UCF Senior Design 1

Lab Toolkit Data gathering for Scientist, Lake Analysis

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75-page document

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1.0 Executive Summary

In the United States alone there are over 1.5 million ponds and over 125 thousand lakes (not including Alaska). And a majority of people do not know the significance that these bodies of water have on their daily lives. Where lakes and ponds play an essential role in supporting biodiversity, regulating the climate, and providing fresh water for human consumption and other uses. Lakes and ponds can serve as a source of clean, fresh water, making them a critical resource for meeting the needs of both humans and wildlife. And with our project we aim to help the conservation and protection of ponds and lakes but with the inclusion of engineering. This led us to create the idea of a Floating Lab Toolkit to help researchers and scientists gain a better understanding of the water that impacts so many peoples day to day lives.

As technology advances everyday we strive to look to apply it to different fields and unique concepts. In our project we hope to achieve that idea to better help our local ponds and lakes. With our project we seek to give scientists a complete set of tools for capturing vital information on the environment and how it affects people. This toolbox contains cutting-edge technology that enables real-time monitoring and analysis of environmental data, such as pH, water temperature, and air sensors all from the ease of a browser.

The Floating Lab seeks to advance knowledge of the environment and how it affects human health and welfare by giving scientists access to this extensive arsenal. By providing a tool that is capable of remotely monitoring a body of water with minimal hassle. Where a scientist could have multiple toolkits monitoring many different ponds at the same time without having to manually collect samples. This could enable scientists to detect possible dangers and create focused strategies to reduce them by gathering and analyzing data on water quality, air quality, weather patterns, and other environmental aspects.

This report documents the research and design process that has gone into making the Floating Lab Toolkit a reality. First focusing on our methodology of research and what steps we have taken to make this the best product possible. And then going into our project description where we define the goals of the project. Then shifting to our research in similar projects and part comparison. And then part selection and the reasons why they were chosen. And lastly listing our constraints that we have faced in development combined with the engineering standards that we have upheld during our project.

Overall, the Floating Lab Toolkit has a great deal of potential to benefit both the scientific community and the general public. This project can help scientists better understand the intricate interactions between the environment and human health by supplying complete environmental data, ultimately resulting in a healthier, more sustainable future for all of us.

2.0 Project Description

This section analyzes the project by giving an initial overview by exploring the research methodology, the project motivations and goals, objectives, project components, requirement specifications, known constraints, house of quality, block diagrams, estimated project budget, and initial project milestones.

2.1 Research Methodology (Applied Research)

"Applied research is inquiry using the application of scientific methodology with the purpose of generating empirical observations to solve critical problems in society. It is widely used in varying contexts, ranging from applied behavior analysis to city planning and public policy and to program evaluation." (Gaber, 2010).

Our project is based on Applied Research in the category of Research and Development. We plan to seek a better understanding of what already is working in the field of Limnology in the lakes of Florida. With Limnology being the scientific study of freshwater ecosystems. And with our project we strive to improve this study by the development and implementation of real time sensor systems, suggesting optimized protocols or any combination of hardware, software, methods or protocols. Our team will attempt to design and implement improvements to the performance of what already exists or to create new systems to cover fields that were not previously covered.

Research Steps accomplished:

1) Completed a State of the Art search about Limnology and systems supporting the discipline. This could encompass both analog or digital systems that are currently used, including hardware, software and methods as well.
    - From this search we found similar projects, for example The Jefferson Project, WaterAtlas, 'Smart' Buoys, Envirobot and Saildrone among other published sources.
    - We also found multiple articles about water quality in Florida which gave us a better idea about what the biggest problems in the lakes are, for example the proliferation of Green Algae and toxic baterias.
2) Got in contact with experts in the field of Limnology, water quality and biology.
    - The team attempted multiple times to get in contact with Dr. Salvaor Almagro who is a well known UCF researcher in the field of water and the evolution of bacterial pathogens but it was not possible until this moment. https://vibriocholerae.org/
    - The team attempted to contact Dr Lisa Chambers who is director of the Aquatic Biochemistry Lab at UCF. Her research is closely related to our team's project. She replied to our message, accepting collaboration and guidance to our team with limited time availability. https://sciences.ucf.edu/biology/abl/contact-us/
    - The team got in contact with the Orange Soil and Water Conservation District, they directed the group to OC Environmental

