2020

Deployable Prototype Documentation

TEAM 2: FLOAT-E

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EXECUTIVE SUMMARY

Dissolved Oxygen in waterways can be analyzed and tracked via floatable device. The device can lead to further data analysis for future use.

In Senior Design, we implemented a water quality system. The system focuses on monitoring pH, Temperature, and Dissolved Oxygen. Over a period of nine months, we work from the societal problem to our Deployable Device. The societal problem will do in-depth in how waterways get contaminated with active and nonactive chemicals. Also, we will talk about how we were able to find a solution that will help us to monitor water quality. The design idea contract will introduce the foundation of how our deployable device will operate. All of the peripherals like the GPS, Dissolved oxygen sensor, temperature sensor, pH sensor, and transmission will be explained in how each part plays a role. For example, the GPS was implemented in our design because we wanted to keep track of the boat and tested locations. The work breakdown structure breaks down all of the assignments into categories. Then team members can decide on what to work on. It also incorporates individual tasks such as who worked on their own peripheral Like Cooper work on the Transmission while Edgar work coding of the GUI. In the next section, we will talk about the risk assessments of the project. The risk assessment involves events that can lead to minor or major events such as error code or short circuit that will cause damage in the hardware system. The design philosophy focuses on the core of our societal problem and the relationship in our deployable device. Now the deployable device status will emphasize the status of the deployable prototype. We will also talk about how each peripheral, like the transmission was able to reach a distance of 500 meters. In our case, the transmission fulfills the feature set. Also, we will talk about the analytical measurements; for instance, we will tell you how the temperature sensor was within +/- 0.5 Celsius. Lastly, we will talk about some of the changes that we made along the way. We will end this with the marketability forecast. This section will go in-depth on how our deployable device can compete with other products that align with similar concepts.

ABSTRACT

California has pressing concerns regarding water quality in many aspects, so Team 2 wanted to be able to create a device to help analyze the health of local waters that can have an effect on the people using them. Team 2's finished a deployable prototype FLOAT-E, a device that is capable of measuring analytes such as pH with +/- 0.1 pH as well as temperature with +/-0.5 Celsius and Dissolved Oxygen with +/-0.5 mg/L. Data collection of the analytes could then be used by professionals to determine the health of bodies of water around the area. Over the spring semester, we were able to add complexity to our design idea in areas such as having accurate coordinates in the GPS. Also, we were able to display real-time measurements with the analytical measurement as well as the coordinates of the GPS. Later we were able to transfer values with radio transmission to the home base. Also, we were able to increase the lifespan of the deployable device by adding a power source. In order to complete our prototype, a work breakdown structure was necessary so each member can work in a specific part of the project, such as temperature sensor, pH sensor, GPS and so on. We will discuss the completed milestones of our project that include finishing significant work packages and features, change of leadership, completion of documentation, prototype testing, and technical reviews. As the deployable prototype is being built and tested, there will be a number of risks that were involved in the project; for example, the danger of the Li-Po Battery, if not been appropriately connected, can cause a short circuit which it can cause a fire within seconds. Also, we will discuss our plans for mitigating such events. We will conclude with the current status of our deployable prototype and how we were able to meet our measurable metrics, and ways we can improve or revise it to make it a marketable product.

Keyword Index- DO, FLOAT-E, GPS, pH, Li-Po, Transmission, Floatability, Power

I. INTRODUCTION

To create a fully-fledged remote data collection unit with built in data transmission and data display was an extremely daunting task that took much more time and effort than expected. This documentation will encompass our complete project design all the way from societal problems to the user manual of our device. It covers a description of our societal problem, the issues we ran into with our original societal issue and solution as well as our journey to resolve those issues. It will cover in detail our design idea and describes each feature of our feature set and how it fulfilled our design idea contract.

The next thing described in our documentation will be that of funding in the form of a table. This table will contain each piece of equipment purchased as well as the price and quantity. After the funding we will explain the major milestones reached throughout the entirety of our project. Next we will give a brief overview of our work breakdown structure as well as a more in-depth idea of our work breakdown structure in the form of a table. This table will contain all of our major assignments and features as well as any and all subtasks and activities for each.

Following our work breakdown structure, we will go over any and all risks potentially associated with our project as well as our plans to mitigate those risks. We will also have a table that will lay out the risk factors, their potential impact, the probability of it happening, and the risk factor's risk score. This will also be accompanied by a risk matrix for each risk factor and an in-depth review of each risk. Next, we will be giving a broad design overview detailing the philosophy that went into our design. After our design philosophy, we will go over the status of our deployable prototype and confirm its status using testing reports. Lastly, we will be giving a marketability forecast for our deployable prototype.

Lastly, we will be adding a user manual, a set of block diagrams as well as schematics for all hardware, a set of block diagrams as well as schematics for all software, documentation on all mechanical aspects, any and all contacts that we had with vendors and advisors during our project, and a set of resumes for each team member.

II. SOCIETAL PROBLEM

One of the largest concerns to humans and the environment alike is that of clean and healthy water. Lakes, rivers, and general waterways spread and wind through most of California, allowing our great state to be able to have a healthy, natural environment as well as boost California's ability to maintain its foothold as one of the world's greatest agricultural producers. As stated, this is all largely dependent on having healthy and clean water. In California, agriculture is one of the highest-grossing fields. In 2018, California produced nearly $50 billion through agriculture [1] while using approximately 43 million acres spread throughout the entirety of the state. With this information being laid out, Team 2 originally looked and found a few different areas of effect that can affect waterway health in a state largely dominated by agriculture. The main aspects that were found included water supply and irrigation, agricultural runoff, and pesticides. In regard to water supply and irrigation, one of the main concerns there was that with the overuse of water in certain aspects of agriculture, the environment in and around that land would deteriorate over time just due to the amount of water used during that time period. The second concern would be what happens after it is used. Does the water now contain certain chemicals that need to be addressed by some cleaning procedures? Does this process of using water for agriculture affect the water table, and if so, what are the steps in place currently to deal with that water reaching the water table where many people rely on that freshwater from the water table. This leads to our findings in regard to agricultural runoff. Agricultural runoff is water from fields due to irrigation that can be absorbed into the ground, enter bodies of water, or evaporate. This can also occur during periods of rain and even snowmelt in which all of these scenarios can lead to chemicals, bacteria, and many other negative things entering California's water systems. We wanted to focus on what may be coming from agriculture, such as the active and inactive ingredients in commonly used pesticides as well as some nutrients put into the water used for agriculture and any potentially unforeseen consequences that we may find. With that being said, we narrowed down our focus to pesticides as they are commonly used in agriculture California. Pesticides are considered as a chemical compound used in a way to kill, repel, control, or prevent any unwanted pests. These pesticides contain a mixture of active and inert ingredients where the active ingredient is the chemical compound in the mixture that will have any effect on the unwanted pests. Ever since the first instance of pesticide use, farms and agricultural producers have seen a large boost to their output as they are able to minimize the amount of pest interference in the entire life cycle of the crop. Unfortunately, like many new groundbreaking products, many of the original pesticides had unforeseen consequences that would greatly affect the environment. One such example is Dichlorodiphenyltrichloroethane, also known as DDT. DDT was originally produced as an insecticide, targeting insects that would go after crops. It worked extremely well to reduce insect interference in the crop's life cycle, but what was not originally known was how stubborn the chemical compound was. DDT was extremely persistent in the environment and would not dissipate quickly at all and would build up quickly in the fatty tissues of animals, such as fish. This situation led to the endangerment of bald eagles where when they ingested fish filled with DDT, their eggshells would be extremely soft and would not be able to survive until the bird hatched. With that being said, all chemical compounds used in pesticides today meet the standards set in place by the Environmental Protection Agency, or the EPA. With rivers and lakes and waterways being such a majorly important aspect of California's life, Team 2 wanted to find a way to help increase efficiency in determining the overall health of a section of water. Recently and over the past few decades, water health has become a larger and larger area of concern than in the past. Many heavy-duty pesticides were in use and had drastic effects on the environment and much more recently E. Coli bacteria have been found in places such as the American river. With that in mind, we still set out to try to find a way that we could measure and determine the concentration of common pesticides in California waterways. This is where Team 2 found the real challenge. With our original problem statement, we had an extensive but general overview of one problem concerning water health that we wanted to focus on. With more research that was done after declaring our first problem statement, we found that we may have bitten off more than we can chew. One aspect that we were extremely lacking in was the chemistry side of everything as we are a team made of Computer Engineers and an Electrical Engineer. We were completely out of our depth and decided that we needed to pivot our original statement. One of our team members, Eleazar Alvarez, reached out to the California Water Board, or the CWB, for any insight or assistance that they could offer us. Luckily for us, they responded and from there we set up a correspondence with one Delany Broome, a staff member there at the CWB with a background in environmental chemistry. Through the communications back and forth between Team 2 and Ms. Broome, Team 2 was able to get a better idea of analytes that we could feasibly build something to find. Ms. Broome suggested four different analytes that can give a good idea of the health of a section of water. We moved on with the Design idea contract.

III. DESIGN IDEA

After the guidance of the CWB, we felt more confident about our societal problem. We had a better understanding of deployable design. We already had an idea of how to address the societal problem. We wanted to create a floatable device that can read measurements from the water. With the information that we got from the CWB, we decided to monitor water quality with a temperature sensor, pH sensor, and dissolved oxygen sensor. Also, the team added more peripherals to the deployable prototype. We end it up, adding a GPS for location and transmission to send data to the user. Without been said, the team came with a very clever name for the Deployable device, which is Floatable on Liquid Observation Accessibility Tool-Engineering (FLOAT-E). We will talk about each part that FLOAT-E will have in the system.

A. Microcontroller/Programming Language

We have dedicated one of our Raspberry Pi 4s to connect our sensor system and run programs to take measurements with our sensors. The pi is an affordable microcontroller that most of the team has worked with before and gives us plenty of options to attach different peripherals to them. They will be loaded with the Raspbian OS. The languages of choice for writing our software are Python and C.

B. Analytical Measurements

The pH, DO, and temperature sensor will be obtained from Atlas company. We will be utilizing the i2c bus for data collection. One of the advantages of using the i2c protocol is that it is designed to communicate with more than one device at a time, in this case all three sensors. It uses two-way open-drain lines: SDA, SCL, and we are applying 5V to all sensors. Each sensor uses a BNC connection that sends analog data that will be converted to digital signals with the provided EZ circuits. The most crucial step before programming the sensors is to find information from their respective data sheets to see how they function. We utilize the knowledge to write our code. The goal is to obtain readable values for pH (pH), temperature (Celsius) and Dissolved Oxygen (mg/L). Lots of testing will be done to ensure our software functions correctly, and we are gathering accurate data. You will find our hardware testing results in the appendix E.

C. GPS

To be able to collect and store the correct GPS measurement take a few different subtasks. First, a good grasp of knowledge on how GPS works as well as a good handle on how the chip being used works is an absolute must. The GPS module that we chose for our project was the Adafruit Ultimate GPS breakout board which allows for extremely accurate data. The purpose of collecting GPS data is to allow for a much clearer picture of the overall measurements. By collecting the positional data, those who will look at the measurements will be able to know where exactly in a possibly expansive waterway the data was collected. Without this information, the other measurements collected would more than likely be completely useless. Since our system is powered by batteries and not a never-ending source of power, we wanted to build our system to try to be as power efficient as possible. In regard to the GPS, we have set up something that we believe fits the bill. The process that we have for the GPS collecting data goes as follows: On startup, the GPS module will draw power for approximately 30 seconds while it attempts to connect to the satellite system surrounding the Earth. Upon getting the connection to the system, it will then go into a low power idle mode and will only switch into active mode when the custom-made python program requests the data, which is once every 30 seconds. The reason that we chose 30 seconds for the idle time was because we still wanted to be able to still have a relatively active live display for our graphical display. For the GPS, Cooper tested it multiple times in twelve different locations comparing the values received to that of his cell phone's GPS application. According to the comparisons, they were exactly the same in every test except for one thus fulfilling our required feature and punch list.

