each thruster an individual role when turning hence providing the rover with the ability to complete tight turns.

1.1.2.1 Software Implementation

This feature will be mainly implemented by configuring parameters within ArduPilot that will allow each thruster to throttle in different directions.

1.1.2.2 Turning Radius Testing

Once this feature is fully implemented, it will be tested manually using an RC transmission controller in order to ensure the rover can make sharp turns in an effortless fashion. This feature will be tested once again in an autonomous manner and the turns will be determined by the routes that were mapped out.

1.2 Wireless Rover Communication

In order to monitor our rover, we will need to implement various forms of wireless communication. These communication channels will enable us to establish a two way form of communication between the rover and our ground station.

1.2.1 Radio Telemetry Modules

2 915MHz radio telemetry modules will be implemented in order to establish a wireless connection between our user interface and the rover itself. A module will be wired into the flight controller which will be on our rover. A second module will be attached to a computer running ArduPilot via a USB dongle.

1.2.1.1 Software Implementation

Our software component named ArduPilot will need to recognize the radio telemetry module attached to the USB port as well as recognize the second module wired to our rover. From here, both modules should be able to communicate with each other. It will allow us to update routes, monitor the rover's location, and track its speed.

1.2.1.2 Range Testing

Our radio telemetry modules will be tested by determining how far each module can be from each other and maintain the ability to communicate with each other. In order to maximize the societal impact of our rover, we will look for a range between 0 -300 meters.

1.2.2 RC Transmitters and RC Receivers

A FlySky RC transmission controller and a 2.4 GHz RC receiver will be used for a short period of time to verify the functionality of the two thrusters and the floatability of the rover.

1.2.2.1 RC Transmitter Channel Calibration

Our RC channels will need to be calibrated and mapped in order for us to perform certain actions. This process will consist of giving each stick on the controller an assigned action when moved. Once the controller is fully mapped, we will be able to manually throttle or steer.

1.2.2.2 Range Testing

Once again we will need to test the range of the RC transmitters and receivers. This will consist of us throttling or steering the rover until we reach a distance where the strength of the signal is lost or weak. Similar to the radio telemetry modules, we are looking for a range within 0 - 300 meters.

1.2.3 Ground Station

Our ground station is where any data or metrics will be displayed in order for us to fully monitor our rover. Our ground station will primarily consist of a user friendly interface that will display data such as the rovers location, its speed, and voltage.

1.2.3.1 ArduPilot Firmware Setup

The user interface we will be utilizing to display data collected by our rover is named ArduPilot. Once the software is flashed and configured to match our design, ArduPilot will be able to provide a map locating our rover alongside providing real time measurements of its speed and voltage. This process will not only flash the software but also ensure it is able to communicate with all hardware components.

1.3 GPS Mapping System

In order to make this rover fully autonomous, a GPS mapping feature will be implemented. This feature will enable the user to map out routes on a lake or river which the rover will then navigate through without human input. This feature will be made possible by implementing a GPS system as well as configuring the ArduPilot software.

1.3.1 GPS and Compass Module

A GPS module with a built in compass will be integrated into our design in order to provide both the flight controller and the user with data regarding its location. This module will be responsible for tracking its movement as well as sending any relevant data to the ground station via the radio telemetry modules.

1.3.1.1 GPS and Compass Module Calibration

The GPS and compass module will need to be calibrated in order for it to be fully functional. This process will consist of calibrating its orientation, accelerometer, and compass. This will be done in coordination with ArduPilot as the software will need to know its calibration settings in order to provide correct data to the user.

1.3.2 Ground Station

As stated above, the GPS and Compass module will be coordinated with ArduPilot. This will allow for ArduPilot to provide correct data such as its current location, speed, and orientation. This will also allow us to map out routes using ArduPilot which the rover will then be able to navigate through.

1.3.2.1 Test GPS Update Rate

The rate at which the GPS module provides its updated location will be measured using the ArduPilot software. This will be key as we will then be able to monitor the rover as it travels through routes. Our aim here is to reach a rate of 5 MHz as long as our telemetry radio modules are within range of each other.

1.3.2.2 Complete Mapped Routes with Rover

The final test to determine if our GPS mapping feature is fully functional will be by mapping out a route on a lake or river and determining if the rover completes it in a smooth fashion. As long as our telemetry radios are within range, our rover should be able to navigate through these set waypoints while transmitting its location to our user interface ArduPilot.

1.4 Central Power Source

The rover will have a run time of between 15 and 25 minutes. We want to be able to travel a predetermined path without the need for intervention, and a critical component of that is having a sufficient battery capacity.

1.4.1 Battery Capacity Requirements

The initial battery requirements were set at 14000mAh with the understanding that the average current drawn from the rover during operation will need to be tested.

1.4.1.1 Runtime Testing

Total operation time will need to be tested after our understanding of average current draw can be estimated with the speed of the rover. After we have sufficient data, we can set the rover to run with different thruster speeds to ensure we are within the desired run time of 15 to 25 minutes.

1.5 Rover Structure

The rover structure will be strong enough to withhold the water conditions and any obstacle that is peasant while in route. It will be capable of holding up to 50lb which is more than enough to carry our hardware and even some trash along the way.

1.5.1 PVC Pipes

The PVC pipes will be used to create the structure. These pipes will be 4in in diameter. Since PVC is water insoluble it would make for the proper material needed to execute this task.

1.5.1.1 Rover Structure Design

The rover will be designed as a trapezoidal shape. The base will be 4ft by 3 ft. and the height of the structure will be less than 1 ft. Also wooden cross beams will be added to provide rigidity and stability to the structure as well as a solid base for our box.

1.5.1.2 PVC Pipes Assembly

The PVC pipe will have to be assembled according to the dimensions in the rover structure design.This process will include cutting the PVC pipes to the correct size. As well as bonding the materials together in order to have a solid non leakable structure.

1.5.2 Buoyancy Testing

This test will determine the overall stability of the structure and if capable of not typing over. The test will be done by submerging the structure in water and observing for any air leaks. As well as applying downward force on each side to observe if the structure will hld and come back to the surface of the water.

1.5.2.1 Weight Capacity Testing

The weight capacity will be tested to determine the maximum weight the overall structure can handle before it sinks. This will be determined by using calibrated weights in the structure about 50lb.

1.6 Plastic Collection Method

With our Plastic abatement project we had to find the best way to collect trash both big and small with our rover. With that we decided that we would use mesh trash bags that we could attach onto our rover as our way of collecting trash.

1.6.1 Mesh Trash Bag

We decided on a mesh trash bag. We will be using two bags. They run about 12 inches wide and 24 inches long. They can collect a variety of small and big pieces of plastic.

1.6.1.1 Mesh Bag Capacity

In the end we will have to actually see how much weight we can attach to our rover. However, according to this mesh bag we can carry almost 20 16oz bottles. So that will be good enough to collect quite a bit of trash. However we need to see how much the rover can actually take.

1.6.1.2 Mesh Bag Attachment

We haven't yet decided how we will do this quite yet. However we are sure it will at least be under the rover. Whether we glue or drill it onto the rover will be the next step we solve. I do not want to put too many holes in the rover and cause water to enter the pipes so that is something to think about.

1.6.1.3 Keeping Trash in Mesh Bag

The last thing I will be focusing on is how to keep our trash in our bag. We don't want our rover to collect all this trash and then once it's done have everything float out. So that is my last thing to decide how we can keep everything in there at the end of the rovers “shift”.

VI. Project Milestone and Timeline

For this section we will be illustrating our project milestones as well as our Timeline for completion. In order to ensure that we complete our task in a timely manner, a Gantt Chart and PERT Diagram were created. Within these charts appear our Project milestones which ensure the completion of our project. These Milestones were chosen by the group to represent items that must be completed to ensure we finish our project in time. Our Class Assignment Milestones are listed as follows.

List of Class Assignment Milestones:

- Design Idea Approval
- Prototype Progress Review
- Project Technical Evaluation
- Functionality of Main Features

Similarly we created a set of milestones considering major build features for our prototype. From here we made out a Gant chart, and PERT Diagram which fully illustrates the steps needed to complete our Rover. Each one of these components are required in order for us to fulfill our design idea contract.