Protection Division Water Sciences where Dr Mitchell Katz accepted collaboration and to schedule a meeting with our team. www.ocfl.net\epd

Research Steps Left to Accomplish:

1) To learn from the experts by asking quality questions and receiving knowledge about the technology currently being used. (Dr Mitchell Katz and Dr Lisa Chambers)
2) To understand the actual needs that Florida has in terms of sensors and measuring technologies. Our design will be customized according to those needs, while keeping the essence of the objective of our project intact.
3) To re-select the parts according to regulations or State preferred standards then implement the first prototype of the project. Which will fulfill the most relevant needs that currently exist in Florida's Limnology and then expand in a modular fashion to other features that are important and might not be covered or considered by other developed projects.
4) To test the prototype in a lake and to discuss with scientists if the results are precise and good enough in general terms to be considered a contribution to Limnology.

2.2 Project Motivation and Goals

The purpose of our project is to design and build a Lab Toolkit. This will consist of a medium-sized floating laboratory which will be able to be maneuvered by remote control. Our target for this project is to deploy our floating laboratory in ponds and lakes that interest scientists in Florida. The goal being to monitor these bodies of water remotely. This will be achieved by providing real-time data about the lake to a cloud database accessible by a website or mobile app. Which can later be analyzed with artificial intelligence, or the preferred method used by the scientists.

The Toolkit will provide a flow of information from onboard sensors and can also take water samples at any point in the lake. Also, with the addition of capturing mosquitoes at any point of the lake. (To better understand their behavior and prevent mosquito-borne illnesses)

A potential buyer for our project is the State of Florida. This is because they have demonstrated the importance of research to prevent infections in lakes and stationary bodies of water. With a focus on dangerous bacteria and pathogens carried by mosquitoes that can be developed under certain lakes and environmental conditions. This is important because of outbreaks of mosquito-transmitted epidemics in Florida. Our project will provide a reliable data source for scientists to understand lakes better and help the people of Florida.

The goal is to have a functioning floating device. This device should be moved using a remote control. It will successfully have sensors to analyze water components as well as air. Additionally, it will successfully collect a sample of water when the person controlling it decides so. The floating device will have solar panels on it to the sun to help keep it running.

2.3 Objectives

Our objectives are to achieve this project in the allowed timeframe. This means that the project should be researched during the spring 2023 semester. Then, it should be completed and fully functional during the summer 2023 semester. Additionally, an objective we have is to not exceed $1,000 when it comes to the cost of the needed material.

2.4 Project Components

To design a “floating autonomous biological control lab” that can read various parameters from static bodies of water to understand possible chemical or biological hazards that could exist or potentially be developed. The lab will be a floating vessel equipped with

- Real-time pH sensors
- Water intake to help with bacteria analysis, chemical analysis, microorganism analysis, and gas analysis.
- Mosquito capture tool
- A variety of temperature, CO2, and humidity sensors outside
- Solar panels with backup battery
- GPS card Arduino
- Remote controlled

A radar that is able to have a real-time count of bigger animals, for example, fish or alligators. This can be used to study their behavior and to count the number of fish in the lake. This is important because scientists could introduce more fish in the lake to reduce the concentration of mosquito larvae if needed. (The radar component of the project is a feature that will not be implemented in this moment for senior design because it is not a priority for the kind of research in water quality but will be implemented in the future to build a more complete analysis tool)

Features of the project:

- pH Sensor (Autocalibration)
    - The device will measure the pH of the water it is on.
- Data Array (Store, send to Cloud, Flush, Repeat)
    - The device will send to the cloud information it has collected.
- Bacteria analysis tools (Sample taking)
    - The device will permit additional analysis in a lab since it will collect sample(s) of water.
- Mosquito recollection tool (Analysis counting)
    - The device will be able to collect mosquitoes in the water for additional analysis. It will be a static net attached to the floating device.
- Outside air sensor
    - The device will contain sensors to give information about the outside air (e.g., humidity, CO2 level, etc.)
- Connection to WiFi

    - The device will be able to connect to WiFi to transmit data.