D. Transmission

One of the key aspects of our project was the ability to not only collect data, but to send it back from the device to a base station where it would then be displayed live and updated when new data would come in. To be able to do this, we selected two nRF24L01 units to do the job as they fit exactly our needs. This set of transmitter and receiver will be controlled by a pair of C programs that are going to be controlling just about every aspect of the transmission. The transmitter program starts by enabling the connection between Raspberry Pi and the nRF24L01 module and setting all required values to their default state. Once defaulted, the program would then collect a single data point from every measurement and fill up a single data packet. Once this data packet was filled, it would then set the transmitter into transmission mode which would then send the data packet out from the built-in antenna. The transmitter program does this on loop as we want it to constantly be sending data to the receiver. The receiver program, similar to the transmitter program, starts by being defaulted. Once defaulted, the program switches the receiver into receive mode which would open up the communication bus for incoming messages. Once the receiver caught a data packet, it would then switch the receiver to off from receive. The receiver program then automatically sends back an acknowledgement packet back to the receiver to give confirmation data was received. The receiver then breaks up the data packet into each of the measurements and sends them where they need to go. During our Whitebox testing, we had a few issues in getting the transmission to explicitly meet our required contract with our professor. The transmission was reaching approximately 350 meters, while good, did not meet our required punch list value. Cooper and Juan took a little bit of extra time to determine a possible fix for this problem. In the end, we decided to try adding a 10uf capacitor to our transmitter to boost the signal. This ended up giving us that bonus 150 meters that we needed to satisfy the punch list.

E. Propulsion and Floatability

One of the essential factors that we included in our deployable device was propulsion and floatability. We planned to create our propulsion system. We purchased a waterproof brushless motor and a waterproof servo. Both the motor and the servo will give us the ability to navigate in water. The motor will compensate for the speed of the boat while the servo will help us to steer the boat. Also, we wanted to make sure that our deployable device would float in water. Our goal was to obtain a decent size hull so that we can distribute the weight of the entire system around the hull, so there is a higher possibility that our hull can float with no issues.

F. Power

One of the things that we needed to figure out was the power consumption of every sensor in the system. With the given information, we can determine the lifespan of the prototype. There are little things that we need to know before we can determine the lifespan of the system. That is the amperage consumption of the sensor, and at what rate of voltage does it consume it. We can determine the power of each sensor, and we can add the power to do the total power of the system. There are two methods that we can use to determine the value, one of them is to inspect the datasheets of each sensor, and we are more likely to find the values that we want. Although some datasheets are not great, so we need to approach the second method, and that is to measure the current of each sensor. Thankfully most of the sensors that we purchased contained all of the information that we wanted. It did take some time to figure out the power consumption because we did excellent research in buying all of the sensors. We were able to determine the lifespan of the device.

G. GUI

One of the most important features for this project is being able to communicate the readings of our sensors to users and scientists via a GUI display. The first goal is to write the measurements from our sensors into a file. This was done using the python file handling system. Open will create or open an existing read/write file, in our case output.txt, then seeks the first line, then truncates. Truncating allows us to replace the value of the first line with a new value if a new measurement is taken. Four output files are created, three for our sensors, one for our GPS. The next step is to create a large window and readable font with our data and correct units. Each analyte has its own label and will read its respective output file. The user will be given different options to read the data whether it would be real time or reading a graph from previous data points.

IV. FUNDING

Table I

FUNDING [2]

Part	Name	Quantity	Total Price
Microcontrollers	Raspberry Pi 4	4	186.00
Batteries	Gens Ace 2s LiHV 100C shorty Li-Po Battery	2	75.00
Power Bank	Portable Charger RAVPower Bank 26800maH	1	37.90
pH sensor/Probe	Atlas EZO pH Circuit/Atlas Consumer Grade pH Probe	1/2	119.98
PH Solutions	Atlas pH 4.00,7.00,10,00 Calibration Solutions	1	19.38
DO sensor/Probe	Atlas EZO DO circuit/ Atlas DO Probe	1/1	291.23
DO solution	Atlas Scientific Dissolved Oxygen Calibration solution	1	21.50
Temp Sensor /probe	Atlas EZO RTD circuit/ Alta’s PT-100 Temperature Probe	1/1	51.60
Voltage noise reduction	Atlas Scientific Basic EZO inline Voltage Isolator	1	28.02
Probe connector	Atlas Scientific Electrically Isolated EZO Carrier Board	1	51.28
Probe connector	Atlas Scientific Pre-Assembled Female BNC	2	23.20
Voltage regulator	STMicroelectronics 3.3V, LD1117V33 Voltage Regulator, LD33v	12	8.03
Transmission	Shine-US NRF24L01+ 2.4GHz wireless RF Transceiver Module	10	12.92

Part	Name	Quantity	Total Price
GPS	Adafruit Ultimate GPS Breakout - 66 channel w/10Hz updates	1	39.52
GPS Antenna	Waterproof GPS Active Antenna 28dB Gain, 3-5VDC, SMA	1	16.10
RC boat	Riverine 22-inch Patrol Boat RTR	1	198.00
		Total	1179.66

V. PROJECT MILESTONES

Milestones are events that lead to progress and improvement in our senior design course. Throughout the fall and spring semester, we achieve significant milestones as well as minor ones. As a team, one of the first milestones that we achieved before the first-class meeting was creating a team. Team members did not know each other, but we were able to create a team with just having a 4 min conversation. That is something that many people would not do because they preferred to work with people whom they know. In our case, we just went with the flow, and we managed to create a team. As a result, we became team 2. The following milestones were based on hard work and dedication towards our senior design project.

A. Picking a Societal Problem

The first milestone that we achieved as a team was that each individual would research a societal problem. The member would present their societal problem to the team and instructor. With the presentation, each member was in charge of giving a summary of the societal problem and give a solution that tackled the societal problem. From this point on, the team was given the opportunity to pick one out of the four societal problems. In our case, we went with the most convenient and appealing to us. As a result, we decided to go with Water pollution

B. Team Problem Statement

After the team picked the societal problem, we turned our gears, and we started working on our second milestone. That was to do intensive research on our societal problem and write a report. The Team Problem Statement explains how water pollution occurs and how it affects the overall community. We also hit a minor milestone. We prepare a presentation based on the report and present it in front of the class.

C. Design Idea Contract

Although we were pretty self-aware of the scope of the project, we were not exactly sure how we would proceed with the design contract. We did not know what types of chemicals to look for because there are hundreds of them. Each chemical needs its sensor, and we wanted to pick a chemical that would bring the most awareness to our societal problem. However, due to the uncertainty, we were not able to hit our third major milestone. As a result, we wanted to tackle a different societal problem. After meeting with the instructor, we decided to continue to work on the same societal problem. Also, one of the team members contacted one of the specialists from the CWB, and thankfully we were guided given more information regarding water pollution and water monitoring. The team gained confidence, and we were able to tackle the Design Idea Contract. In addition to the design idea contract, we also tackled a fundamental milestone that was setting up our punch list, which was the metric measurement of the Deployable prototype. Although there were minor concerns in one of the feature sets, we were given the green light to continue to work on the work breakdown structure.

D. *Work breakdown structure*

Once we finalized the punch list, we had a clear idea of how we can break down each feature so each member can work on a specific feature set of the deployable device. Without being said, we have reached our fourth milestone, which is the documentation of the WBS. The WBS concluded with all of the tasks of both semesters. Cooper was in charge of the transmission, while Edgar and Eleazar were in charge of the coding of the analytical measurements and the GUI. Also, Juan was in charge of the power consumption and the circuit layout. For the assignments, we went with the flow, and each person picked a section to write about.

E. *Timeline*

After we accomplished the WBS, we had a clear vision of the task that we had to accomplish, which led us to the 5th milestone. We created a timeline for all of the tasks that we had done in the past and future ones. It also includes individual tasks as well as significant assignments and minor ones. The timeline helps us to visualize the progress of the project and the course. It also reminds us of all of the due dates for the assignments. Also, we created a PERT Diagram which showed all of the tasks of each team member. With this milestone, we were ready to start ordering parts for the prototype that we had built by the end of the semester. Also, each member had to start brainstorming how they would approach their individual task. Lastly, the first team leader, Cooper, has ended his term. The second team leader, Edgar, will take over the team.

F. *Risk Assessment*

Once we figured out all the parts of the prototype, the timeline, and individual tasks. We had to create a risk assessment documentation. We had to list all of the possible events that can go wrong with the project. It can be something simple like a code error up to blowing up the entire system. With the given risk event, we also had to come up with a solution in how to prevent them. For instance, we can check all of the wires to make sure that our system does not have a wiring issue, so the hardware system does not blow up. In this case, we were able to complete the sixth milestone. Also, we a breakthrough in our hardware system. We were able to set up all of the Raspberry Pi's and set up the pH sensor.

G. *Testing Sensors*

We did not have any significant documentation that we had to turn in. However, we did hit up minor milestones, and that was to set up most of the sensors that we planned to have in our prototype. Each member works in setting up their sensors. The GPS, the transmission was ready to be programmed, while the temperature sensor got set up, and simple testing was done. Also, one of the team members worked in constructing the GUI. Also, a simple code was tested for the propulsion. For the following week, we continued to work on the sensors. We started to make improvements. We wanted to make sure that the sensors work properly. Although we were still missing one DO sensor as a team. We decided to take action, and we ordered one from online.

H. Laboratory Prototype Review

With the time that we had, we were able to set up all of the sensors, some needed some work, but overall, they were able to be presented. This led us to our seventh milestone, and that was to have our technical review. The technical review was a good thing because the instructor pointed out some of the things that need it more in-depth and some of the things that we can improve. Overall, we were able to complete the technical review, which was very important because it gave us the approval to continue to the spring semester. Lastly, we hit the final milestone, which was to present in the showcase. We had to showcase our prototype to the public. We talk about the achievements that we accomplished in our prototype and talk about some of the goals that we will target in the spring semester.

I. Teamwork and Revised Test

From the beginning of the course, we went right back into work. There was no time wasted. We started with Teamwork documentation, which was pretty much setting up the bulletin board in our lab. The board displayed all of the work that we have done and the progress of the project. Although we did not follow through, we did fail this milestone because we did not follow directions, and we did the bare minimum. However, we did complete the problem Statement Review, which was a reflection on how we have a better understanding of our societal problem and how our deployable system can address the societal problem. Also, we redefine our timeline to make sure that we have all of the due dates correct and adjust any individual task.

J. Device Test Plan

The team has reached another milestone. The second team leader, Edgar, has ended his term, and the third team leader, Eleazar, will take over the team. At the same time, we have reached a significant milestone, which was the device test plan documentation. The documentation is based on testing each peripheral. For instance, we want to test all of the analytical measurements by making sure that the meat the feature set that we propose at the begging of last semester. The testing has broken into different sections, and each team member will complete a test and document the results.

K. Market Review

It led us to our next milestone, which was to the market research for our deployable device. Mostly, we had to look up how our device can compete in the market and how will it be different from other products. Also, we hit another milestone, which was the transition of the team leader. So, the third team leader has ended his term, and the final member will become the team leader. At the same time, there was progress in the testing of the sensors.

L. Testing Completed

We have reached a fundamental milestone because all the testing was completed. We were able to troubleshoot all of the sensors in the system, and we integrated them as a whole unit. The final step was to set them up and put them into the boat.

M. Midterm Progress Review

As a team, we were able to finish the Mid-term documentation and turn it in on time, but we were not able to turn in the video on time due to not integrating the hardware sensor into the boat. Thankfully the instructor gave us time to finish the video and turn it in 4 days late. So, we took the opportunity, and we were able to deliver the video to the instructor. With the video, we were given all of the credit for the assignment. It concludes the Finalization of our deployable device.

N. Ethics Quiz

We have reached our two final milestones. We have finalized the final documentation, and we created a two-minute video. The final documentation is based on the overall of our senior design course that focuses on the deployable device. Thankfully the team was on target on the final documentation, and we were able to wrap up the final documentation and the two-minute video.