Major Build Features for Prototype:

- Autonomous Mapping Feature
- Propulsion/Differential Thrusting
- Power Source
- Wireless Rover Communication
- PVC Structure
- Plastic Bagging Method

The importance of each of these individual Milestones can be better described in our Work breakdown Structure. Before we got to this point the team had to go through a portion or when large amounts of research was being done. We each individually came up with a project. from each individual member we came to the deception of just one. This idea was to create an autonomous water rover that can clean up garbage as it is navigating through rivers and lakes.

Once we decided to move forward with the autonomous water rover that can clean up garbage the team split up the task in four. We began by researching four main components to this Autonomous rover. One of these tasks was finding the proper solution to power our rover. Jonathan was in charge of this task and he came up with dual LiPo batteries that store up to 7K what hours each. Jonathan also ensured he had a power management system in place in order for us to manage the batteries while the rover is in use.

The second major component is the Structure of the rover, for this task Arnulfo was in charge. He researched the proper material that would need to be used. As well as drawing a schematic for the rover in order to ensure proper balance and buoyancy so it can hold the amount of trash required by our mesurables. His solution was to use PVC pipes in the shape of a trapezoid so the base is wider than the top to ensure the rover doesn't flip over.

The next major build feature that is crucial for our project is the Propulsion/Differential Thrusting as well as the Autonomous Mapping Feature, and Wireless Rover Communication. For this portion Rodrigo was in the driver seat. He researched and found a software called Ardupilot. Using this we can control the rover Autonomously using a GPS module and mapping feature the River will be capable of flowing in the water with ough any interaction from us. The trustees themselves will be the sterling mechanism of our rover.

The last Major build feature that needed to be researched was the thrash collection system. For this Robert took the lead and came up with a few solutions.The main solution he came up with is using a mesh bag that we will adjust to the river and will collect trash as the rover is maneuvering through the water. This solution is eco friendly and wont endanger any wildlife.

After getting our project approved, we all move forward with our individual portions by purchasing the required material needed. Arnulfo purchased and built the PVC Structure. Jonathan purchased the LiPo batteries and wired the power monitoring system for them. Rodrigo purchased and calibrated all the components of the mapping features, Propulsion / Differential Thrusting, and wireless communication. And Robert purchased the water proof box and Mesh bag to use for our trash collection system.

Our next steps are to research and purchase any needed hardware, wires, or harness needed in order to mount our thrusters to the PVC Structure as well as mounting our waterproof box. Once all these materials are purchased we can move forward with the build and begin testing in water with a prototype that is complete. The final step would be to ensure our rover is completing the predetermined maps route assigned as well as picking up trash along the way.

VII. Risk Assessment

Environmental Risk: (A)

As an engineer there are many factors that are in our control but, there are also factors that are out of our control. One of those is the environment and what mother earth has to offer. For the past few years, we have seen many environmental risks that may have an impact on the completeness of our project. These risks for the most part are low in probability ranging from 0% to 19%. They may be unlikely but the impact they can have can range from low to severe.

One major risk that California as of recent has been susceptible to is fire. In the past few years, there have been more wildfires than in the previous years. Wildfires not only cause a risk of possibly burning down areas that members of our team live close to, but there is also the hazard of the smoke. There is close to nothing that can protect us from the smoke, and something like that can cause a closure at Sac State which has happened in the past.

Other Environmental risks pose threats as well such as flash flooding, earthquakes, and thunderstorms. These risks have not been as common but can come out of nowhere with no warning. Flooding is very unlikely but still poses a risk especially having a river so close to us here in Sacramento if it were to overflow and flood it can cause some serious issues. Similarly, thunderstorms are not very likely but can cause delays for when we want to do testing outside. Earthquakes are also not very common but being in the state of California can cause a serious threat and can range from little to no impact if it's a category two or lower to serious impact if it's any higher than a category four.

Some potential impacts that can come from these environmental risks range from little to no impact up to Intolerable Impact. Fires can typically range from Medium-Impact all the way up to Intolerable impact depending on how close to home the fire is. Similarly, floods and earthquakes can also range from Low impact up to High impact. At the same time, most of the probability of the risk is low from 0% to 19%. Although they can have a high impact they are very unlikely and not expected to happen.

There are different ways to possibly mitigate these risks. For floods or severe weather storms, a way to mitigate these can be to constantly monitor the weather condition from resources like water stations, apps, or weather channels. Usually, these are predictable and with proper planning can be avoided therefore the impact is low and the probability is as well. Another Threat is earthquakes, but unlike severe weather storms, there are no ways to predict an earthquake. Also, earthquakes can range from little to no impact all the way up to high impact. Ways to mitigate this is to have a backup plan or spare parts placed at different members' homes. We all live in different areas and it is not likely that we will all be impacted the same due to an earthquake.

A risk like a Wildfire is more unpredictable and is not easy to predict. However, the conditions in which wildfires thrive are predictable and power companies such as PG&E and SMUD have found ways to mitigate some of these risks by shutting off power when there is or will be high winds. For mitigation, the team has determined to stay constantly monitoring the weather channels as well as having masks that can protect us from the smoke if we need to meet up outside for testing purposes.

Technical Risk: (B)

The technical risk can be broken down into power risk, design risk, and construction risk. The power risks include improper powerup with polarity swapping, which would burn up our power management board and potentially destroy the other components as well. The rover could continue to operate when the batteries reach a critically low operating voltage, which could damage the thrusters through overheating and reduced life. We have mitigated the risk of improper battery hookup by having battery connections that can only be plugged in one direction. The battery critical voltage is also being monitored by the power management board to ensure that we will have a measure in place once the batteries begin to deplete. The final thing that should help mitigate any electrical damage to the batteries in case of a short circuit anywhere down the line is the use of a fuse on the power line of the battery leading to the distribution terminals. The idea is to cut off power between the battery pack and the rest of the power distribution in the event of a short circuit or any other unwanted high current draw.

The next risk comes in an improper design relating to our electrical housings and box. If we get any water inside the main electrical box, there could be short circuits and damage to all of our components. These risks are being mitigated through our use of a weather resistant electrical box which should not let water in if it were to rain or if we have some splashing while the rover is in operation. The other water intrusion into the box could come through the antenna hole, which will be mitigated by using a gasket maker to ensure a watertight seal.

The final risk factor comes in through the frame design. Since we are using PVC as our buoyancy source, any water getting into the structure will eventually cause our rover to sink. Sealers were used between the PVC connections, and anywhere that wires are breaching the PVC are being sealed with a marine sealer to ensure all aspects are watertight.

Logistical Risk: (C)

I think throughout our project one of our biggest concerns has been the availability of our products. The way everything is going with COVID-19 we just weren't sure how hard it would be to get what we needed. Not only that but we were also concerned as to what our shipping times would look like. Fortunately we were able to get everything we needed in a timely order. However to mitigate these issues we made sure to order everything early to ensure enough time for everything to arrive. Like I stated at the beginning we were able to get everything we needed. I think as we go we may need to order little things. As far as our big items though, we do have everything. In the end I would say this was our biggest logistical issue. But we were able to beat it in a sense, and hopefully it won't be an issue later on if we need to order more parts.

Systematic Risk: (D)

There are many events that occur throughout life that cause severe problems for individuals and teams as a whole. Examples include health issues, automobile accidents, and personal problems in general. To be specific, as engineering students nearing the end of their time as undergraduate students it is often stressful to balance both the completion of your studies as well as beginning the shift into the engineering industry. These stress levels often lead to personal and academic crises. However, there are still many options our group has discussed that will allow each of our members to maintain low levels of stress and mitigate any impacts on the success of our project.

There are many resources available on campus such as counselors or advisors specifically within the ECS department that can help our group if needed. Our group plans on utilizing these resources when any of us feel as if we are going through personal or academic struggles as engineering students. This will be a major key to our success as any personal or academic crisis within our group will lead to our progress coming to a complete standstill. Although we prefer to distribute the workload equally, our group will gladly take on additional work for a group member for a short period of time if we feel they are going through some sort of crisis.

In the past two years, the world, in general, has gone through a health crisis via COVID-19. In order to ensure our group remains healthy, each of our members has been vaccinated prior to in-person group meetings. In addition, any in-person group meetings that have been held thus far all followed COVID-19 protocols such as the usage of masks. Unfortunately, social distancing is a protocol we will not be able to follow at all times as we may have two or three members working on the same power board or microcontroller. However, our group is confident that we will be able to avoid health issues specifically COVID-related due to our vaccination status and usage of masks.