Benefits for user:

- Provides reliable data sources in real time.
- Provides the possibility of data sampling.
- Provides 24/7 availability in the study field.
- Can be used to feed AI in big data for research.

2.5 Requirement Specifications

The following is a table of our requirements specifications. The units with a star (*) are subject to change after consulting with research experts. The highlighted requirements specifications are the ones that will be demonstrated.

Table 1: Requirements Specifications

No	Requirements	Units
1	The system shall measure the water's pH	1x per hour*
2	The system shall transmit the readings to the cloud	1x per hour*
3	The system shall collect samples of water	≥ 30 mL
4	The system shall collect bugs in the water	1 min minimum
5	The system shall detect the water's temperature	1x per hour*
6	The system shall detect the outside temperature	1x per hour*
7	The system shall have solar panels that charge rechargeable batteries	1-2 solar panels,
8	The system shall be waterproof	IP67
9	The system shall be moved with a remote controller	Response time < 2s

2.6 List of Known Constraints

- The system shall not exceed $1,000 in cost.
- The system should be researched, developed, and built-in 2 semesters (Spring 2023 and Summer 2023).
- The microcontroller used will be an Arduino, a parallel system of Arduinos.

2.7 House of Quality

The house of quality is a design tool that we used to visualize the design aspects and requirements for our Lab Toolkit from the perspectives of the

engineers making the product and the customers using the product. And then focusing on the intersection of these two requirements and how to manage levels of importance in our design.

The following is a figure of our house of quality. It contains engineering requirements and customer requirements.

Column #	1	2	3	4	5	6	7
Direction of Improvement	▼	▲	▼	▲	▼	◇	◇
Customer Requirements (Explicit and Implicit) / Engineering Requirements	Part Dimensions	Power Reliability	Weight	Data Throughput	Cost of Materials	Collection of Water Samples	Device Mobility
Cost	▽	●	▽	○	●	●	○
Ease of Use	▽	▽	○	○	○	●	○
Durable	▽	●	○	▽	●	▽	▽
Small Form Factor	●	○	○	▽	○	○	▽
Device Longevity	○	●	▽	○	●	○	▽
Target	< 5 x 5 feet	Above 95% of Time	< 15 lbs	1 set of readings per hour	<$1000	≥ 30 mL	Manuverable from at least 500ft

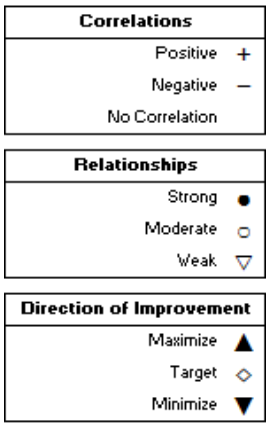

Figure 1: House of Quality

For our product, our customer requirements are a list of aspects a potential customer would like to see in our product when it is on the market. This includes having a low overall price so customers are more likely to buy our project. Another customer requirement would be having it easy to use and easy to take care of, to improve our customer satisfaction. This also includes the customer requirement of making it having a small form factor. They would also prefer if the product is durable to make sure it can survive outside to withstand the hot temperatures and heavy rain. Combine with an increased product longevity so consumers can see a higher value in our product.

The second part of the House of Quality diagram is from the perspective of the engineers designing the product. Where it includes what the designers want to implement as features of the product. And for our project we decided to focus on mitigating the size of parts to make the overall form factor smaller. This combined with our design aspect of making it lightweight. These two aspects should go hand in hand in the design process. Also we are attempting to maximize the reliability of our power which encompasses our battery and use of solar panels to recharge. With another engineering requirement decreasing the overall cost of each material to minimize the total cost. These two requirements are negatively related because if we want to improve the quality and reliability of our power supply these will naturally cost more. Furthermore we want to maximize data throughput of our system so we are able to provide reliable data from our sensors to the consumer. And our last two engineering requirements relate to two key features that will be implemented that have minimal direct relationship. With it being able to be maneuvered and having a system to collect water samples.