VI. WORK BREAKDOWN STRUCTURE

Our work breakdown structure consists of seven features from our project punch list, each having their own subtasks and activities to give a better idea on how the work is broken down. These seven features include a floatable boat, propulsion, batteries & power, remote control & transmission, global positioning system, analyte measurement, and graphical data representation. The more refined activities of each subtask specify what needs to be completed for the greater subtask and feature to be completely implemented into our system. By laying out every feature, every subtask, and every activity, our team will have a better idea on how to effectively use their time when attempting to complete each feature in the appropriate time frame. Once every feature has been implemented, our team hopes to be able to greatly increase the efficiency of collecting data in regard to water quality health. This will be done by first collecting data measurements through the four probes connected to our device which include temperature, pH, DO, and GPS. The data that is collected through those probes will then be stored on device as well as be transmitted by using our nRF24L01 modules to transmit between the device and a base station. This information will then be sorted and displayed to an application and will show a live feed of the data being transmitted. The main device will be housed in a floatable boat that is paired directly to a standard RC controller to allow for ease of

Table II

WORK BREAKDOWN STRUCTURE [3]

Assignment 1			
Level 1	Level 2	Level 3	Level 4
1. Societal Problem			
	1.1 Individual Report		
		1.1.1 Cover Page	
		1.1.2 Individual Topic	
	1.2 Team Report		
		1.2.1 Cover Page	
		1.2.2 Elevator Pitch	
		1.2.3 Executive Summary	

		1.2.4 Abstract	
		1.2.5 Information on Agriculture	
			1.2.5.1 Research on agriculture
		1.2.6 Introduction to Pesticides	
			1.2.6.1 Research on pesticides
		1.2.7 Use of Pesticides	
			1.2.7.1 Research on pesticide use
		1.2.8 Chemical Makeup of Pesticides	
			1.2.8.1 Research on the makeup of pesticides
		1.2.9 Conclusion	
		1.2.10 References	
	1.3 Problem Statement Presentation		
		1.3.1 Global water problems	
			1.3.1.1 Sewage discharge
			1.3.1.2 Industrial effluents
			1.3.1.3 Surface runoff
			1.3.1.4 Natural disasters
		1.3.2 What is runoff	
			1.3.2.1 Irrigation runoff causes
		1.3.3 Pesticide Pollution	
			1.3.3.1 What they are
			1.3.3.2 Active chemicals
			1.3.3.3 Examples
		1.3.4 Why should we care	
			1.3.4.1 Humans
			1.3.4.2 Environment
			1.3.4.3 Water systems
2. Team Weekly Report			1.3.4.4 Developing countries

	2.1 Individual reports		
		2.1.1 Hours spent on tasks over the past week	
		2.1.2 Hours expected for the coming week	
	2.2 Weekly reports		
		2.2.1 Major component worked on per person	
		2.2.2 Percent increase of project completion from previous week	
		2.2.3 Summary of teams work week	
		2.2.4 Expected work for the following week	
3. Design Idea			
	3.1 Team Report		
		3.1.1 Cover Page	
		3.1.2 Elevator Pitch	
		3.1.3 Executive Summary	
		3.1.4 Abstract	
		3.1.5 Introduction	
		3.1.6 How our Design Idea Solves the Problem	
			3.1.6.1 Address Water Quality Problem
		3.1.7 Technologies Used	
			3.1.7.1 Research Technologies Needed
		3.1.8 Different Approaches	
			3.1.8.1 Bouy
			3.1.8.2 Arduino Project
			3.1.8.3 Human Sampling

		3.1.9 Resources Need for Project	
			3.1.9.1 Research Parts and Resources Needed
		3.1.10 Features and Measurable Metrics	
			3.1.10.1 Floatable Boat
			3.1.10.2 Propulsion
			3.1.10.3 Batteries and Solar Panel
			3.1.10.4 Remote Control Transmission
			3.1.10.5 GPS
			3.1.10.6 Analyte Measurement
			3.1.10.7 Graphical Data Representation
		3.1.11 Conclusion	
		3.1.12 References	
4. Work Breakdown Structure			
	4.1 Visual display of breakdown		
		4.1.1 Table like display of all work done in senior design	
	4.2 Written report		
		4.2.1 Cover Page	
		4.2.2 Table of Contents	
		4.2.3 Table of Figures	
		4.2.4 Elevator Pitch	
		4.2.5 Executive Summary	
		4.2.6 Abstract	
		4.2.7 Keyword index	
		4.2.8 Introduction	

		4.2.9 Semester 1 Assignments	
			4.2.9.1 Assignment 1
			4.2.9.2 Assignment 2
			4.2.9.3 Assignment 3
			4.2.9.4 Assignment 4
			4.2.9.5 Assignment 5
			4.2.9.6 Assignment 6
			4.2.9.7 Assignment 7
			4.2.9.8 Assignment 8
		4.2.10 Semester 2 Assignments	
			4.2.10.1 Assignment 1
			4.2.10.2 Assignment 2
			4.2.10.3 Assignment 3
			4.2.10.4 Assignment 4
			4.2.10.5 Assignment 5
			4.2.10.6 Assignment 6
			4.2.10.7 Assignment 7
			4.2.10.8 Assignment 8
			4.2.10.9 Assignment 9
		4.2.11 System features	
			4.2.11.1 Floatable boat
			4.2.11.2 Propulsion
			4.2.11.3 Batteries & solar panel
			4.2.11.4 Remote control transmission
			4.2.11.5 GPS
			4.2.11.6 Analyte measurement
			4.2.11.7 Graphical data representation
5. Project Timeline			
	5.1 Gantt Chart		

		5.1.1 Group and order tasks	
			5.1.1.1 Description
			5.1.1.2 Team Members
			5.1.1.3 Dates
	5.2 PERT Diagram		
		5.2.1 Task Dependencies	
			5.1.2.1 Project Milestones
			5.1.2.2 Dates
6. Risk Assessment Report			
	6.1 Team Report		
		6.1.1 Cover Page	
		6.1.2 Elevator Pitch	
		6.1.3 Executive Summary	
		6.1.4 Abstract	
		6.1.5 Introduction	
		6.1.6 Risk Assessment	
			6.1.6.1 Critical Paths
			6.1.6.2 Events and Risks
			6.1.6.3 Mitigation Strategies
			6.1.6.4 Risk Chart
		6.1.7 Conclusion	
		6.1.8 References	
7. Technical Design Review			
	7.1 Presentation		
		7.1.1 Technical Discussion	
			7.1.1.1 Demonstrate individual features of device
		7.1.2 Team Milestones	

			7.1.2.1 Show Milestones from Nov 2019 to May 2020
		7.1.3 Tasks Remaining	
			7.1.3.1 Document List of finished and future tasks
		7.1.4 Statistics Breakdown	
			7.1.4.1 Documentation of Hours spent on features
			7.1.4.2 Document Hours spent on assignments
8. Laboratory Prototype Presentation			
	8.1 Oral Presentation		
		8.1.1 Device Functionality	
			8.1.1.1 Hardware Demo
		8.1.2 Visual Aid	
			8.1.2.1 Handout
		8.1.3 Other Topics	
			8.1.3.1 Work Breakdown
			8.1.3.2 Difficulty
9. Problem Statement Revision			
	9.1 Problem statement review		
		9.1.1 Cover Page	
		9.1.2 Table of Contents	
		9.1.3 Table of Figures	
		9.1.4 Elevator Pitch	
		9.1.5 Executive Summary	
		9.1.6 Abstract	
		9.1.7 Keywords	
		9.1.8 Index	
		9.1.9 Introduction	

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			9.1.10.1 Better understanding of problem
			9.1.10.2 Reaffirm or modify statement
		9.1.11 Conclusion	
	9.2 Design idea revision		
		9.2.1 Change order request	
			9.2.1.1 Justified changes
	9.3 Timeline revision		
		9.3.1 Update timeline	
			9.3.1.1 Change any revisions needed
	9.4 Oral presentation		
		9.4.1 Oral presentation	
			9.4.1.1 Overview of revised problem statement
		9.4.2 Visual aid	
			9.4.2.1 PowerPoint
10. Device Test Plan			
	10.1 Necessary test factors		
		10.1.1 Measurement devices	
			10.1.1.1 Dissolved oxygen
			10.1.1.2 Temperature
			10.1.1.3 pH
			10.1.1.4 GPS
		10.1.2 Battery	
			10.1.2.1 Duration
		10.1.3 Navigation	
			10.1.3.1 Propulsion
			10.1.3.2 Direction control

		10.1.4 Data transfer	
			10.1.4.1 Verify data before and after transfer
	10.2 Test timeline		
		10.2.1Eleazar Alverez	
			10.2.1.1 Navigation testing
		10.2.2 Juan Campos	
			10.2.2.1Battery testing
		10.2.3 Cooper Gooch	
			10.2.3.1Data transfer testing
		10.2.4 Edgar Vazquez	
			10.2.4.1Measurement device testing
	10.3 Test plan report		
		10.3.1 Cover Page	
		10.3.2 Table of Contents	
		10.3.3 Table of Figures	
		10.3.4 Elevator Pitch	
		10.3.5 Executive Summary	
		10.3.6 Abstract	
		10.3.7 Keyword index	
		10.3.8 Introduction	
		10.3.9 Main Topics	
		10.3.10 Conclusion	
11. Market Review			
	11.1 Written Report: Market Review		
		11.1.1 Cover Page	
		11.1.2 Elevator Pitch	
		11.1.3 Executive Summary	

		11.1.4 Abstract	
		11.1.5 Keywords	
		11.1.6 Index	
		11.1.7 Introduction	
		11.1.8 Main Topics	
		11.1.9 Conclusion	
	11.2 Required Element: Oral Presentation		
		11.2.1Topic	
			11.2.1.1 Market review overview
		11.2.2 Visual aid	
			11.2.2.1 Summary handout
12. Feature Presentation			
	12.1 Written report		
		12.1.1 Brief description of societal problem	
		12.1.2 Brief outline of entire system & feature set	
			12.1.2.1Measurements & analytes
			12.1.2.2Navigation
			12.1.2.3 Power
			12.1.2.4 Data transfer
		12.1.3 Detailed technical completion of subset features	
		12.1.4 White box testing & testing results	
		12.1.5 Illustrations	
	12.2 Oral presentation		
		12.2.1 Elevator pitch	
		12.2.2 Introduction	

			12.2.2.1Necessary background
		12.2.3 Visual aid	
			12.2.3.1 PowerPoint
13. Mid-Term Progress Review			
	13.1 Team Report		
		13.1.1 Revised Test Plan	
			13.1.1.1 Update test plan: Emphasize how we modified tests
		13.1.2 Testing Results Report	
			13.1.2.1Cover Page
			13.1.2.2 Elevator Pitch
			13.1.2.3 Executive Summary
			13.1.2.4 Abstract
			13.1.2.5 Keywords
			13.1.2.6 index
			13.1.2.7 Introduction
			13.1.2.8 Main Topics
			13.1.2.9 Conclusion
14. Engineering Ethics			
	14.1 Quiz		
		14.1.1 Quiz	
			14.1.1.1 Each student will complete a quiz on engineering ethics
15. Deployable Prototype Review			
	15.1 Post-project audit		
		15.1.1 Questions to Answer	

			15.1.1.1 Achieve design fully with implementation of features
			15.1.1.2 On time
			15.1.1.3 Address societal problem
			15.1.1.4 Management deficiencies
			15.1.1.5 Appropriate budget
			15.1.1.6 Significant issues
	15.2 Prototype Demonstration		
		15.2.1 Prototype	
			15.2.1.1 Measurements
			15.2.1.2 Propulsion
			15.2.1.3 Power
			15.2.1.4 Data transfer
			15.2.1.5 GUI
		15.2.2 Visual Aid	
			15.2.2.1 GUI
16. Deployable Prototype Documentation			
	16.1 Final Documentation		
		16.1.1 Executive Summary	
			16.1.1.1 Elevator pitch and Executive Summary
		16.1.2 Abstract	
			16.1.2.1 Brief summary of the report
		16.1.3 Keyword Index	
			16.1.3.1 Brief summary of the report and the most significant primary concepts
		16.1.4 Introduction	

			16.1.4.1 Summarize the important topics (societal Problem, design idea, Prototype)
		16.1.5 Societal Problem	
			16.1.5.1 Problems statement, dissolved oxygen, fully explored
		16.1.6 Design Idea	
			16.1.6.1 Review the design idea contract
		16.1.7 Funding	
		16.1.8 Project Milestones	
17. Deployable Prototype Presentation			
	17.1 Poster		
		17.1.1 Relevant information	
			17.1.1.1 Intro to project
			17.1.1.2 Synopsis of project with technical solution
			17.1.1.3 Significant milestones
			17.1.1.4 Summarize crucial technical aspects
			17.1.1.5 One-page handout of main features
	17.2 System demonstration		
		17.2.1 Performance	
			17.2.1.1 System features
18. Floatable boat			
	18.1 Design		
		18.1.1 Size & shape	
			18.1.1.1 Determining hull capacity
			18.1.1.2 Designing hull
		18.1.2 Waterproof	

			18.1.2.1 Caulking
		18.1.3 Buoyancy	
			18.1.3.1 Determining required load
			18.1.3.2 Calculation to determine required buoyancy
19. Propulsion			
	19.1 Movement		
		19.1.1 Forward & back	
			19.1.1.2 On/off control of motor
			19.1.1.2 Fine control of motor
		19.1.2 Left & right	
			19.1.2.1 On/off control of servo
			19.1.2.2 Fine control of servo
20. Power			
	20.1 Power system		
		20.1.1 Battery	
			20.1.1.1 Supplying power to one device
			20.1.1.2 Supplying power to all devices
21. Remote control transmission			
	21.1 Connection		
		21.1.1 Data transfer from controller to device	
			21.1.1.1 Determine frequency
			21.1.1.2 Get two transceivers communicating with simple inputs (movement controls)
		21.1.2 Data transfer from device to display system	
			21.1.2.1 Determine secondary frequency

			21.1.2.2 Create data packets
			21.1.2.3 Send data packets
22. Global positioning system			
	22.1 Positioning		
		22.1.1 Setup	
			22.1.1 Confirm connection to satellite system
		22.1.2 Location	
			22.1.2.1 Output position as horizontal, lateral, and altitude
23. Analyte measurement			
	23.1 Sensors		
		23.1.1 Temperature	
			23.1.1.1 Determine how to connect
			23.1.1.2 Output data value
		23.1.2 pH	
			23.1.2.1 Determine how to connect
			23.1.2.2 Output data value
		23.1.3 Dissolved oxygen	
			23.1.3.1 Determine how to connect
			23.1.3.2 Output data value
24. Graphical data representation			
	24.1 Display		
		24.1.1 System	
			24.1.1.1 code for GUI
		24.1.2 Data	
			24.1.2.1 Display single values

			24.1.2.2 Display single values & update them
			24.1.2.3 Display previous values
		24.1.3 Comparison	
			24.1.3.1 Compare values through line graph

Project schedule including milestones and other significant events including summary of hours worked in total and by team member Task assignments needed to complete each feature including summary (by feature) of hours in total and by team member. For most of the senior design project, our team has done well at splitting up the workload for each and every assignment into fourths to make sure that everyone has an equal workload. For the first semester we did a total of 383 hours of work. However, we were more productive, and we did over 680 hours of work.