There is an obvious risk we run outside of the project such as car accidents on the way to a group meeting that is hard to avoid in many cases. Although each of our members practices safe driving, many accidents have been caused due to the negligence of other drivers. In order to mitigate this risk, our group primarily meets on campus so that our group has many routes to get there in case we want to avoid the highways. As stated earlier, in any unfortunate event our group will gladly take on an additional workload if needed to help a group member recover from any sort of injuries.

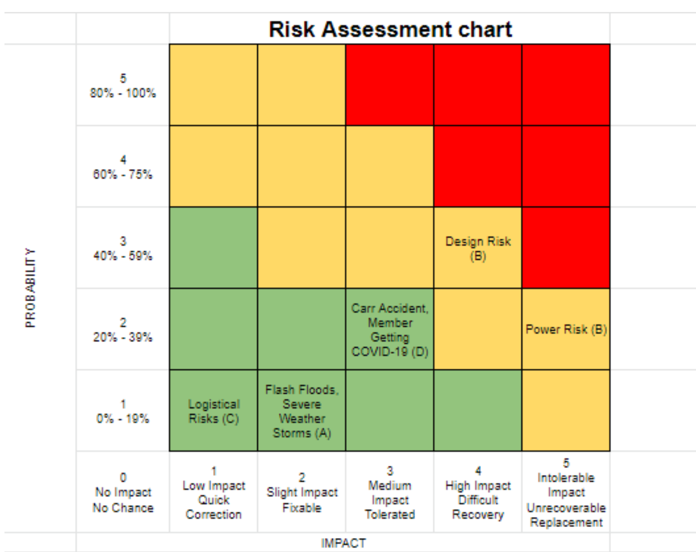

Figure 11. Risk Assessment Chart [19]

VIII. Deployable Prototype Status

As the semester moves along, our group will progress the lab prototype we built in the first semester into a deployable prototype. In order to accomplish this, we will be testing all major components of our design such as our thrusters, flight controller, LiPo batteries, and the rover structure itself. A variety of tests will be held to provide information regarding what kind of improvements should be made if needed. As it stands, our current design meets all measurable metrics in satisfactory fashion. The rover can follow routes set via ArduPilot and follow them at an approximate speed of 1 m/s while collecting plastic debris simultaneously. To be specific, we will be shifting our focus to the larger components of the prototype. Below is a simple overview of the larger components and how we plan on testing them.

A. Rover Structure

Since our rover will carry both hardware and plastic, we will want to test the durability of the rover to prevent issues when it is out on the water. Major tests include the weight required to sink the rover, the amount of impact needed to break/fracture the PVC structure, and also how much weight can the rover hold before it hinders the performance of the rover. These tests will indicate what kind of improvements will need to be made to the structure prior to confirming that it is a deployable prototype.

B. Brushless Motors / Thrusters

We have two DC brushless motors located at the rear end of the rover which are responsible for the vertical and lateral movement of the rover. These are essential to the success of our prototype. Therefore, tests such as thrust, RPM of motors, turning radius, and speed in multiple scenarios will be held. To be specific, we will be testing the speed the rover can reach while the collection tray is at different capacities. We will also be testing how it does in different environments such as lakes with current and lakes with little to no current.

C. LiPo Batteries / Power Source

Our rover is powered using a single 14000 mAh LiPo battery with a second one on standby. This battery is responsible for powering both our ESCs/Motors as well as our flight controller. To prove that this power system is effective, we will be taking many measurements such as the capacity of the battery, duration of battery when in use, and output voltage of the battery. The overall goal with these tests is to ensure our batteries can provide enough power for the rover to operate between 20-25 minutes.

D. ArduPilot Software / Hardware

Due to our main feature being autonomous travel, we will ensure that the rover can navigate routes in an accurate manner. This means that the rover will stay on track with the set route rather than drifting off. There are several software/hardware components that play a role in this like the flight controller, 915 mHz Telemetry Radios, and the ArduPilot software. The telemetry radios will be tested for its maximum range which should be around 300 meters. From here, we will perform various routes from simple to complex to determine if the rover can follow the route.

The following tests will determine which areas require improvement in order to turn our current model into a deployable model.

E. Testing Conclusions

Table 3: Device Test Plan

Test ID	Description	Expected Result	Actual Result	Pass/ Fail	Team Member
#1	Test RPM of thrusters	14,800 RPM	15,000 RPM	P	Arnulfo
#2	Test thrust of thrusters	5Kg / 11.lb	11Kg	P	Arnulfo
#3	Test turning radius of rover	Less than 10 meters	< 10 Meters	P	Entire Team

#4	Test Range of PWM Signal	2200-1500 us	2200-1750 us	F	Rodrigo
#5	Test frequency of PWM Signal from Flight Controller	50.0 Hz	50.1 Hz	P	Rodrigo
#6	Test Duty Cycle of PWM Signal from Flight Controller	+10%, -90%	+11.03%, -89.97%	P	Rodrigo
#7	Test Maximum Range of 915 MHz Telemetry Radios	300 meters	320 meters	P	Rodrigo
#8	Test MAVLink connection between Rover/Ground Station	Sent/ Received Correct Data	Sent/Received Correct Data	P	Rodrigo
#9	Obtain Weight of Entire Rover	30lb	43lb	P	Arnulfo
#10	Compass Accuracy Test		always in general direction with a slight correction	P	Robert
#11	Test ROV operating times over different throttle ranges	15-30 minutes	30+ min	P	Jonathan
#12	Test total weight capacity of rover structure / buoyancy	25lb	< 27lb	P	Arnulfo
#13	Test amount of force needed to fracture structure	2K N	2.18K N	P	Arnulfo
#14	Test Degree	80 Degree	90	Pass	Arnulfo
	required to flip		Degree		
#15	Test Voltage passed into Flight Controller	4.9-5.5 V	5V	P	Jonathan
#16	Test Voltages provided to Motors	14.8-16.8V	14.75-16.8V	P	Jonathan
#17	Test Functionality of Each Thruster	Both Functional	Both Functional	P	Rodrigo
#18	Test Waypoint Accuracy during Missions	Rover should follow each waypoint	Rover followed each waypoint	P	Entire Team
#19	Test Reliability of Waterproof Container	Inside Contents should remain dry	In all our ventures nothing has gotten wet	P	Robert
#20	Test for any Disturbances when using Telemetry Radios	Zero Disturbances	Zero Disturbances	P	Rodrigo
#21	Check Speed of Rover when Collection Net is Empty	0.7-1.3 m/s	.9 m/s	P	Entire Team
#22	Check Speed of Rover when Collection Net is at 50% Capacity	0.7-1.3 m/s	.9 m/s	P	Entire Team
#23	Check Speed of Rover when Collection Net is at 100% Capacity	0.7-1.3 m/s	.7 m/s	P	Entire Team

#24	Test Speed of Rover against flowing current	0.7-1.3 m/s	.6 m/s	F	Entire Team
#25	Test Speed of Rover at a location with zero current	0.7-1.3 m/s	.9 m/s	P	Entire Team
#26	Testing Max Trash Collection	60 Bottles/ Cans	65 Bottles	P	Robert
#27	Test Trash Collection Radius	5 feet	5 feet	P	Robert & Arnulfo
#28	Test Durability of Trash Collection Netting	Might Get Caught, however don't expect any rippage	Has yet to get caught in anything	P	Robert
#29	Test 168 Hours PVC underwater leakage	Should not have any water leak through	No water was found.	P	Arnulfo

Rover Structure

In order to determine the reliability of our rover structure it was put through various tests. One was the weight capacity or buoyancy of the overall structure.We determined that it can hold up to 25 lb. Because the trash being collected is floating on the surface it doesn not add additional weight. To test this we used a 25lb weight on the structure to see if it would sink or float. With the 25ln weight the structure did float however with an additional 5ln the structure would begin to sink. From this we can determine it can hold up to 25lb.

Similarly a test was conducted to determine what would reure for the rover to flip over in terms of degree from the water level. The results were that 90 degrees are required in order for the rober structure to flip on its back rather than fall back in place.