2.8 Block Diagrams

2.8.1 Hardware Diagram

The following is a figure of our hardware block diagram. It also shows which parts each member of the team will be working on.

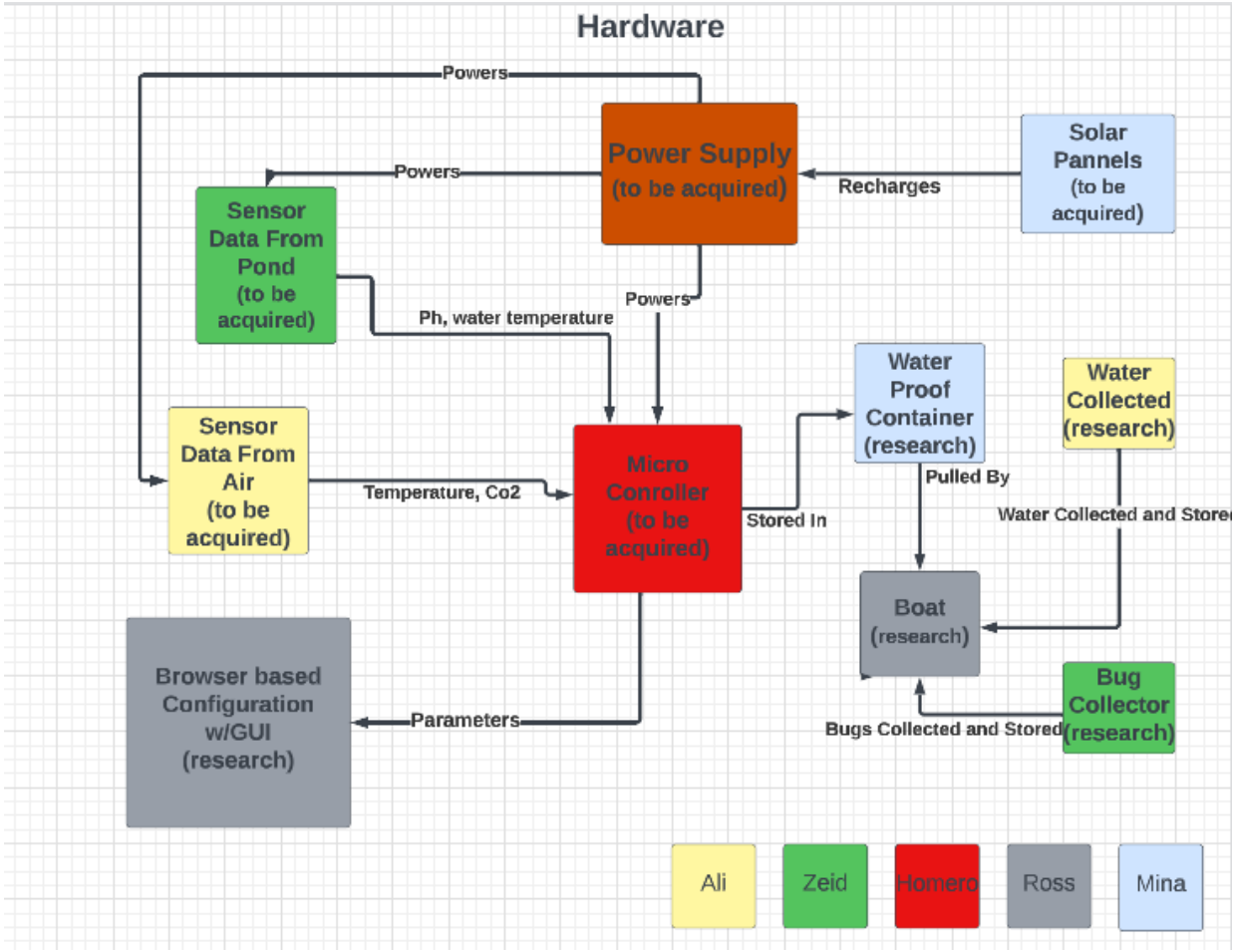

Figure 2: Hardware Block Diagram

2.8.2 Software Diagram

The following is a figure of our software block diagram. It also shows which parts each member of the team will be working on.