VII. RISK ASSESSMENT

After establishing our work breakdown structure, we identified risks that are associated with the work packages. By doing a risk assessment, we can place ourselves in the best position to succeed knowing the consequences and chances for each risk. Beneath is our risk assessment chart which represents each risk's probability and impact. Looking at impact versus probability will give us a good idea of which risks have a rare, moderate, and severe impact to our project. We rate the probability on a scale from 1 to 5, which is the likelihood of a risk event occurring with 5 being highly likely to occur. Then we rate impact from a scale from 1 to 5, which is the consequence of the risk on the project with 5 being a highly result in project failure. In the table beneath, we have given each risk their respective ratings, and gave them a risk score, which is the product of impact and probability. Next, for each of the risk factors, we will briefly summarize the impact of these risks and the strategies we used to mitigate them.

Table III

RISK ASSESSMENT TABLE [3]

Risk Factors	Impact	Probability	Risk Score
Hull Takes Water	5	2	10
Hull Stability	4	3	12
Brushless Motor	3	2	6
Servo	2	2	4
Lipo Batteries	3	3	9
Voltage Regulator	4	3	12
Solar Panel	1	1	1
Loss & Data	4	3	12
Connection	4	2	8
Incorrect Location	2	1	2
DO	3	3	9
GUI	1	1	1
ER: Earthquake	4	1	4
ER: Fire	3	3	9

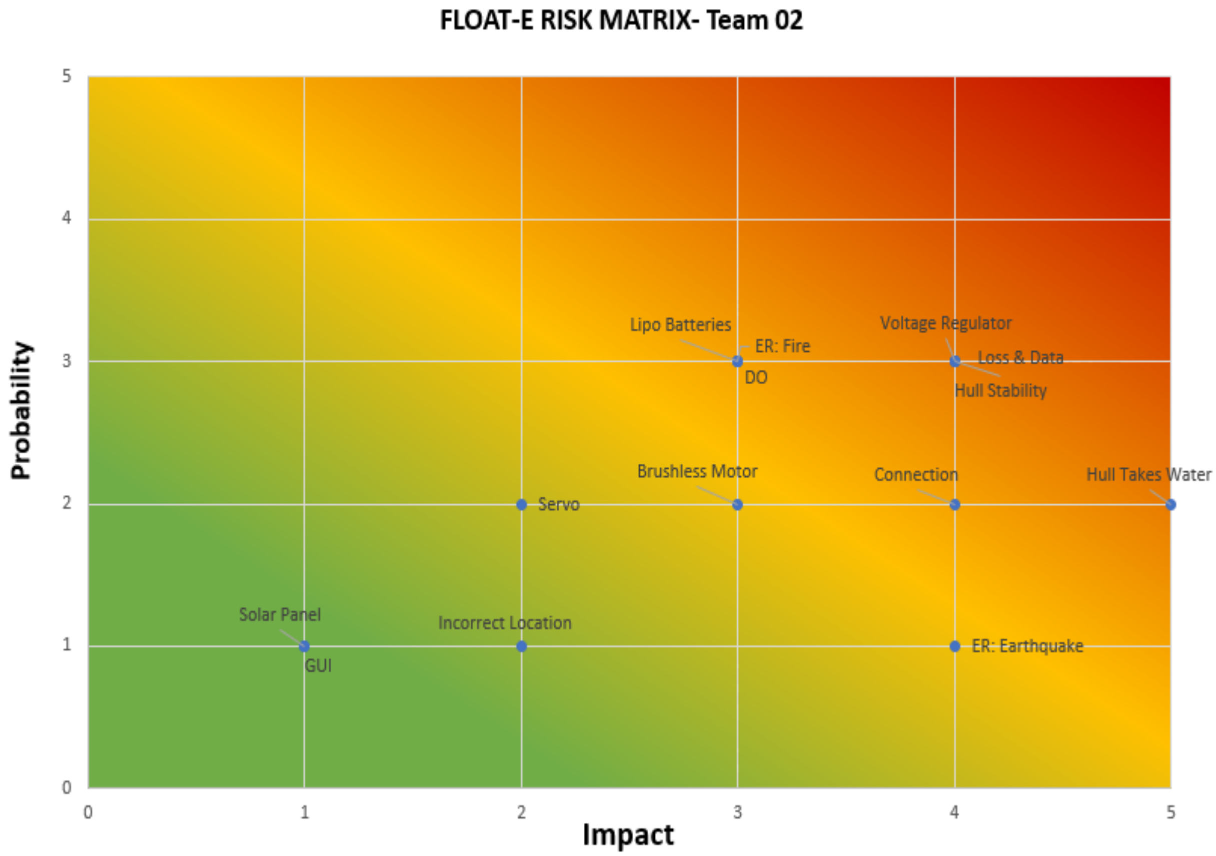

Figure 1:Risk Matrix [5]

A. Making the Deployable Device Waterproof

This could occur in the form of slight water leakage to high water leakage from the part of the hull being submerged under water or water leaking in from the part of the hull that is above the water line. This can lead to a much greater problem if not dealt with properly such as completely destroying all the electronic parts that are contained within the hull. This will in turn lead to the failure of the project. There are a few steps that we can put into place to prevent this from occurring, especially during the final technical review. The first step is to test the hull in a small amount of water before putting anything inside. This will allow us to be able to check for any leaks that may have slipped through. Once we are able to test the seals of the hull, we can then test to make sure that our electronics fit inside the hull but to keep them outside of it until it is needed. Hull isn't able to hold the proper amount of weight Another issue in regard to the device's hull is its ability to hold the proper amount of weight. Without being able to hold all of the varying parts of our project, we will not be able to have a working project. This potential risk could lead to the loss of our device if it were to sink into the river. To prevent this, we will be testing the hull in a small amount of water and placing the equivalent amount of weight as all of our parts to make sure that its weight capacity is up to what we need. If it is not able to hold the proper amount of weight, we will have to make some changes. Another problem that we may run into, specifically with the hull of our project, is the hull's stability during movement. This is an issue that may cause us to lose the device itself or to potentially break some parts of our project. This can range from having the device get flipped upside down to the point where we are unable to control it/retrieve it to it getting flipped over upside down where the waterproofing may not be as perfect as the bottom. These may happen during varying events. This could include rough waters in which the device loses control and capsizes, turning too fast to the point that the device inverts upside down. To mitigate this potential problem, our first idea is to think about where we want to put all the weight of the electronics. As stated above, a concern for the hull is that it won't be able to carry the correct amount of weight. If it has the proper weight limit, we will try to put the heavier parts as low down into the hull as possible. By doing this and focusing the weight as low as it can go, the device will become bottom heavy thus making it far more difficult to flip. Another possible way to mitigate the boat flipping would be to add a fin to the bottom of the boat that goes straight down. This would also limit the amount and speed that the hull could roll thus increasing stability.

B. Propulsion

One of the issues that we will encounter in this particular area will be how fast or how slow our prototype will move. We can see that we need to consider the weight of the RC boat, and the additional weight that we will be adding to the RC boat. The problem with this is that if we don't use the proper motor, we will force the brushless motor to do additional work. Since the brushless motor is forced to do more work, this also means that the brushless motor will want to absorb more power. As a result, the brushless motor can drain the Li-Po battery at a faster rate. Since the Brushless motor is consuming more energy than usual, the time to operate the RC will reduce exponentially. Another potential event that can cause a risk in our project will be the ECS that came with our waterproof brushless motor. Unfortunately, the manufacturer mentions that the ECS is waterproof; however, there have been cases where some of the ECS malfunction. On a particular occasion, if the right amount of water enters into the ECS, then the ECS will Burn. As a result, this can internally affect our Brushless motor and our Li-Po battery. Due to this event, our prototype can be in the water with no movement. As a result, the flow of the water can steer off the direction of our prototype, which we can lose all of the hard work that we have done throughout the semester. Another factor that correlates with the propulsion will be the servo. The servo will be the one that steers our prototype. There could be a small factor that can affect the steering of the prototype. †The size of the propeller will come to a critical factor in our steering. If the fin of the prototype is too small, then the boat will not have enough leverage to move. The prototype won't have enough motion to make a left or the right. We have to find the right size. At the same time, we need to make sure that the servo is installed correctly. If the servo loses connection with the fin, then the boat will be able to move in a single direction. this scenario can become critical when we do test on the river.

C. Batteries

One of the biggest concerns that we have this semester and the following semester will be the power that we have to deliver into our system. Since we are dealing with Li-Po batteries, we have to be extremely careful in how we operate the Li-Po batteries. If the Li-Po Batteries are not handled with safety, they will burn out. Some of the events that will lead to burn out of the Li-Po batteries will be setting the polarities in reverse. In a matter of seconds, the Li-Po battery will burn. Another factor that can lead to damaging the Li-Po battery is the excessive use of it. The Excessive use of the Li-Po battery will cause the battery to puff up, which is an indication that it is unsafe to operate the Li-Po battery. Once again, this can also lead the Li-Po battery to explode. As a result, the battery will catch up on fire. At this point, we can do anything about it, but watch how all our equipment burns down. There is no doubt that the Li-Po batteries will always be a concern when they are in use. Therefore, we have to be extremely careful when we set up the Li-Po batteries. We want to make one of the Li-Po batteries do not start a fire in the classroom nor the lake. One way to prevent reverse polarity will be by connecting them in the right direction. If electrical engineering does not feel confident with the connection, he will ask their colleagues to reassure them that the connections are correctly set up. If everything fails, then the final step will be to ask the instructor. We want to make sure that nothing dangerous happens inside and outside of class. One of the events that can lead to a shortage of power will be the voltage regulator. We want to make sure that we are feeding the proper amount of voltage to the voltage regulator. Without been said, we need to set up the capacitors the proper way, or else they can blow, causing a malfunction on the voltage regulator. As a result, the transmitter can be affected, and it is more likely to burn up because it exceeds the voltage limit. For future test runs, we can run low on the batteries. We can potentially lose some of the data we obtained from the probes. To mitigate this potential risk, we are going to have to perfect the circuit for the voltage regulator before we connect it to any other part.

D. Transmission

Remote Control Transmission One of the main problems that we may run into in regard to the remote-control data transmission is that of data loss. Data loss can occur at any point when we are trying to transfer data from either the control unit to the device or from the device to the display unit. If this were to happen during the former, that could lead to the device moving in the wrong direction or at the wrong speed. If this were to happen in the latter, it could lead to incorrect data being displayed on the display unit. To prevent this, we are going to be using a pre-existing radio protocol that works specifically for the situation we are in. Another way we plan to minimize the loss of data collected is that we will be storing the measurements on the device itself as well as a sort of backup. Another issue regarding the radio transmission is going to be the connection over longer distances. This can lead to potential loss of the device if the user tries to navigate too far from the control unit. There are only a few things that we can do here to mitigate this potential risk. This includes having an explicit clause that states a working range that is smaller than its maximum range so that the user will more likely stay within the range.