Another test that was performed was the stress fracture test. For this test I dropped a 25lb weight onto a PVC pipe.From 12 Feet a 25lb weight was dropped onto the PVC Structure. From here we took those values and calculated the force at which that weight hit the PVC pipe. We know the velocity due to gravity. The displacement that was used would be the diameter of the PVC pipe. From this we determined that the structure held and is capable of being struck by such force from the following formula $F = \frac{mgh}{d}$ [24] .

Also a test was performed to determine the integrity of the pvc as far as allowing any water to league through and compromise the structure. For this We submerged a caped of PVC pipe and submerged it under water for a week. After a week passed we opened the pipe and found no evidence of any water leaking through therefore were able to determine the structure holds and allows no water leakage.

Brushless Motors/Thrusters

In order to measure RPM an external source was needed such as a photo sensor tachometer. By placing the tachometer perpendicular to the truster the RPM was determined to be at about 15,000 RPM. From this we can see the thrusters provide enough to get the system working properly.

The final test for the thrusters is to measure the trust that they create. In order to measure this there was a rig that needed to be created. The thruster was attached to an arm. This arm was submerged in water and connected to our pull scale. We would then turn on the thrusters which would pull on the pull scale. The value which we read was the number we used to determine our thrust. From this test, we determined that our thrust was around 11kg.

LiPo Batteries/Power Source

Estimating the run time was a bit more difficult than we originally thought because different environments are going to change the load on the thrusters. Jonathan made a test bench using the electrical panel and used spare motors to run at different speed percentages to get a baseline for the run times. Unfortunately, without a real load on the motors which happens during normal operation overcoming currents and moving through water, we can only estimate run time based on previous runs. With our lowest run time being 20 minutes on our original 7000mAh setup, the estimated time for our larger battery pack is around 35 to 40 minutes. The environment that the rover runs in will have the largest impact on the allowable run time, so we can only estimate based on the limited environments we have already tested in.

ArduPilot Software/Hardware

There were multiple tests held regarding both the ArduPilot software as well as multiple hardware components, specifically the Durandal Flight controller. Our group, specifically Rodrigo, ran smaller tests on the connectivity between the telemetry radios as well as MAVLink connection as this is the primary method of data transfer. These tests included the maximum range until the telemetry signal was no longer reliable which resulted in a passing range of 320 meters. The MAVLink connection was also tested by manually looking at the contents of messages sent between the rover and ground station to ensure proper decoding.

However, the primary tests that our group was concerned with was the PWM signals sent from the Durandal Flight controller to the thrusters. This test was used to obtain further data regarding the PWM signal such as duty cycle, signal range, and frequency. This test was held by Rodrigo using an oscilloscope and a probing kit to obtain the PWM signal. Below is an image of the testing circuit that was setup to test the PWM signals from both servos used.

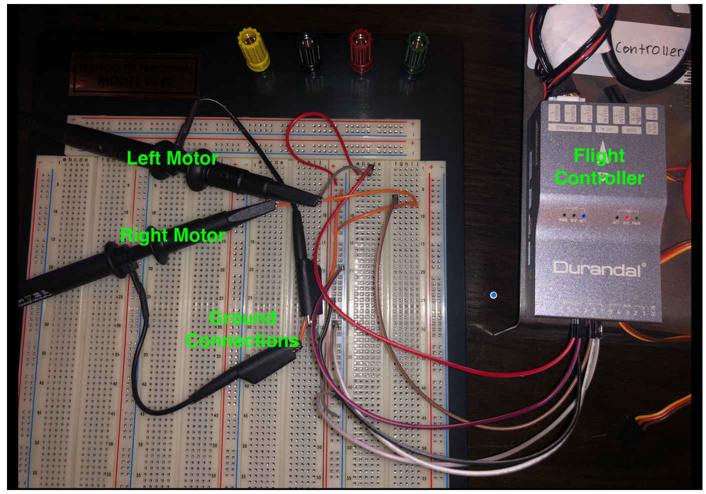

Figure 12. PWM Test Circuit [21]

Once the circuit was set up, Rodrigo set up an oscilloscope to ensure proper display of not only the PWM signals but also data such as duty cycle, signal range, and frequency. Below is an image of the resulting PWM signal for both motors and the resulting data.

Figure 13. PWM Signal Display [22]

Figure 14. Data Display [23]

The PWM signal displays similar signals due to the fact that the rover was directed to move forward in a straight line hence both motors going in the same speed and direction. The oscilloscope also provided data such as the frequency of the signal which was 50.1 Hz, the range of the PWM signal that resulted in 2200 - 1700 us, and a duty cycle of 90% -10 % duty cycle. All of these were satisfactory values and passed although the PWM signal range was 200 us higher than expected in reference to the lower end. Overall, these tests proved effective in proving the functionality of the ArduPilot hardware and software.

IX. Marketability Forecast

A. Target Consumers

As far as our target consumers go I believe it is going to be more of a government funding type program right now. There aren't quite enough people interested in just fishing for plastic at the moment. However government funding will decide how and how often we sell. Maybe someday we can step foot and sell these in a RC Willeys or a Target however today is not that day.

B. Product Environment

The group wanted to focus on creating a rover that would function in a specific environment to help narrow the focus for our work. Our design is focused on servicing areas of low water movement that have waste which collects frequently. In researching other competitors, a main point of concern was having waste come in from outside of their environments (marinas, docks, etc).

The way we map and run the rover is best suited for cleaning up the same area and being able to really fine tune the mapping over a number of runs. The mapping
feature will allow users to adjust after each run to target and focus on specific areas rather than allowing random pathing to map a large area where no spot gets a majority of the attention.

C. Market Competitors

As of now, there are multiple models available that accomplish the same goal as Project Plastic Abatement. Our primary competitors are watercraft or rovers that are designed to be either fully autonomous or semi autonomous and collect water waste as it travels through lakes and rivers. Currently, Project Plastic Abatement is facing three major competitors known as *The Interceptor, Mr Trash Wheel, FRED(*Floating Robot for Eliminating Debris).

The Interceptor, developed by The Ocean Cleanup®, is a solar powered watercraft that flows with the current to collect waste via a conveyor belt into multiple dumpsters. This model comes in at a price of about $770,000. In essence, this model is capable of collecting up to 100,000kg of plastic waste per day. [8]

Mr Trash Wheel is a semi-autonomous robot that is placed at the end of rivers to collect waste via a conveyor belt. This model utilizes both solar and hydro power to energize its conveyor belt and pull waste into its dumpsters. *Mr Trash Wheel* costs $100,000 per year and is a recurring expense.[9]

FRED (Floating Robot for Eliminating Debris) is another major competitor as it is an unmanned robot that collects trash via a conveyor belt and is also capable of alerting marine life of its presence using acoustic pingers. The cost of *FRED* is nearly $230,000. This model is capable of propelling itself at about 2 knots and navigates autonomously as it takes instruction from mission staff via GPS commands.[10]

When comparing these models to our current prototype, it is clear that *FRED* is our most direct competitor due to it being autonomous and is capable of taking GPS commands to navigate similarly to ours. However, the price point is drastically different. *FRED* costs nearly $230,000 whereas our prototype would enter the market between $2000-$3000. The other major difference is the capacity as our model can contain a maximum of 40-60 bottles whereas *FRED* could hold up to 38,000 pounds of waste.[10]

It is clear that our competitors offer far more capacity for waste collection however it comes at a very steep price. We are confident that local lake and river departments will be willing to invest in Project Plastic Abatement due its affordability.

D. SWOT Analysis

Strengths - One of the largest strengths we have going for us is the cost of our rover. As seen in our Market competitors overview, most other rovers are well over 10 times more the cost of ours. Also because of the size of our rover compared to the competition is cna fit in smaller locations and more remote ones. Also the fully stonomy allows to be more than one rover deployed at a time

Weaknesses - A large flaw in our system is the lack of detection. Because the program we run is on ardupilot there are limitations to our rover. It has no recognition on it so it is driving “blind” similar to how rumbas operate, where it has pre mapped destinations and collects whatever is in its way. Another flaw is the GPS compuse signal. We tend to have trouble connecting to the satellite when indoors and near large obstacles like buildings and large tees. For the most part, our rover needs to be outdoors and out of large obstacles for better results.

Opportunities - There are many opportunities to improve our rover. With a larger budget we can increase the scale of the rover withoughs paying for it in moverability and without increasing the cost as much. Also we coils add more batteries in order to increase the run speed we have currently. Another opportunity is to take advantage of the fact that it is way cheaper than the competitor and create a whole flete to clean up a whole leake of basin of a river.