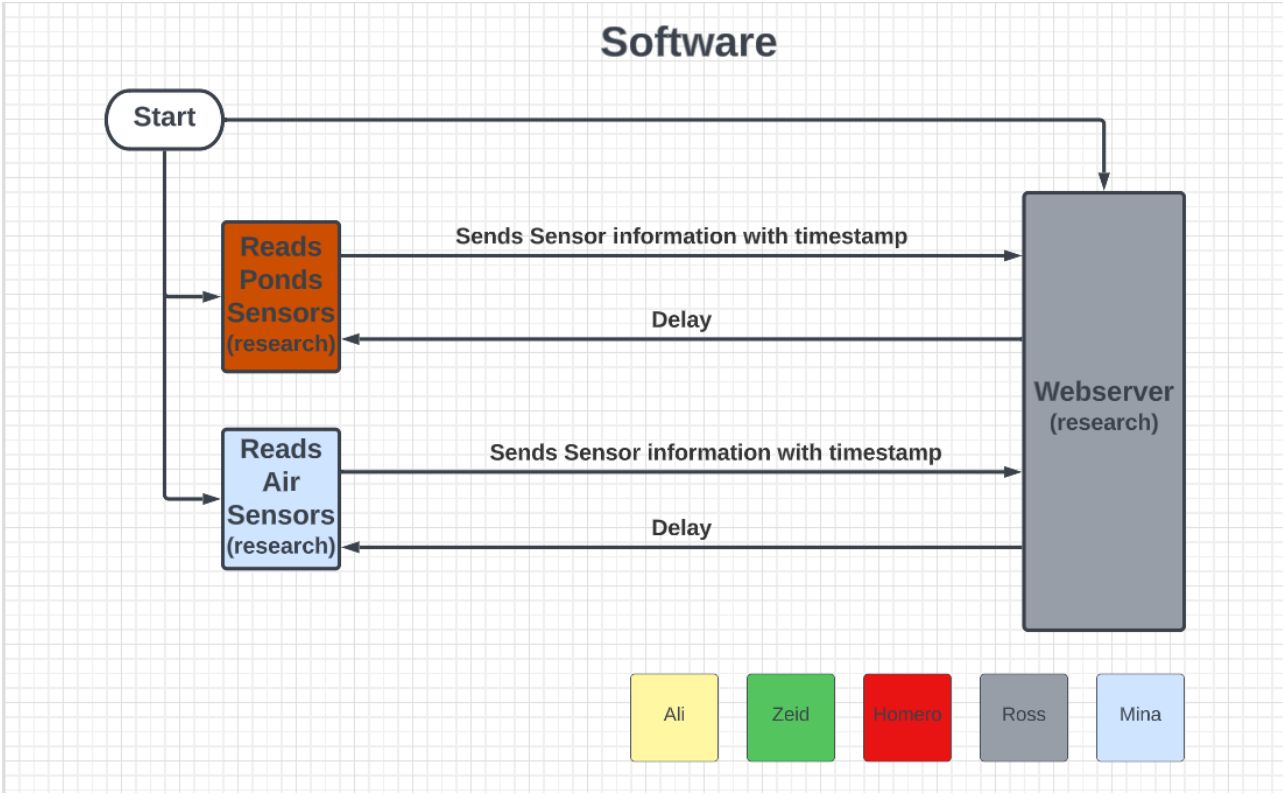

Figure 3: Software Block Diagram

2.9 Estimated Project Budget and Financing

Our budget for this project will be shared among members of the team since this project is not sponsored. Each member is expected to contribute an equal amount of money as the other members. The prices listed below are only an estimate of how much we believe parts are going to cost us for this project.

The following is a table that shows an estimation of what we believe each part will cost us. We then add those up to get a total estimation.