E. GPS

One possible risk that comes from the GPS will be getting and recording incorrect positioning. This could cause the locations where data is collected to be incorrect or mismatched. One potential method to reduce the risk of this happening is to take multiple samples of the location and then average them to find a possibly more concise point

F. Analytical Measurements

Analyte Measurement One of the main concerns that we have in our analytical measurements will be setting the Dissolved oxygen. Our biggest concern will be how to set the YSI probe to the raspberry pi without taking it apart. We are stilling waiting to obtain the YSI probe from the California Water Board department. Another factor that we aren't sure will be if the YSI probe will either take analog or digital signals. The communication between the raspberry pi and the YSI probe can become an issue because the raspberry pi can only take a digital signal. If the YSI probe is not compatible with the raspberry pi signal, then it will be tough for us not to take it apart. To prevent this from becoming an issue, we can purchase a separate probe that will work in a very similar manner which we will be able to use as needed.

G. Graphical Data Representation

The biggest potential risk that we may run into with the graphical representation of the data that we collect would be that incorrect data gets displayed to the GUI. With this, the only real way to prevent this is to test the GUI with different sets of data before adding it to the system.

H. Environmental Risk

Something that has become an all too real situation that we may find ourselves in is that of a large-scale fire. This can affect us in many ways. If it is directly on our campus, we may completely lose our entire project. If it is a large enough fire but far away, it could cause a campus closure. Our plan for the campus wide closure due to a fire is to have backups of all digital material that can be accessed by any device connected to the internet. At some point, if there is a fire, there will be an increase in smog in the area. The campus won't close immediately, so we will begin to store all physical materials at one person's house instead of on campus. This will allow us to continue working on our project without needing access to the campus in case of closure. One thing that we have to take into serious consideration while working in California is a serious risk of an earthquake. While there have not been many earthquakes recently, it is still a possibility we need to take into account. An earthquake of varying size could hardly affect us to halt us in our tracks. In the account of an earthquake, our plan will include getting hardware from campus as soon as possible. After getting our physical materials, we will then schedule when each team member will grab whatever parts they need to keep working. This will allow us to have the parts we are working on and to continue working on.

VIII. DESIGN PHILOSOPHY

The design philosophy for our project was one that was efficiency centric while also keeping in mind the overall idea of the project in mind as well. The general health of California's waterways has become a great concern to many different people and groups and presents multiple and different water quality challenges. Our team's philosophy is to address this problem is for us to be able to quickly and efficiently test for certain analytes that influence our waterways: this includes pH, temperature, and dissolved oxygen at a given location. With data from measuring these analytes, scientists from the California Water Board can determine the overall health of a body of water. We wanted to be able to create a device to help in some way within this field because water quality makes an impact in everyone's lives. With that being said, we wanted to make things for someone at the CWB to be much easier. Initially, we learned that a team of two going out and collecting the measurements we wanted to collect would take a whole day, an eight-hour shift, to collect info regarding a stretch of water less than one mile and return to the CWB building. With this painstakingly long process in mind, we set out to increase data collection efficiency. As detailed in the design idea, we wanted to create a device that would be remotely controlled that would collect data the same data points someone at the CWB would collect. This remotely controlled device would allow for the operator to collect data remotely and without the need of another human being or without a much larger man operated boat. Overall, with our device in mind, it can be split up into approximately two modules.

The first module of the device is the remotely controlled boat. This consists of a majority of our features, including a floatable boat, the propulsion, the data collection, a transmitter, and the power system. Two of the three probes that we used were made by the same company, Atlas Scientific, which allowed for a much easier time implementing these two probes. As for the temperature sensor that we ended up using, we chose it due to its power efficiency as well as its capabilities of collecting data while underwater. The propulsion we decided on ended up being a pair of non-brushless motors and the main reason we picked them was directly because of accessibility. The power system we used was a pair of Lithium-ion polymer batteries working in tandem with a portable power bank to greatly increase our operating time. The reason we decided on Li-Po batteries was to show as a proof of concept that the device could be powered using them and the reason for the battery bank was more for a backup power supply to allow for a much longer use. The transmitter that we ended up choosing was nearly a perfect match for what we required, it was a low power drawing transceiver that could be operating in both transmission and receiving modes that was capable of sending 32 character data packets. With this 32 character data packet, we were able to send every piece of data collected to the required significant figures in a single packet. The programs written for this module are relatively complex, needing to translate the voltage received by the probes into usable data, storing this data, and then transmitting the data.

The second module would be the base station which is in charge of receiving data and displaying data. This module only really contains two major things, that being a transceiver that acts as a receiver in this scenario and a whole bunch of code to be able to do exactly what is needed. The code for this module is relatively similar to the deployable model, only less complex due to its need to only receive data and to parse it and display it to a GUI.

IX. DEPLOYABLE PROTOTYPE STATUS

With the time that we have spent working on the deployable device, we have come far in achieving goals that we have set in the fall semester. During the spring semester, we managed to work twice as hard in order to complete the deployable device. First, we needed to test each system to ensure they function correctly and give us accurate results. This was done with developing a device test plan and doing numerous testing. You can refer to appendix B for a summary of these results. We’ve made some modifications in order to achieve better results and improve the quality of the prototype. Beneath, we will go into further detail for each system.

Figure 2: Laboratory Prototype vs. Deployable Prototype [6]

A. Transmission

During the entire two semester long project, one of the biggest troubles that our team ran into was the transmission. From the start, the devices we used seemed simple enough and that we shouldn't run into any problems. Well, that wasn't necessarily the case. Cooper was able to hook everything up correctly and through the help of Juan, was able to verify that the correct voltages were applied to the correct pins and that there was a current going through the device. Upon initial testing, everything worked as it should, and the team was happy with where it was. When tested a second time, nothing ran properly and that left the team dumbfounded. How could something work one second and then not work the next? During the second semester, Cooper was able to narrow down the issue that was causing the now lack of transmission. Upon some research, it was found that the exact model that we had purchased had a pair of extra features that were not needed, but their design actually made the transceiver module require power from a higher voltage pin, a 5V pin, instead of a 3.3V pin. Upon finding this out, resolving this issue was as simple as swapping the voltage pins for the transceivers. Now, upon testing, we can find that we were able to transmit data reliably up to 350 meters. While less than our required punch list value, it was a much better standing than not being able to transmit at all. After getting the transmission to work, Cooper and Juan began to look into ways in which the transmission distance could be increased. They finally settled on adding a 10uF capacitor to boost the signal on the transmitter which did in fact boost the signal to the required 500 meters and thus fulfilling our punch list requirement.

B. GPS

While the transmission might have been one of the most stubborn pieces to work on, the GPS was fairly stubborn itself. During the first semester, this device was the first thing that Cooper worked on. Upon connection to the raspberry pi, the team noticed that the led on the chip that we were using was blinking constantly every second or so which, based on the data sheet, meant that the device was not receiving a fix on the satellite system. After much deliberation, the team decided to purchase an active antenna that would then be attached directly to the GPS chip in hopes that it would increase the likelihood of it getting a fix. Much later, in the second semester, our Professor actually gave us a better idea as to why it was not getting a fix. It was most likely due to the nature of our school's buildings having many Wi-Fi hotspots which would create interference thus blocking the GPS chip from getting a fix.

While this was an issue while testing, we did not feel that it would be much of an issue upon deployment as our device would be out on the water likely very far away from anything as drastic as a school's Wi-Fi setup. We found that once we had the antenna it was much easier for the chip to get a fix, although it was still difficult in the building. Upon testing, we found that the GPS chip for our project, when compared to the GPS location based on a cell phone, was just as accurate in every test other than one where it was a single digit off.

C. *Analytical Measurements*

By adding voltage noise isolators and a couple resistors, we were able to get accurate readings from each of our sensors. Our sensors work in hand with GUI. It can collect pH, temperature, and Dissolved oxygen values in real time. During our deployable prototype review we were able to demonstrate the sensors working submerged in the water. When we read the polling and GUI it was adhering to the measurable metrics staying +/- 0.5 degrees Celsius, +/- 0.1 pH, +/- 0.5 mg/L when the boat is sitting on one location on the surface of water. You can clearly see the values shift when moving to a different area for example, a contaminated area where the pH and temperature is higher, or when you lift the boat out of the water.

D. *GUI*

During the last couple months of the spring semester, a number of improvements and options for reading data were added to the GUI. Improvements include being able to enlarge or full screen the GUI and exit the program by clicking Quit. The GUI can now plot ten most recently collected data points via line representation, which meets are measurable metrics. Users can also receive an average value of those ten points.

E. *Propulsion and Hull*

Initially, the team wanted to have its propulsion, which we got a brushless motor, a servo, and remote control that was acquired from a team member. In addition, a prefabricated hull was purchased for our desire. Our goal was to put everything inside the hull. That means that we would put all of the sensors, power source, brushless motor, and the servo. Due to the circumstance, we were not able to obtain the hull on time because of the seller, so we were not able to set up the entire system inside the hull. Unfortunately, we had to change the direction of the hull and the propulsion. As a result, we ended up buying an RC boat. The RC boat came with its system. The boat came with two motors, and it came with the remote control. With the short period of time that we had, we were not able to use our system, so we decided to keep the boat system, although we did modify the boat, and we opened some areas of the boat for easier access. Overall, we did manage to make the boat to navigate and navigate in water. Since the boat had much weight, we decided to add Styrofoam around the boat so it can have better buoyancy, so the boat does not skin.

F. *Power*

From the beginning of the semester, we wanted to power up the entire deployable device with two Li-Po batteries. After doing some research, we concluded that having two Li-Po batteries was not enough to power the entire system. We came with the acceptance of the lifespan, which was very short. However, during the spring semester, we did some research, and we ended it by changing the power source. We end up adding a power source. Now we have two Li-Po batteries, and we have a power bank in our system. The power bank will be hooked to the hardware system, and it can run up to 102 days. On the other hand, both of the Li-Po batteries will be hooked to power the boat. We manage to increase the lifespan of the propulsion. We can use the boat for almost 25 minutes. Overall, we were able to increase the lifespan of the deployable device.

X. MARKETABILITY FORECAST

When researching the target market for our device we found that there was no true market. The area has several one offs and outdated forms of capturing data but nothing similar to our project. Water quality collection and measurement has a strong chance to always be a market given that we must maintain our water supply and test it. There is a strong chance of growth as there is no major competitor. The device would end up being sold in the government sector and non-profits similar to the California Water Boards. If we were to pursue a marketable device, we would first need to make the device be closer to an IP67 rating. Although it is a boat and should float if it were to be submerged as it is now some internals may fry but more importantly it should be able to handle several splashes of water. Making the device utilize a more modular style can allow for customizations and updates in the future. Prolonging the lifespan of the device along with continuing to lean and improve the technology. The price of the device inherently will decrease since we have solidified the parts being used.

XI. CONCLUSION

At long last, this year-long project is finally coming to a close. The experience of working with a team through challenging tasks and assignments for the better part of a year has been fulfilling to say the least. Whether it be working on a single part of the project for a good portion of a weekend to finally get it working or accidentally knocking a part over and having to start over on that part, this experience will not be forgotten. While we may have had a challenging start to say the least, we were eventually able to overcome any challenges that we ran into and have been able to successfully form a meaningful project that we are all happy that we worked on.

This documentation provided a reasonably in-depth outline of our entire senior design career. Starting with our societal problem and the real problem that came from it. We also proposed and confirmed each feature and design idea contract and how each feature measured up to the punch list. We explained the breakdown of funding for our project with the help of a table showing the materials purchased, their quantity, and their price. After this, we explained many of the major milestones that Team 2 hit throughout the entirety of the two-semester project.

In order to maximize the team’s efficiency while working on the project, we set up a flexible guideline in the form of a work breakdown structure which allowed each team member to get a better idea of what needed to be done at any point in time. This work breakdown structure took the form of a large table containing any and all assignments and features that needed to be completed as well as all subtasks and activities associated with each. Following our work breakdown structure, we explained in depth any and all risks associated with our project as well as explained our plans to mitigate them. By laying them out in the form of a table and risk matrix, we were able to better convey the risks and their meaning.

Following the risk assessment and mitigation, we showed and explained our design philosophy by giving a broad overview of our design. After this we explained our deployable prototype’ status by using testing reports. Lastly, we gave a marketability forecast for our deployable prototype.

Appended to the end of our end of term documentation includes a user manual, a set of block diagrams as well as schematics for all the hardware, a set of block diagrams as well as schematics for all software, documentation on all mechanical aspects, any and all contacts that we had with vendors and advisors during our project, and a set of resumes for each team member.

REFERENCES

[1] California Department of Food and Agriculture, "California Agricultural Production Statistics," CDFA. [Online]. Available:https://www.cdfa.ca.gov/statistics. [Accessed: 26-Apr-2020].