Threats - One large threat would be our competitors which have more resources disposable and have larger budgets to get all the parts they need. Another threat is the environment itself. Because this is a rover eich will be in the water there can be a threat to the components being used to control the device. These can get wet and malfunction. As well there can be a threat that the rover sinks and the whole thing goes down. Lastly there could be a bigger emphasis on microplastics moving forward which can cause the larger floating plastics to be overlooked.

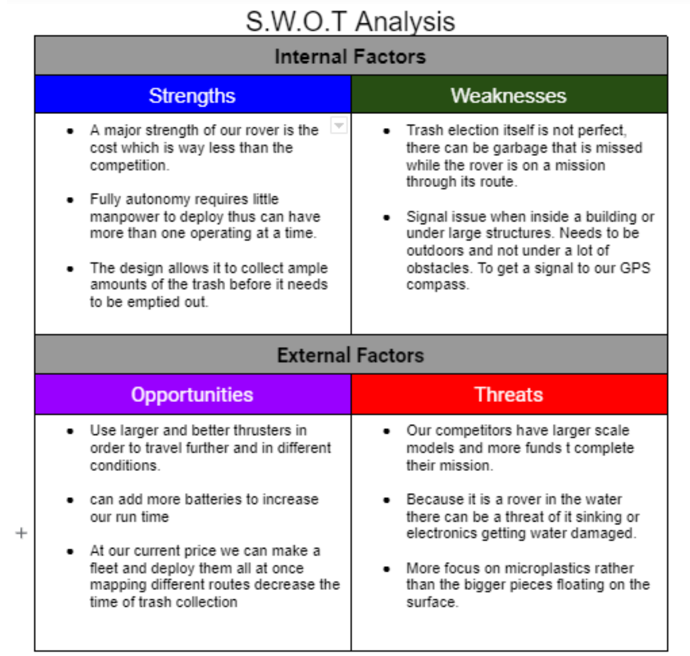

Figure 15. S.W.O.T Analysis Chart [25]

X. Conclusion

To conclude, our team has identified plastic pollution in water bodies as the societal problem we intend on solving. We aim to design a fully autonomous water rover capable of collecting small plastic debris located at the sea level of local water bodies. This autonomous rover will provide a more modern and efficient solution to the ever increasing plastic pollution occuring in our lakes, rivers, and oceans.

A. Societal Problem

As stated at the beginning of our report, as our world continues to grow and evolve in production so will our waste. Again as we mentioned, around 20 percent of coastal waste make their way to the ocean through rivers [2]. Then what is even worse is our waste production is expected to rise substantially over the coming years. However that is where we step in as a group. Now we understand the ocean is huge, so big in fact that a lot of the ocean has not been really explored. Well with our design idea we aim to slow the waste from reaching the ocean. We know we cannot solve this world problem completely however we hope to find a small solution that could go a very long way in the long run.

B. Design Idea

As stated in our earlier pages our design was pretty broad at the beginning. However after a few meetings and a very thought out process, we decided it would be best if we could have a design that fits our timeline the best. Now that does not mean we will skimp on any aspects however we will be doing our best to ensure we have a complete and final project by the time our project is due. In the end we will be dividing the project into sections to maximize our time and skill sets. And hopefully through this we will be able to come up with our best product.

C. Work Breakdown Structure

In the end like we have stated our Plastic Abatement project is a very unique project. Because of its unique features we decided to divide everything based on our skill sets and past experiences. With our method we thought it would be the best way to divide the work between all of us. And in our eyes was the most effective way to achieve our final goal.

Our final goal is to create a project/product that is a rover that will be able to autonomously navigate through pre-mapped routes in a river or a lake collecting small pieces of plastic along the way. To get our rover to complete these tasks we had to incorporate quite a few features to get everything to work. Some of those things are a flash controller, a GPS module, a radio telemetry module, underwater thrusters, LiPo batteries, and lastly our bagging system to collect and store the trash.

Currently with our project we have estimated our costs to be around 700 dollars. This will all be divided among our group members by the task we are each assigned. We have all decided we are okay to help each other if needed with these costs. Other than that we have tried our best to order what we needed as quickly as we can because we understand with COVID-19 that products and other such things may be hard to get.

Rodrigo is set to mainly focus on the software side of things for our group. Not to downplay anything that side at all because there are quite a few components we are using. We have our GPS module and the two telemetry radios. With all this Rodrigo is using ArduPilot Mission Planner, which will allow us to control and monitor our rover as it moves autonomously. Again due to the various components we decided it would be best if one person worked on this.

Jonathan has been our electrical guy for our project as stated earlier. His main job was to configure all our electrical stuff and find a good and lightweight power source for our rover. He was also responsible for finding thrusters that would work under water. In the end as we have stated, Jonathan decided that 2 14000mAh LiPo batteries would be best for us. They gave us about a 15 to 25 minute run time which was really good in our opinion.

Arnulfo has been in charge of our rover structure. As a group we decided he would be in charge of deciding what would be the best construction of the rover so that in fact it does float. In the end we decided on PVC pipe being our best bet for the rover. We also made sure the size ensured the rover wouldn't flip over. In the end because of his experience in electronics we decided Arnulfo would help Jonathan with the power source as well.

Lastly Robert was in charge of finding an effective trash collecting method. After some research we decided as a group that a bagging system would be best for what we wanted. This would allow for the most space and biggest opening to collect trash. Robert was also in charge of finding a waterproof solution for our electronic hardware. Obviously we needed a good solution as our rover will be in water a lot. Due to his experience in software we decided it would be best for the team if he helped Rodrigo on the software side of things as well.

D. *Project Timeline*

In the end like we have stated in order to keep us on track we have implemented a GANT & a PERT chart. It provides us with a good efficient structure that provides a good timeline in a sense. It also provides us with milestones which can be good as a group. It gives the group a good sense of where we are and a pat on the back in a sense.

To give an idea of what kind of milestones we are looking at. As far as our milestones, those will consist of implementation and functionality. Our 3 biggest implementation milestones will be the GPS mapping, differential thrusting, and our reliable power source. However beyond this you can also see different milestones for our senior class in general. This can be seen in the prototype progress review and the project technical evaluation. All this is within the GANT chart which is why it is a very good resource to have.

The final implemented chart we will use is the PERT chart. It's more of a generalized idea of what we are doing. It still gives us a good direction and general idea of how everything is going. However it also includes tasks for the group. With this we are allowed to see stepping stones to help us along the way. In the end both of these keep us in line and help us toward our final goal in our project.

E. *Risk Assessment*

In the end like we have stated, Risk Assessment is our group's way of trying to predict what problems may arise from our project. Then from there we do our best to try to counteract these problems with different actions. Obviously a lot of what we did was ordering early. As in our situations we stated how stock and shipping might be an issue with parts and such things. However that is not all when it comes to risks. Beyond those simple risks are environmental, technical, systemic, and logistical risks like I stated above. In the end we divided this among our go members and had each one of us talk about one of these risks. In the end we hope to mitigate our risks as much as possible and have a smooth project.

F. *Problem Statement Revision*

In the end, in order to tackle our societal problem as large as plastic pollution in oceans, a much more focused approach must be taken in order for this issue to be solved in the long run. We noticed in testing that lakes and rivers tend to be the source of plastic due to them being near more populated areas. Therefore, our group has taken priority in collecting plastic pollution located in these lakes and rivers to prevent further plastic from reaching oceans. In the end even if we do not solve our societal problem right away, we realize we are heading in the right direction in the long run.

G. Device Test Plan

Overall our goal is to get our Rover to the point of a deployable prototype. In order for us to achieve this we will have to put it through various tests in order to confirm or not confirm whether it will need any updates to meet our specific measurable metrics. We as a team have various devices that will test the legitimacy of our rover. From these tests we will push our rover to its limit in order to verify if it can withstand real life conditions.

Various aspects like our Rover structure will go through rigorous tests in order to test its durability, buoyancy and max capacity. As well as our brushless motor will get tested for thrust, RPM, and turning radius. Similarly our LiPo batteries will get tested for maximum run time as well as output voltage. Finally we will test our Ardupilot Hardware and software which includes our Flight controller, telemetry Radios, and the Ardupilot software with tests that involve range and usability.