Table 2: Estimated Project Cost

Item Description	**Total Estimated Cost**
Microcontroller	$60.00
Water Temperature Sensor	$30.00
Outside temperature, CO2, & humidity sensor	$100.00
Net (Mosquito collection)	$10.00

RC Boat	$75.00
Water Holder	$60.00
Solar Panels + Accessories	$100.00
Batteries	$15.00
pH Sensor	$75.00
GPS Card	$20.00
Lab Container + Accessories (Floater, silicone, etc.)	$100.00
Servo Motors	$30.00
MicroSD, 32 GB	$10.00
WiFi connection	$100.00
Total Estimated Cost:	$785.00

2.10 Initial Project Milestones

The following is a table showing the milestones we need to respect during our Senior Design 1 course.

Table 3: SD1 Milestones

Date	Details
1/18	Project Conceptual Brainstorming
1/23	Project Idea Discussion
1/25	Project Selection: *Lab Toolkit Data gathering for Scientist*
1/26	10-page DC initial
1/28	Divide & Conquer v1.0 Complete the D&C
2/3	Divide & Conquer v1.0 Due. Submit the completed D&C
2/6	D&C V1.0 Meeting with Dr. Wei Discuss project idea, (approval)
2/10	Divide & Conquer v1.0 Updated and Completed
2/17	Divide & Conquer v1.0 Due Submit the final D&C
2/25	Paper V1 50 draft
3/1	Paper V1 75 draft

3/24	75-page Paper V1 Due 75 Pages
3/27	Group meeting for 75-page feedback
4/7	Updated 75-page draft on website
4/18	Finishing touches
4/25	Final document due
4/25	Order parts

The following is a table showing the milestones we need to respect during our Senior Design 2 course.

Table 4: SD2 Project Milestones

TBD	First day of summer semester goals
TBD	May goals – Build and test components
TBD	June goals – Work on software
TBD	July – work on testing, final paper, and presentation
TBD	Last Day of Class goals – Presentation of the project
TBD	Last day of final exams – Submit the final report

3.0 Research and Part Selection

This section constitutes a research of similar projects and products to our project. Additionally, we explore different technologies that are available on the market. Those technologies will be explored to find the best one that fits our needs. We then compare different parts and components, and we explain why we chose a certain one over the others.

3.0.1 Research Related to Project Definition

After completing the State of the Art search, a wide range of similar projects were found from open source initiatives to professionally elaborated works. For example, the Jefferson Project on Lake George which has been developed by Rensselaer Polytechnic Institute in New York and IBM. And from learning about their project there are some areas that our proposal does not cover but contains features that we would like to add in the future. For example:

- randomized and selective bugs & mosquitoes recollection (using nets for randomized and light frequencies for selectives)
- Camouflage for the Lab station. (In order to record the most natural behavior including wild life with the least interference possible)

3.1 Existing Similar Projects and Products

With the rapid expansion of technology in the world, people have had exemplary ideas to simplify and automate tasks in many fields. This also extends to the fields of Biology and Hydrography. Where Biology is defined as the science of life and living organisms and Hydrography is defined as science that measures and describes the physical features of bodies of water and the land areas adjacent to those bodies of water. This innovation of designing objects to float in water and collect and output data to provide real-time analytics on the quality and information on the water is an imperative step towards helping maintain bodies of water around the world. Most similar projects take this idea and apply it to large bodies of water like lakes. We hope to gain inspiration from these successful products. With our project we plan on focusing on ponds in Florida because of the importance of these bodies of water. Where they provide a diverse habitat for wildlife and produce a home for numerous animals. And also, contribute benefits for humans with flood control, irrigation, and drinking water.

3.1.1 ‘Smart’ Buoys

‘Smart’ Buoys have been strategically deployed in Cleveland, Ohio to improve the quality of drinking water for 1.5 million Cleveland water drinkers. These buoys provide readings measuring vital criteria such as dissolved oxygen levels, water temperature, pressure, wind speed and direction. These readings are important to discern low-oxygen levels in the lake and warn when harmful algae has moved too close to Clevalnds water intake systems. This collected data is important because it is crucial to keep drinking water clean from many people and it is a challenge to notice harmful changes in the water without having it being tested constantly. In this case, it is important to monitor the oxygen levels

in the water because low dissolved oxygen is usually associated with high levels of manganese and iron which can cause changes in water taste, color, and odor. Another side effect of this lowered oxygen is decrease in pH which can cause corrosion in the distribution system, resulting in a potential increase in copper and lead in the water that has been treated. Another application of this collecting water sample is that it can be fed into experimental National Oceanic and Atmospheric Administration (NOAA) models. With this constant stream of data these models can continually be improved on and continuously help benefit researchers and civilians.