[2] Funding table by Team 02

[3] Work Break down structure by Team 02

[4] Risk Assessment Table by Team 02

[5] Risk Matrix by Team 02

[6] Laboratory vs Deployable Prototype by Eleazar Alvarez

[7] Battery Cover created by team 2

[8] Switch photo taken by Juan Campos

[9] GUI by Eleazar Alvarez and Edgar Vazquez

[10] Undocking the RC Photo by Eleazar Alvarez

[11] Hull Connection photo taken by Juan Campos

[12] Schematic Layout by Juan Campos

[13] Battery Connection by Juan Campos

[14] Team 02's Block Diagram by team 02

[15] Team 02's Pseudo Code for i2c Sensors and GUI by Eleazar Alvarez

[16] State Machine for Transmission System by team 02

[17] Sensors, GPS, Transmission working hand in hand with GUI by Cooper Gooch

[18] modified RC boat to have better Space photo taken by Juan Campos

[19] Remote control of the Boat photo taken by Juan Campos

[20] Eleazar Resume by Eleazar Alvarez

[21] Edgar Vazquez Resume by Edgar Vazquez

[22] Copper Gooch Resume by Cooper Gooch

[23] Juan Campos Resume by Juan Campos

GLOSSARY

1. DO- Dissolved Oxygen
2. FLOAT-E- Floatable on Liquid Observation
   Accessibility Tool – Engineering
3. GPS- Global Positioning System
4. pH- Measure of acidity or alkalinity
5. Li-Po- Lithium Polymer Battery

FLOAT-E USER Manual
Team 02

Parts Needed

- FLOAT-E Boat + Li-Po Batteries+ RC Remote Control
- Raspberry Pi + Connection to 5V Power Source with Raspbian OS and FLOAT-E's loaded software
- Monitor + HDMI Cable or Laptop/PC with VNC viewer

User Requirement

- User must know how to open a Linux terminal and type basic commands to use software.
- FLOAT-E can be remotely controlled and reliably transmit data as long as the boat is within 500 meters of the user.

Turning on FLOAT-E

- First install the Li-Po batteries inside the hull to their respective terminals. You can access the battery cover by lifting the cover near the tail of the boat. Once installed, ensure the cover is placed back on to prevent any water from coming in.

- To turn on/off FLOAT-E boat, simply use the switch located inside the hull. You can access the switch by lifting the cover in the middle of the boat. Once on/off, ensure the cover is placed back on to prevent any water from coming in.

Figure A-1: Battery Cover [7]

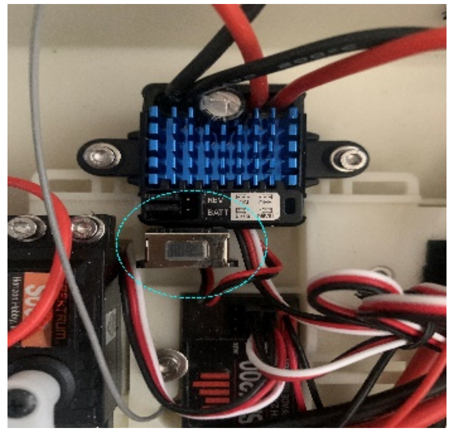

Figure A-2: Switch [8]

Loading Software

- Connect the raspberry pi with Team 02's loaded software to a power source. Video feed from this pi can received, by either connecting it via HDMI to a monitor, or using VNC software.
- Open up the folder containing Team 02's software and run receive.exe to start receiving transmitted data from the transmission system.
- Open up terminal and ensure that you are in the folder of Team 02's software. Next type or paste the following command and hit enter:
  python Final.py & python GUI.py & GPS.py
  The following window will appear giving you a variety of data collection options. To start collecting real time data, choose Real Time Logging. To close software, simply hit Quit.

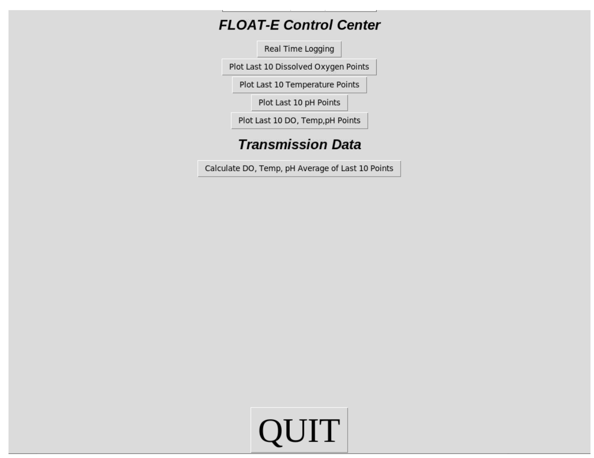

Figure A-3: GUI [9]

- Ensure all the covers to access the inside the hull are closed and secure the water cover on the hull.

- Once you are ready to collect data, turn on the RC controller, and gently place the boat on the surface of water you are sampling. Using the remote control, keep the boat within 500 meters.

Figure A-4: Undocking and RC [10]

Troubleshooting

- If software crashes when trying to run, open the hull and ensure cables are connected and devices are securely plugged in.

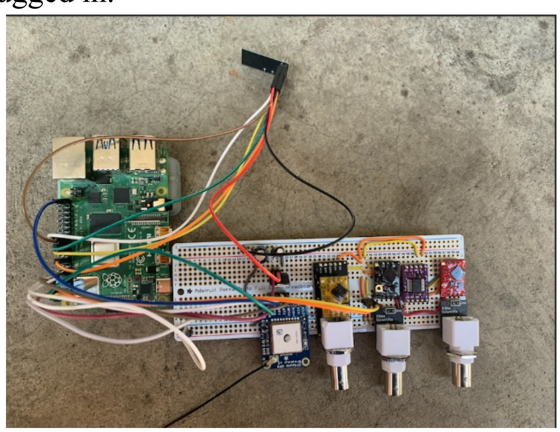

Figure A-5: Hull Connections [11]

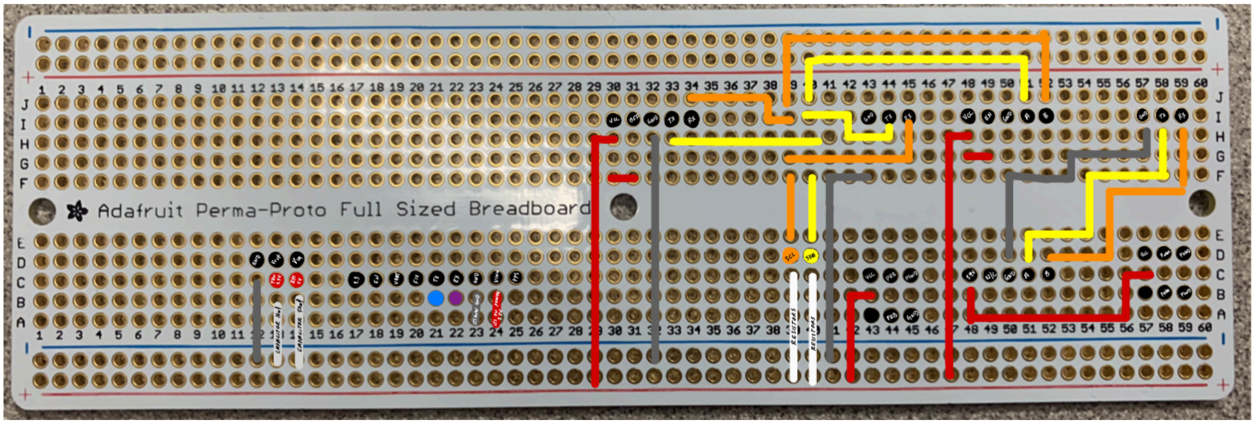

Figure B-1: Schematic Layout [12]

With the given layout we were given a clear idea on how to set up each sensor. The following step came to solder all of the sensor into the PCB board. Side note the Transmission is not being displayed in the diagram because the pins are too close to each other and we can't solder it into the PCB board. The analytical measurements will share the same power, but the transmission and GPS will have its own power, but all of the sensors will have a common ground except GPS. We used 100uf and 50uf to the voltage regulator. For the analytical measurements we added a 4.7Kohm resistor to SDA (orange) and SCL (yellow).

We connected the batteries in parallel for longer lifespan

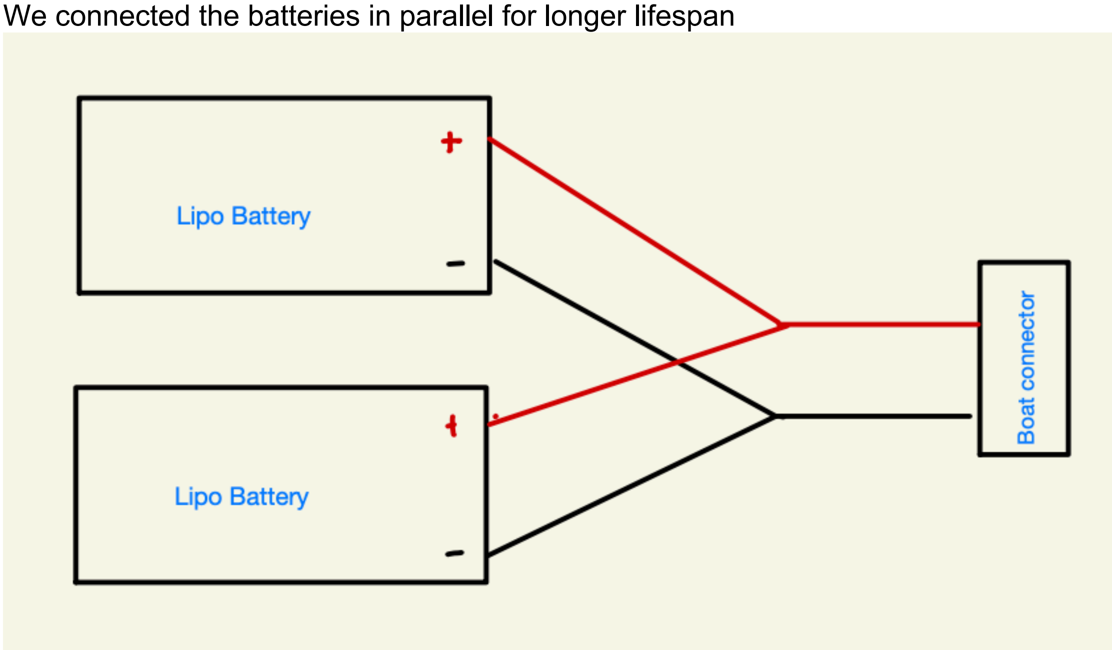

Figure B-2: Battery connection [13]

APENDIX C. SOFTWARE

The following figure shows a block diagram of our GPS, sensor system, transmission system, and GUI working together with the raspberry Pi's.