H. Market Review

In our market review, we identified competing products and who those products were marketed towards. We wanted to compare our prototype and find a niche where ours would be able to fill some of the market needs. Our rovers ability to map and focus on specific problem areas is its biggest feature while also adding a limitation to its uses. Being able to refine and adjust the pathing it takes makes it particularly well suited to customers who are servicing specific areas. Given its affordability, it seems to fit in the current market even if it does have some hindrances in its overall design.

I. Testing Results

The device test plan was formulated to verify and validate the punch list items set forth in the punch list of features from Table 1. The test plan was broken down for testing batteries and power, hardware and software, rover structure, and thrusters and motors. All the punch list items were verified and our team is satisfied that the rover is functioning properly.

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GLOSSARY

Water Bodies - Referring to a body of water ranging from tiny ponds to enormous oceans.

ArduPilot - Name of an open sourced software suite used to design and construct unmanned vehicles such as drones, rovers, and planes.

Autonomous - Device or object capable of carrying out instructions and tasks without human input or interference.

Propulsion - Action of driving or pushing forward usually enabled by thrusters or motors.

PWM - Term that is short for Pulse Width Modulation. Refers to a manner of controlling analog devices using digital outputs.

Flight Controller - Refers to a small circuit board capable of directing other hardware components in response to input either from software or human input.

PVC - Term that refers to Polyvinyl chloride which is a synthetic polymer.

Appendix D. Work Breakdown Structure

Table 4: Project Plastic Abatement Work Breakdown Structure

Level 1	**Level 2**	**Level 3**	**Team Member**	**Estimated Completion Time (Hours)**
1.1 Propulsion and Steering System				
	1.1.1 Underwater Thrusters			
		1.1.1.1 Voltage Supply Calculations	Jonathan	4
		1.1.1.2 RC Communication with Microcontroller	Rodrigo	6
		1.1.1.3 Speed Testing	Jonathan & Rodrigo	6
	1.1.2 Differential Thrusting			
		1.1.2.1 Software Implementation	Rodrigo	15
		1.1.2.2 Turning Radius Testing	Rodrigo	6
1.2 Wireless Rover Communication				
	1.2.1 Radio Telemetry Modules			
		1.2.1.1 Software Implementation	Rodrigo	8
		1.2.1.2 Range Testing	Rodrigo	6
	1.2.2 RC Transmitters and RC Receivers			
		1.2.2.1 RC Transmitter Channel Calibration	Rodrigo	8

		1.2.2.2 Range Testing	Rodrigo	8
	1.2.3 Ground Station			
		1.2.3.1 ArduPilot Firmware Setup	Rodrigo	30
1.3 GPS Mapping System				
	1.3.1 GPS and Compass Module			
		1.3.1.1 GPS and Compass Module Calibration	Rodrigo	8
	1.3.2 Ground Station			
		1.3.2.1 Test GPS Update Rate	Rodrigo	7
		1.3.2.2 Complete Mapped Routes with Rover	All Members	30
1.4 Central Power Source				
	1.4.1 Battery Capacity Requirements			
		1.4.1.1 Runtime Testing	Jonathan	20
1.5 Rover Structure				
	1.5.1 PVC Pipes			
		1.5.1.1 Rover Structure Design	Arnulfo	10
		1.5.1.2 PVC Pipes assembly	Arnulfo	14
		1.5.1.3 Buoyancy Testing	Arnulfo	6

		1.5.1.4 Weight capacity Testing	Arnulfo	6
1.6 Plastic Collection Method				
	1.6.1 Mesh Trash Bag			
		1.6.1.1 Mesh Trash Bag Capacity	Robert	10
		1.6.1.2 Mesh Trash Bag Attachment	Robert	10
		1.6.1.3 Keeping Trash in Mesh Bag	Robert	16

Table 5: Course Assignment Work Breakdown Structure

Week - Semester	**Assignment**	**Team Member(s)**	**Estimated Completion Time (Hours)**
Week 1 - Fall 2021			
	0 - Elect First Team Leader	All	1
Week 3 - Fall 2021			
	1 - Individual Problem Statement	All	24
Week 4 - Fall 2021			
	4- Team Activity Report	All	12
Week 5 - Fall 2021			
	2 - Team Societal Problem	All	12
Week 6 - Fall 2021			
	3 - Design Idea Contract	All	47
Week 7 - Fall 2021			
	7- Team Activity Report	All	12

	Team Member Evaluations	All	4
Week 8 - Fall 2021			
	8 - Team Activity Report	All	12
Week 9 - Fall 2021			
	4 - Work Breakdown Structure	All	40
	9 - Team Activity Report	All	12
	Senior Design Project Safety Form	All	5
Week 10 - Fall 2021			
	5 - Project Timeline	All	50
	10 - Team Activity Report	All	12
Week 11 - Fall 2021			
	6 - Risk Assessment	All	40
	11 - Team Activity Report	All	12
Week 12 - Fall 2021			
	Prototype Progress Review	All	4
	12 - Team Activity Report	All	12
Week 13 - Fall 2021			
	Outgoing Team Leader Report	Arnulfo	3
	13 - Team Activity Report	All	12
Week 14 - Fall 2021			
	Team Work and Team Member Evaluations	All	20
Week 15 - Fall 2021			
	7 - Project Technical	All	30

	Evaluation		
	Senior Design Showcase	All	2
	8 - Laboratory Prototype Presentation	All	10
Weeks 1 - Spring 2022			
	1 - Team Activity Report	All	12
Weeks 2 - Spring 2022			
	2 - Team Activity Report	All	12
	Revised Problem Statement	All	24
Weeks 3 - Spring 2022			
	3 - Team Activity Report	All	12
	Device Test Plan Report	All	24
Weeks 4 - Spring 2022			
	4 - Team Activity Report	All	12
	Prototype Progress Review	All	20
Weeks 5 - Spring 2022			
	5 - Team Activity Report	All	12
Weeks 6 - Spring 2022			
	6 - Team Activity Report	All	12
	Market Review	All	20
Weeks 7 - Spring 2022			
	7 - Team Activity Report	All	12
	Feature Report	All	16
	Team Member Evaluations	All	16
Week 8 - Spring 2022			

	7 - Team Activity Report	All	12
	Outgoing Team Leader Report	Jonathan	3
Week 9 - Spring 2022			
	Spring Recess		
Week 10 - Spring 2022			
	8 - Team Activity Report	All	12
	Prototype Progress Review	All	4
Week 11 - Spring 2022			
	9 - Team Activity Report	All	12
	5- Testing Results Report	All	15
Week 12 - Spring 2022			
	10 - Team Activity Report	All	12
	Team Member Evaluations	All	20
Week 13 - Spring 2022			
	11- Team Activity Report	All	12
	6 - Ethics Quiz	All	10
	Outgoing Team Leader Report	Robert	3
Week 14 - Spring 2022			
	7- Deployable Prototype Eval	All	4
Week 15 - Spring 2022			
	8: End of Project Report	All	12
	Viewing of three minute Video	All	4