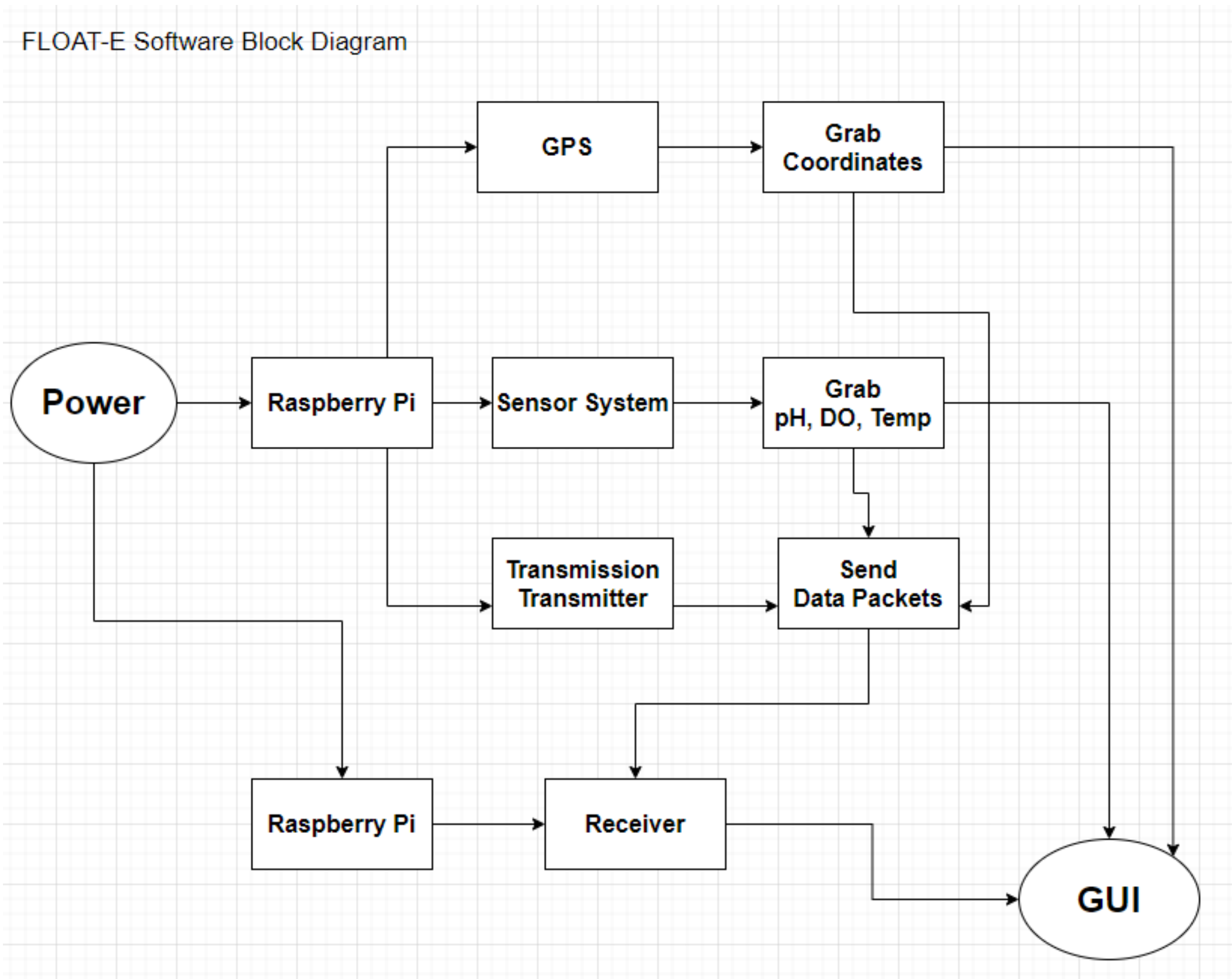

Figure C-1: Team 02's Block Diagram [14]

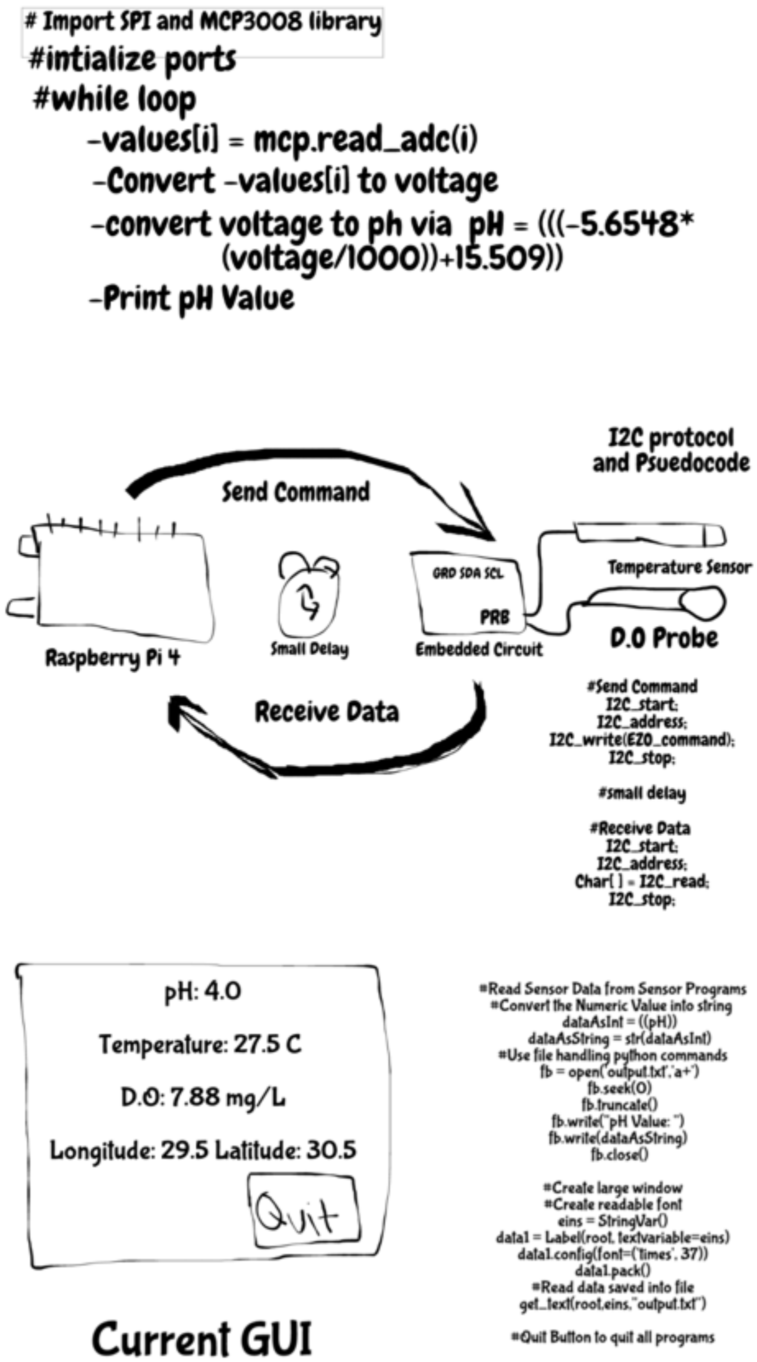

Figure C-2: Team 02's Pseudo Code for i2c Sensors and GUI [15]

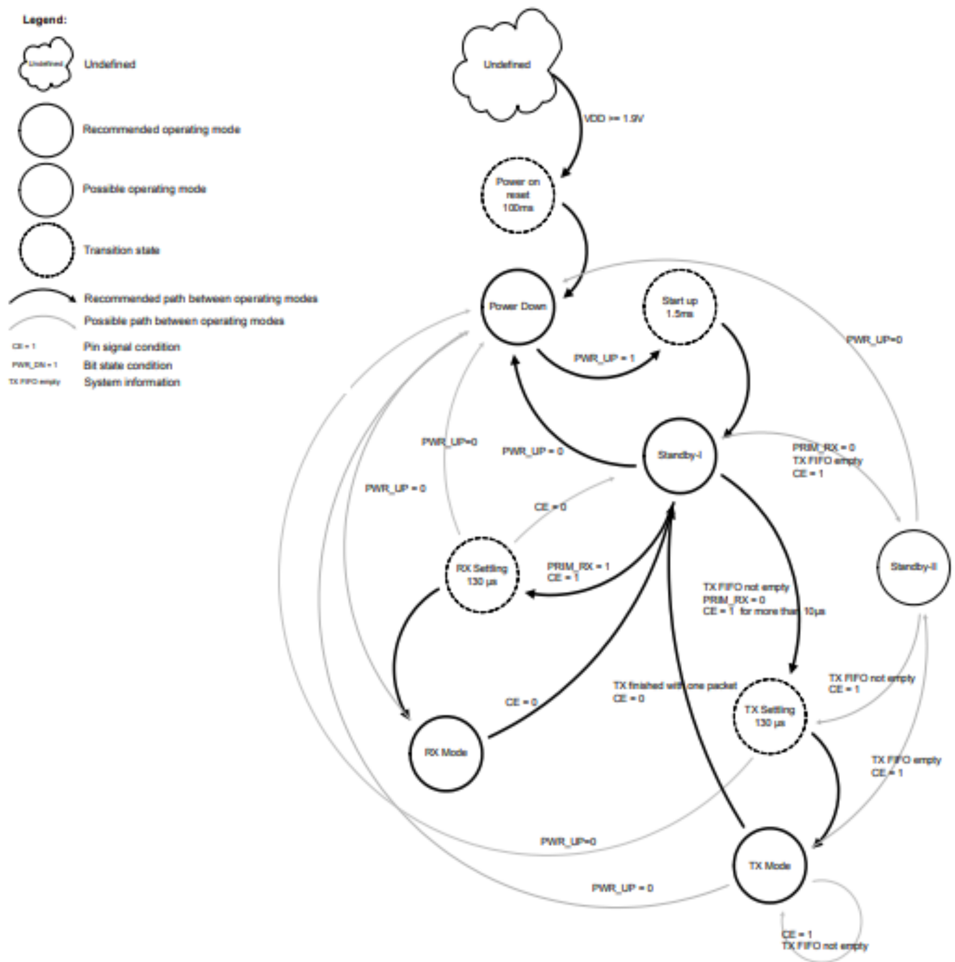

Figure C-3: State Machine for Transmission System [16]

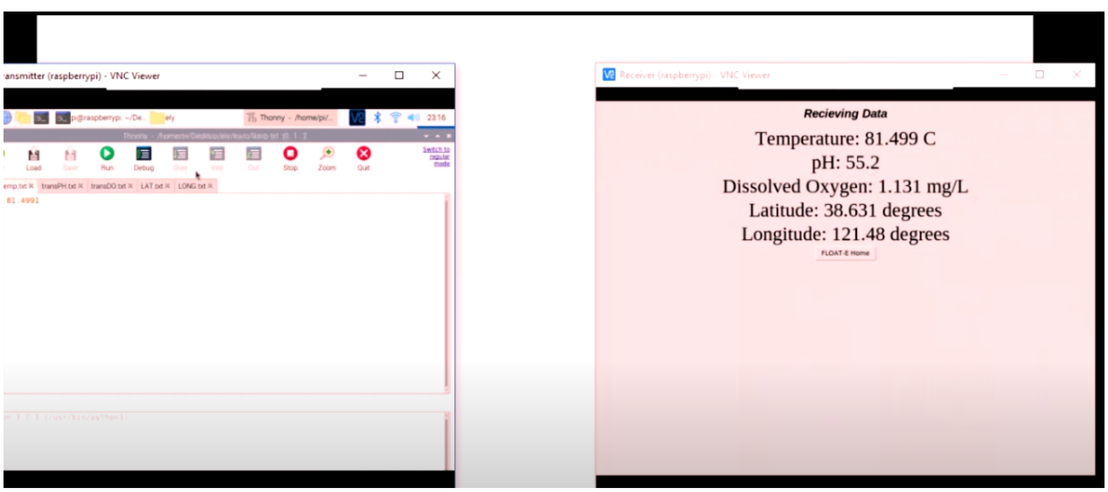

Figure C-4: Sensors, GPS, Transmission working hand in hand with GUI [17]

APPENDIX D. MECHANICAL ASPECTS

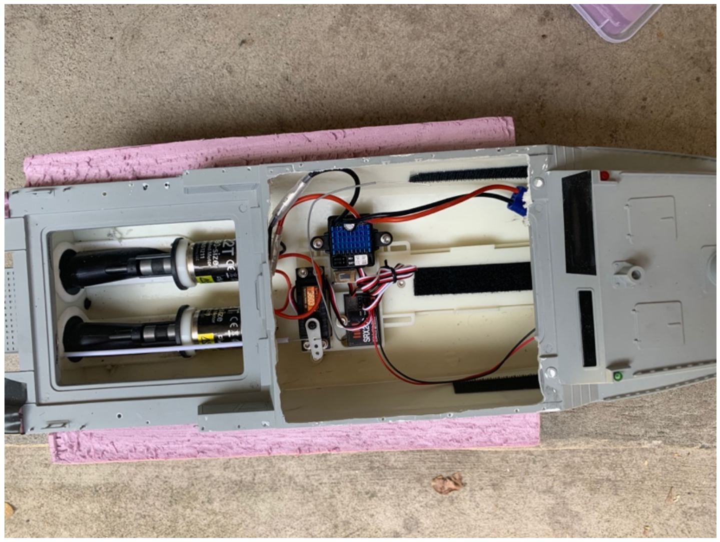

Figure D-1: modified RC boat to have better Space [18]

Figure D-2: Remote control of the Boat [19]

APPENDIX E. VENDOR CONTRACTS

One of the reasons that we were able to complete our senior design course was with the Help of Ms. Broome. She works for the California Water Board. Ms. Broome is an environmental Scientist who's focus on physical Habitat, Deployable sensor, and sample protocol. At the beginning of the semester, one of our team members reach out to her for help, and she was willing to help us out and give us advice on how to address our societal problem. Ms. Broome guided us in picking all of the analytical measurements that we have in our Deployable device. Big thanks to MS. Broome for having the time to help us out.

APPENDIX F. RESUMES

Eleazar Alvarez

Profile

Future computer engineering graduate carrying a wide variety of technical skills and a passion for technology. I am a team player looking to use my computer engineering knowledge and skills to deliver high quality results for the company. Always looking forward to learning new technology and skills.

Education

Bachelor of Computer Engineering Expected May 2020
California State University - Sacramento, CA

Customer and Technical Skills

- Verbal and Written communication promoting positive language and following a required format
- Team player. Promote or adapt new ideas
- Microsoft Word, Excel, PowerPoint, Familiar with Windows 10/Linux/Mac Systems
- Programing Languages: Python, C, Java, Assembly X86 and Mips, Basic Scripting, Verilog/VHDL
- Hardware Experience: Oscilloscopes, Logic and Spectrum analyzers, Circuit design and simulations, CMOS design and layouts, FPGA design, Raspberry Pi, Arduino, Basic Computer Building, Testing and Validating
- Quickly learn and adapt to new technology

Projects

- CSUS Senior Design Project: FLOAT-E September 2019 - May 2020
  1 Year Project to create a floating device designed to help improve the general health of California water bodies.
  In charge of connecting, testing, coding and maintaining the sensor system
  Created GUI interface to help log, track, and graph data
- Operating System January 2020 - May 2020
  Building a basic OS with kernel and associated system utilities using tools for embedded-system development.
- CMOS Project April 2019- May 2019
  Created 1001 Sequence Detector and 4x4 Multiplier in CMOS Logic using Cadence
  Truth Tables, Encoded STTs, State Machines, Flip-Flops, Mosfets
- Environmental Service February 2019 - May 2019
  Clean up environment in various Sacramento Areas including creeks, schools, and parks.
- 32-Bit CPU November 2018 - December 2018
  Created a pipeline CPU capable of handling multiple instructions. Constructed using Verilog
- Integrated Smart Weather Station November 2015 December 2015
  Smart system capable of measuring different weather elements, and predicting weather
  Contributed code and built system using Arduino

Work Experience

- **Apple Inc**, **AppleCare CPU Technical Advisor** May 2013 to May 2014
  Multitask across systems and applications, analyze and resolve a variety of complex technical issues
  Adapted communication and troubleshooting style based on customer personality
  Utilized probing techniques to isolate and confirm the customers' issues
  Researched various resources to quickly resolve issues
  Document concise notes in a call tracking application
  Use of verbal and written communication skills to help support and promote apple products

Figure F-1: Eleazar Alvarez Resume [20]

EDGAR A. VAZQUEZ

EDUCATION

California State University, Sacramento|B.S. Computer Engineering - Spring 2020 Graduation

SKILLS

Programming: Bootstrap, C, C++, CSS, HTML5, Java, PowerShell, Python, React Native, SQL, Verilog, VHDL
Software Tools: CA Service Desk Manager, Expo, Firebase, GitHub, MS Office, MS Active Directory, VMware Horizon, Xcode
Hardware: Analog Discovery 2, FPGA's, Micro Controllers, Oscilloscopes, Raspberry Pi 3 and 4
Bilingual: Proficient in English and Spanish

EXPERIENCE

Information Technology Associate|*California Franchise Tax Board* Mar 2019 - Present

Automated via a PowerShell script my team's method of alerting major incidents to the managers.
Apply customer service and customer support principles in an IT environment.
Work collaboratively and independently to identify problems and provide resolutions.
CA Service Desk environment managing calls, live chat, and email with 25+ daily tickets created or managed.
Troubleshoot Windows 7, Windows 10 and Apple OS, and installing or configuring software.
Assist users with Virtual Desktop Infrastructure (VDI) / VMware Horizon.
Have assisted with Break/fix; replacing the internals of systems and laptop screens.
Image, encrypt, and secure equipment to temporarily loan out to staff.

Extreme Engineering, Team Boeing|*SHPE National Convention 2019* Oct 30th - 31st, 2019

One of 60 participants selected out of 540 engineers to contribute in a team of 1 0 making a miniature lunar rover.
Created and modified marketing material and a team website.
Paced 3rd in the competition exemplifying teamwork.

Information Technology, Student Assistant|*California Franchise Tax Board* Sep. 2016 - May 2019

Utilized a knowledge base to maintain a high level customer experience.
Maintained and troubleshooted 150+ printers/copiers throughout 4 buildings.
Communicated technical information to non-technical customers verbally via email.
Updated and stayed up to date with the team on any issues or pending fixes.
Deployed and tracked monitors, computers, and printers.

App Developer|*FanGo (Start Up)* May 2018 - Aug 2018

Along with 3 other students we developed an all in one Sports/Social Media app.
React Native, Google Firebase, Xcode, and Expo were used developing the media viewer portion.

IT - Student Assistant|*California State University, Sacramento* Mar 2014 - Dec 2014

Resolved level one Hardware or Software issues via phone and walk ups.
In HTML I shaped and composed emails to 500+ students in attempt to improve retention/graduation.
Maintained 7 webpages under CSU Sacramento Website, SASEEP branch.

PROJECTS

SHPE App: When completed it will have a login, profile, member status, club information, and a chat. Oct 2019 - Present

Code in Swift within Xcode and utilizing Google Firebase for database, storage, and authentication.

Senior Project: Engineering a floatable device that traverses the river gathering water quality metrics. Aug 2019 - May 2020

The device will gather data of Dissolved Oxygen, Ph, temperature, and GPS location.
The data points gathered will be transferred back to the remote and replay data via a GUI.

Smart Safe: A box that would lock itself if sensors indicated somebody was nearby. Nov 2016 - Dec 2016

Wrote control logic in C for the audio and light sensors to function with the Raspberry Pi.
Designed and implementation of all hardware components and schematics.

LEADERSHIP ROLES/HONORS

Webmaster|*Society of Hispanic Professional Engineers (SHPE)* July 2019 - Present

Maintain and refresh the chapter website with self-taught HTML5, CSS, JS, Bootstrap5, and hosted on GitHub.
Chapter Awarded "Outstanding Professional Development" at the SHPE 2019 National Convention.

Member|*MESA Engineer's Program (MEP)* - Member July 2013 - Present

Figure F-2: Edgar Vazquez Resume [21]

Cooper J. Gooch

OBJECTIVE:
- To obtain a computer engineering position with people of both similar and diverse interests that will allow me to utilize my past experiences and desire to learn.

RELEVANT COURSES:
- CPE 185: Computer Interfacing
- CPE 186: Computer Hardware Design
- CPE 142: Adv. Computer Organization
- CPE 166: Adv. Logic Design
- CSC 130: Data Structure + Algorithm Analysis
- EEE 180: Signals & Systems

LANGUAGES:
- Java
- C
- Assembly
- Python
- Verilog

EDUCATION: **Bachelor Degree in Computer Engineering (Grad Spring 2020)**
California State University of Sacramento. Sacramento, CA. (3.0 GPA)

PROJECTS:

Exploring Computer Science Course (HS Extra Curricular)
- Helped set up an intro computer science class for Folsom High School
- Worked closely with the teacher to set up the curriculum
- Tested projects students taking the class would make

Parking Lot Sensor w/ License Plate Identification (CPE 185)
- Would sense if a car was in a parking spot
- Would update a website with graphics of which spots were taken live
- When a car was parked, would find the car's license plate and update the web page to display the current license plate

32-bit Pipelined CPU (CPE 142)
- Designed in Verilog
- Contained four different addressing types
- Used 16 different 32-bit instructions

WORK EXPERIENCE:

CSUS IRT, Sacramento, CA
Service Desk, August 2018 - Current
- Offered tier 1 help desk support to students and faculty for varying tech issues
- Help students with the security of their school accounts
- Managed laboratory utilities
- Troubleshooting unknown issues

Costco, Folsom, CA
Food Court, May 2018 - Current
- Prepares and sells food to members
- Pulls and stocks supplies
- Provides prompt and courteous member service
- Cleans and sanitizes relevant machines and tools

Figure F-3: Copper Gooch Resume [22]

Juan Y. Campos

OBJECTIVE

Highly motivated individual who seek an occupation that will grant the opportunity to gain experience in the working field.

EDUCATION

American River College, Sacramento CA

Plan: Engineering Technology Major

Fall 2014 -Spring 2018

GPA:3.0

California State University, Sacramento CA

Fall 2018 - Present, Expected Graduation Spring 2020

Major: Electrical and Electronics Engineering

Depth Area: Control Systems

GPA: 3.3

KNOWLEDGE & SKILLS

- LANGUAGES: BASIC PYTHON, BASIC C++
- SOFTWARE: PSPICE, MULTISIM, MATLAB,
- HARDWARE; ARDUINO, RASPBERRY PI, PROPELLER ACTIVITY BOARD, OSCILLOSCOPE
- Fluent in Spanish

Spring 2020 Coursework

- EEE 178: Machine Vision
- EEE 185: Modern Communications
- EEE 193B: Product Design II
- ENGR 120: Probability + Random Signals
- Anth 1: Intro to Biological Anth

Projects

Senior Design Project: FLOAT-E

It's a floatable device That will measure the following analytes pH, Temperature and Dissolved Oxygen. The measurements will be given to experts for further analysis.

Control Light system (Team Project): Simulated a two-way stoplight with a pedestrian sidewalk. Additionally, we added a sensor to detect cars.

Robotics (Team Project): Control a robot with PID Control, Path Planning, and Object Avoidance.

WORK EXPERIENCE

A &J Drywall, Inc. Rancho Cordova - *Hanger*

Feb 2019 - Agu 2019

Dec 2019 - Present

TDH Construction DBA Foothill Painting & Drywall - *Hanger*

Aug 2019 - Dec 2019

Capital City Drywall Inc. - *Hanger*

Aug 2014 - Feb 2019

Figure F-4: Juan Campos Resume [23]

APPENDIX G. TEST RESULTS

Component: Temperature Sensor
How: Two ways to test our temperature sensor: one is using our Raspberry Pi to read data, and the other is to test our component is using an ohmmeter.
Modifications: N/A
Result: **Success.** When we want to get a temperature reading of the -126 Celsius, we inserted a 498-ohm resistance into the RTD EZO circuit. Calculated value was close to the actual value. Meets accuracy provided by data sheet.

Component: pH Sensor
How: We will be taking measurements with our Raspberry Pi and use 3 different calibrated solutions: 4.0, 7.0, 10.0.
Modifications: Noise reduction with voltage isolator
Result: **Success.** We tested the 7.0 pH solution and our multimeter was giving us a voltage of 1.492 which is within +- 0.2 accuracy the sensor promises in the data sheet. We plug the voltage into the equation and get T 2 a pH value of 7.072.

Component: DO Sensor
How: with the DO Test Solution we have we can use it to calibrate the probe as best we can. DO solution is 0 mg/L
Modifications: Noise reduction with voltage isolator
Result: **Success.** When testing the solution, we received what was close to 0.31 mg/L instead of 0. We took into consideration the fact that a 0 value is under perfect conditions and we had the solution for several months and had opened it a few times before then.

Component: GPS System
How: In testing the device, the portable unit connected to the GPS to approximately 12 separate locations, 5 around Sacramento, 3 in Orangevale, and 4 in Folsom.
Modification: Debug Code
Result: **Success.** Unit has just about a 99% accuracy when compared to the smartphone.

Component: Transmission System
How: Our testing for these units included sending a set data packet containing a set string. The amount of the string sent would be varied at each distance tested to act as different strings. The tests would be run at 25 meters, 100 meters, 225 meters, 350 meters, and 500 meters all while keeping an eye on the data received while walking between each location.
Modifications: Added capacitor
Result: **Success.** During the testing, we concluded that when it was within a working range of approximately 350 meters, the transmission would succeed, and the receiver would get the correct data 19 out of 20 times (95% accuracy) so long as they were within line of sight of each other. When not in line of sight, the success rate would fall to about 10 out of 20 times (50% accuracy). At about 300 meters, we were getting much less, about 5 out of 20 with line of sight and 1 out of 20 with no line of sight. By implementing a capacitor, we expect to keep these same accuracies up to about 500 meters with correct implementation.

Component: Propulsion System
How: Move the boat around a surface of water up to 5 mph
Modifications: RC Boat, Remote Control
Result: **Success.** Boat can successfully move up/down, left/right. Boat is able to accelerate up to 5 mph.

Component: Power System
How: Distribute the power consumption with proper cable management
Modifications: Power Bank**,** Voltage Regulator
Result: **Success.** Each peripheral is given adequate power. Boat can last up to 15 minutes.

Component: Power System
How: Distribute the power consumption with proper cable management
Modifications: Power Bank**,** Voltage Regulator
Result: **Success.** Each peripheral is given adequate power. Boat can last up to 15 minutes.

Component: GUI
How: To test the GUI, we used a cup filled with tap water. Our sensor program will poll data every 1.5 seconds.
Modifications: Debug Code
Result: **Success.** In about 16 seconds, we were able to generate graphs from the time we started polling.