Week 16 - Spring 2022			
	9 - Deployable Prototype Public Presentation	All	4

Appendix E. Timeline Charts and PERT Diagrams

PERT Diagram

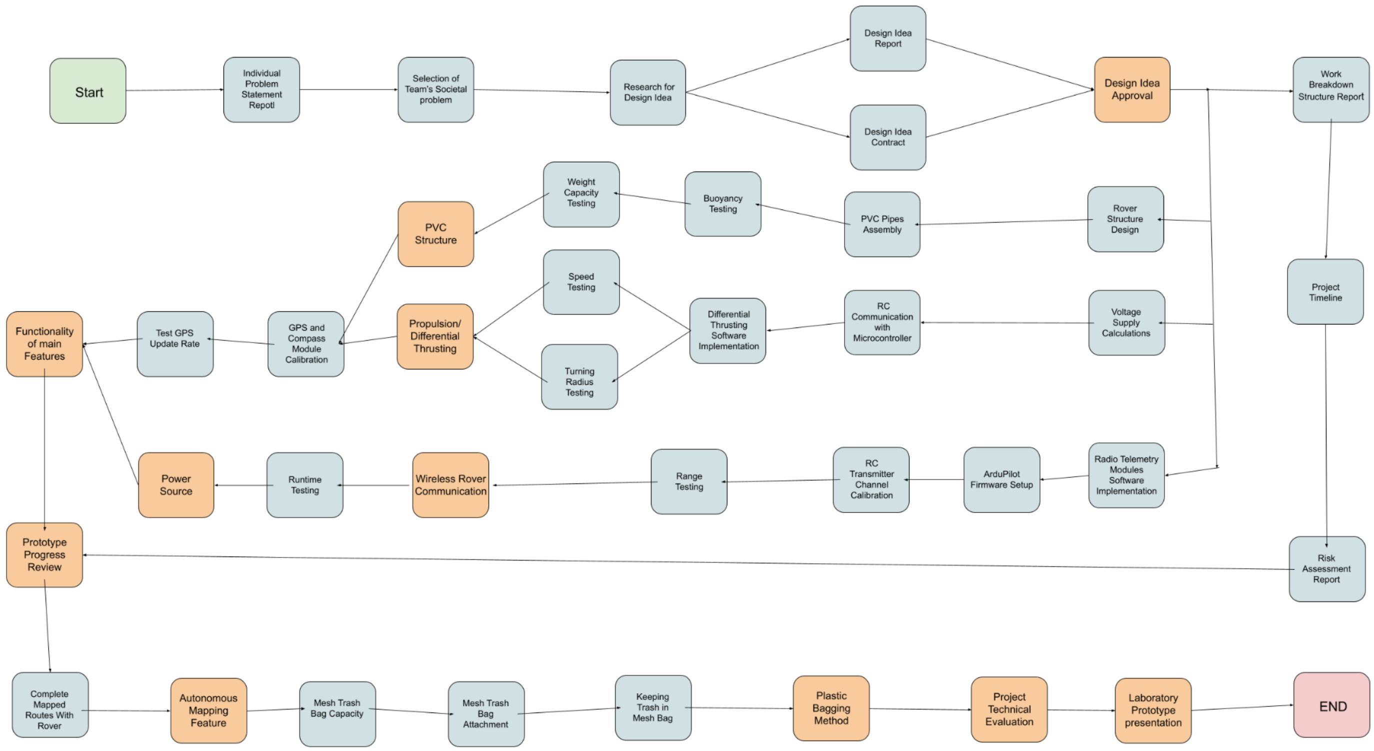

Figure 8: PERT Diagram [20]

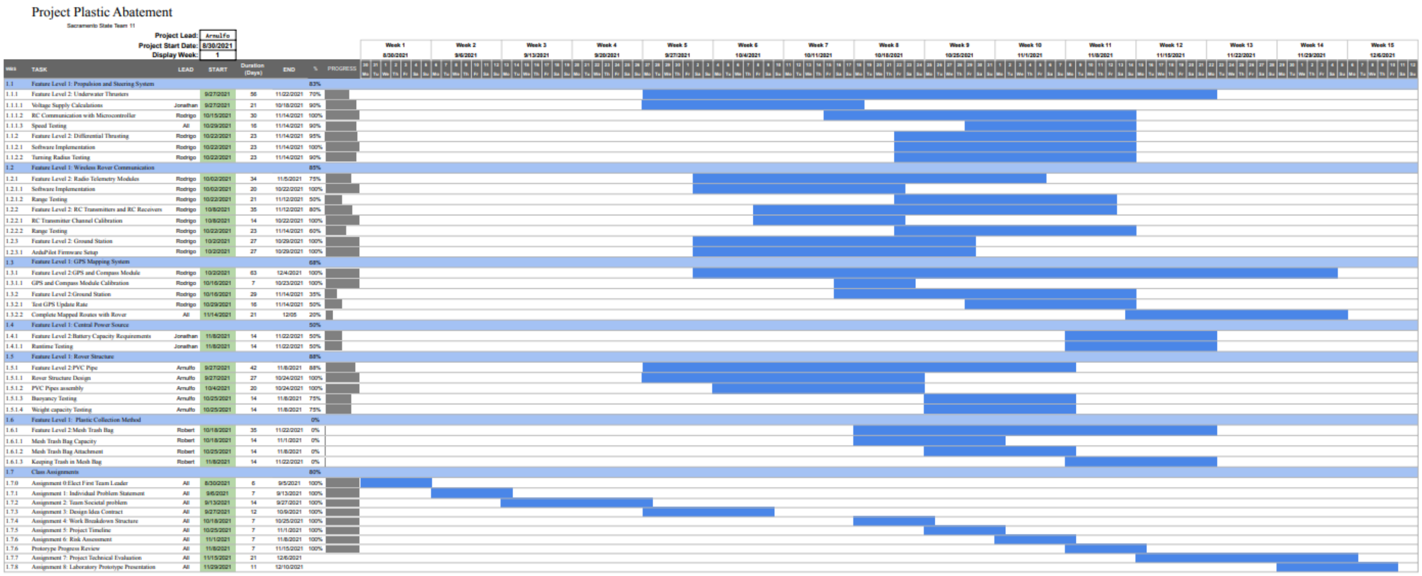

Figure 9: Gantt Chart (Fall 2021) [20]

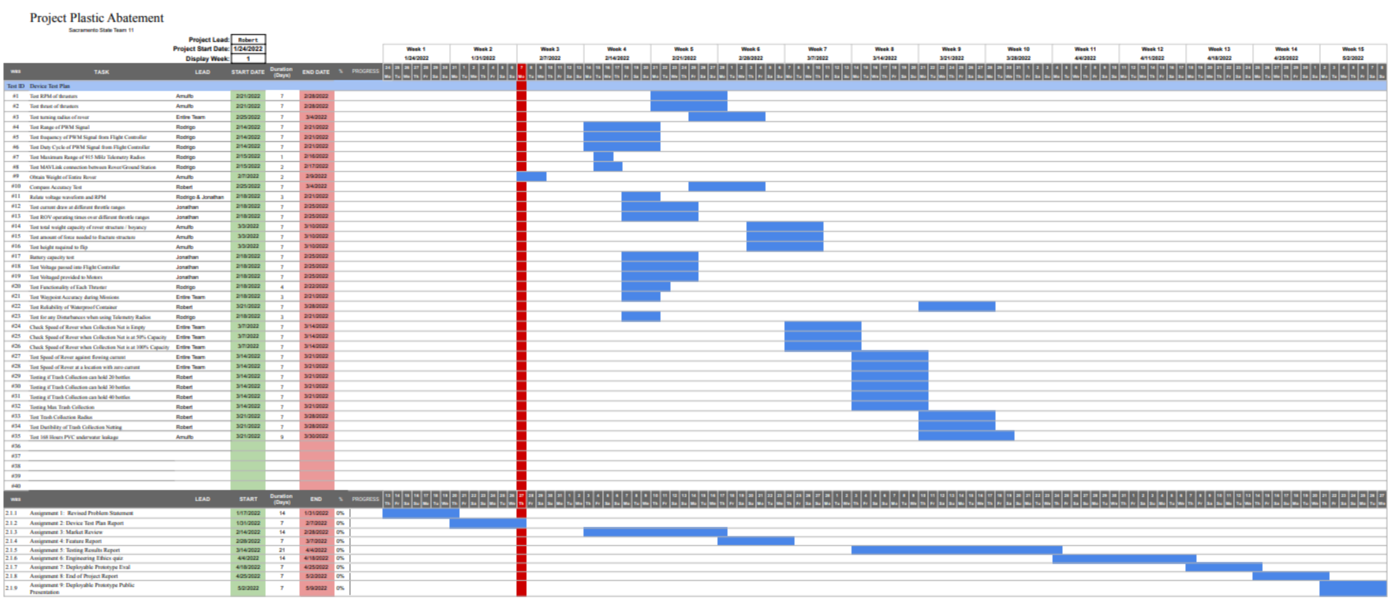

Figure 10: Gantt Chart (Spring 2022) [20]

Link to Gantt chart

https://docs.google.com/spreadsheets/d/1t_o-WjdmWBs8L9GbLXI25lLq53AXh9Eqv8s3aSMt7lc/edit?usp=sharing

Rodrigo Ambriz

OBJECTIVE:

- Actively seeking a position in a hardware/software related field.

EDUCATION:

Bachelor of Science, Computer Engineering
California State University, Sacramento, CA Expected : June 2022
Overall GPA: 3.51

WORK EXPERIENCE :

Stadium Operations Assistant Sacramento Republic FC July 2019 - March 2021

- Built and prepared stadium in preparation to host 10,000+ guests with tasks including stadium preparation & cleanliness, and supply replenishment
- Assisted Stadium Operations team to ensure best practices in operation of stadium & provided services in accordance with company policy and operating standards.

House Remodeling Day Laborer July 2018 - March 2021

- Completed 50+ indoor and outdoor residential construction projects as part of a crew.
- Assisted skilled workers with construction projects in all phases of carpentry.

SKILLS - LANGUAGES, TOOLS, PLATFORMS :

Java, C, C++, Verilog, VHDL, Python, JavaScript, MERN, Quartus Prime, Xilinx Vivado, OrCAD PSpice, Raspberry Pi 4, PIC24F Curiosity Development Board, VMWare, MultiSim, Analog Discovery, Oscilloscope, Logic Analyzer, Signal Generator, FPGA, x86 Assembly.

PROJECT EXPERIENCE:

Microcontrollers Project :

- *Authentication Device with Password and Alarm Detector :* Designed & Built an automated security device using the Raspberry Pi 4 microcontroller with 8+ hardware components and C code with 2 other team members.

Verilog and Computer Architecture:

- *MIPS Datapath:* Designed and simulated a datapath with its control unit for a pipelined system that is capable of executing 30+ MIPS instructions using Verilog.

App Development :

- *TrainedByU***:** Currently developing a web application using the MERN stack (MongoDB, Express, React, Node.js) that allows users to fully customize & track their weight training and nutrition.

ACCOMPLISHMENTS AND SCHOLARSHIPS:

Dean's Honor List Fall 2018 - Present
MESA Engineering Program - Member Fall 2018 - Present
MEP Honors Scholarship - Recipient Fall 2021- Spring 22

Arnulfo Ramirez

OBJECTIVE

To obtain an internship within the RF engineering field.

EDUCATION

Bachelor of Science, Electrical and Electronic Engineering Expected June 2022 California State University, Sacramento
Associates of science, Mathematics/Physical Science Completed May 2018 American River College
Advanced Electronics and Telecommunications Certificate Completed May 2017 American River College

KNOWLEDGE AND SKILLS

Technical

Advanced troubleshooting, soldering, experience measuring and collecting data with an oscilloscope, Experience taking measurements of Gain ,VSWR , and P1-dB using a spectrum analyzer. Training in electronic system component identification and characteristics, semiconductor theory and application, power supply design and operation, ability to apply mathematics for circuit analysis.

Software Applications

Experience using: MatLab, Microsoft Office, Word, Powerpoint, Adobe Acrobat, Adobe Illustrator, C/C++, OrCAD PSpice

Communication/Organization

Excellent time management, fluent in speaking, writing and reading Spanish, team member, exceptional customer service, able to speak in front of a large group, adaptive, problem solver, able to meet deadlines with little supervision.

EXPERIENCE

TECHNICIAN I / ENGINEER IN TRAINING *Sacramento, CA* Aldetec Inc. May 2019 - Current
Involved in optimizing designs of RF microwave amplifiers by testing and tuning. Troubleshooting equipment or amplifiers when they are not performing correctly. performing under tight deadlines with minimal supervision.

CLEARER *Sacramento, CA* BJ's Restaurant & Brewhouse / Jan 2016- Feb 2018
Assist co-workers with numerous tasks, Including taking over a table if they feel overwhelmed. Coordinate with hosts and servers to ensure effective service.executed customer service properly.

SALES REPRESENTATIVE *Sacramento, CA* Cutco / August 2015- March 2016 This was an appointment based job, helped implement new sales strategies, Managed time properly to optimize my trip

GROCERY CLERK Cotati*, CA* Oliver's Market / Feb 2012- August 2015 Made sure everything was prepped on time in order for my team and I to get through the day.Making sure customers were in and out in a timely manner to keep customer satisfaction

Robert Daniel Medina

WORK EXPERIENCE

Caltrans **Sep. 2020 – Present**
Junior Engineering Technician *Sacramento, CA*

- § Worked as an Inspector on I5 Corridor Project
  - o Overseen several operations such as paving, saw cutting, concrete work, K rail placement and removal, in addition to Traffic Control.
  - o Prepared several Engineer Reports for each operation supervised.
  - o Established strong working relationships with Teichert & Granite Construction which has enhanced my knowledge in their field.
- § Maintained strong in-office qualities and traits while working night shifts such as scanning, filling, and reviewing quantity sheets and meeting submission deadlines.
- § Participated in being a presenter for Safety Meeting presentations where I provided all materials and examples needed to thoroughly explain safety topics to my peers.
- § Effectively communicate with local and out of area CHP to place them in the correct spots for closures and complete paperwork for nightly overtime work.

Davis Food CO-OP **Feb 2020 – Aug 2020**
Produce Associate *Davis, CA*

- § Worked as Produce Associate doing wet line work. Daily tasks involved prepping fruits and vegetables, ensuring there was enough stock on hand for customers, all while working on time management as tasks needed to be completed by certain times.
- § Provided exceptional customer service skills and gained a lot of knowledge from building professional relationships with colleagues and customers.
- § Ensured to set myself up for success daily and would consistently prepare extra produce for the next day.

City of Davis **Jan 2019 – Jan 2020**
Maintenance Worker *Sacramento, CA*

- § Worked alongside my supervisors maintaining City of Davis parks. Tasks included lawn work, bush trimming and maintaining, tree trimming and maintaining. Occasional tasks included concrete work and park bench placement and removal.
- § Managed supervision of any work that was to be completed over the weekends.

EDUCATION

CSU Sacramento **Expected June 2022**
BS, Computer Engineering *Sacramento, CA*

- § Taken and Gained skills in Computer Science Courses (CsC 20, 28, 35, 130, 131, 138, 139, 159)
- § Taken and Gained skills in Computer Engineering Courses (CpE 64, 138, 142, 151, 166, 185, 186, 190)
- § Taken and Gained skills in Electrical Engineering Courses (EEE 17, 117, 108, 180)

SKILLS

- § **Skills:** Bilingual in Spanish and English, Proficient in Microsoft Suite, Proficient in Programming (Java, C, C++, Python), exceptional communication skills.

Jonathan Crachy

Objective

- Seeking employment in hardware development and integrated circuit / pcb design.

Education

California State University, Sacramento || 2020-Present

- Major: Electrical and Electronic Engineering || Focused in analog and digital electronics
- CSUS GPA: 3.93 || Expected Graduation Date: May 2022

American River College || 2017-2019

- Obtained an Associates in Electrical Engineering, Physical Science/Mathematics, and Mathematics.

Core Qualifications

- Knowledge and application of Electrical theory and practice.
- Detailed experience with PLC, HMI, and ladder logic using RS232 and RS485.
- Experience working with control systems theory and application.
- Proficient in AutoCAD electrical software. Experience with HSPICE schematic building and batch sims in class.
- Experience in Python, C++, C, Java, MATLAB, OrCAD, Cadence Virtuoso, and Eldo.

Work Experience

Electrical Engineering Technician || Aqua Sierra Controls || 6/2020 - 12/2020

- Put together submittal packages and documentation based on contract documents and plans and specs.
- Designed conduit for electrical panel interconnects from P&ID diagrams as well as contract documents.
- Made changes to electrical panel designs during installations to accommodate discrepancies in design requirements and change request orders.

Electrical Engineering Intern || Harris & Bruno Int. || 1/2018 - 6/2020

- Supported product troubleshooting through remote diagnostic for equipment around the world.
- Created electrical schematics and diagrams for industrial equipment and control systems.
- Adhered to safety regulations laid out in CSA compliance and UL/TUV certifications.
- PLC programming for industrial printing/coating machines and liquid circulation units.
- Created drawings and documentation for onsite prep guides and sales order prep forms.

Manufacturing Technician || Harris & Bruno Int. || 3/2013 - 1/2018

- Built electrical panels for liquid circulation units.
- Lead daily operation meetings related to safety, quality, delivery, inventory, and productivity for an assembly department (QDIP).
- Diagnosed and repaired 480V 3 phase, 240V single phase, and 24VDC signal wiring.
- Tested, diagnosed, and repaired machines after assembly to ensure that there were no errors in PLC programming or manufacturing processes during assembly.
- Created reports detailing errors and troubleshooting processes required for repair.
- Created technical manual for following testing and safety procedures to complete Factory Acceptance Testing for a product line.