Figure 4: Buoys (picture taken from noaa.gov)

3.1.2 “Envirobot” Robot

This project is a remote-sensing robotic eel to track the quality of water and detect the pollution source in the water and swim towards it. The robotic eel “Envirobot” was designed and created by researchers from the Swiss Federal Institute of Technology Lausanne (EPFL). The motivation behind the creation of the robotic eel was to help scientists and experts determine the safety level of a body of water for the people to do their normal activities near it such as swimming, fishing, and drinking. In the process of determining the safety of lakes and ponds, usually scientists face problems and challenges that could prevent them from obtaining the data needed safely. For example, some locations are difficult and dangerous for researchers to reach and collect data or water samples. The robotic eel is created to make the process of getting the data easier, less expensive, and safe for scientists.

Figure 5: Robotic Eel (picture taken from inhabitat.com)

The robotic eel design was inspired from nature and the movement of an eel. The robot is equipped with motors powered by batteries, Wi-Fi and radio antennas, embedded system, and a GPS receiver. In addition, the robot has water temperature sensors, salinity sensor, Oxygen sensor, and pH sensor. The robotic eel is capable of recording data needed for scientists from the sensors and storing the data in the embedded computer in the robot. There are many similarities between our project and the robotic eel “Envirobot”. The main similarity is the ability to help scientists gather the needed data to study a body of water in addition to other similarities such as the use of on-board sensors. The difference from our project is in the design of robotic eel. The robotic eel design was inspired from nature and it looks like an eel, and it is capable of detecting the toxicity of water and swimming towards it. But, both projects serve the same purpose but in a slightly different approach.

3.1.3 Saildrone Autonomous Vehicle

Saildrone autonomous vehicles are one of the most used and efficient products in the world to gather valuable data about the ocean at low cost compared to other products and less dangerous for scientists. The autonomous vehicle Saildrone was designed and manufactured by the U.S. based company Saildrone which is one of the leading companies in the world to provide services of collecting data of the ocean using an uncrewed vehicle. The vehicle has multiple features that are attracting many customers and scientists to use because the vehicle fits the needs of the users and with a lower cost. The brilliant design of Saildrone enabled engineers to harness the power of the sun and wind. The vehicle gains its power by wind and solar using solar panels on the top of the vehicle including the wind propulsion technology used in the vehicle. The tall wing tail adjusts its angle according to the direction of the wind. The Saildrone autonomous vehicle can endure the harshest environments in the ocean which is

the reason why an autonomous vehicle like Saildrone can be used for a mission of up to 12 months without the need of maintenance. As a result, the Saildrone is capable of gathering high quality data from each mission.

Figure 6: Saildrone (picture taken from saildrone.com)

The control of such an autonomous vehicle is important due to the harsh environments it has to endure, the long period of missions, and the importance of the data to be gathered from each mission. Therefore, engineers were able to add an important feature to the vehicle which enabled them to control the Saildrone via satellite by a human pilot. The vehicle has many crucial parts onboard to ensure the safety of the vehicle and to gather high quality of ocean data. For example, The vehicle has transceiver, navigation lights, four high quality cameras, radar, and high-visibility wing colors. All of the mentioned features of the vehicle are important for ocean data collection. There are similarities and differences between our project and the Saildrone vehicle. Our project is intended to be used in less harsh environments than the ocean such as lakes and ponds. Also, our project can be powered using solar panels the same as the Saildrone but without Saildrone's patented wind technology. In the end, both projects are able to ensure safe and cost-effective data collection for scientists and researchers.

3.1.4 Jefferson Project on Lake George (New-York)

Figure 7: Jefferson Project (picture taken from arstechnica.com)

The Jefferson Project in Lake George is a research station developed by the Rensselaer Polytechnic institute in partnership with IBM in order to monitor the lake and extract the most information they can from its waters. The station has the capability of measuring pH, temperature, salinity, conductivity, algae content and dissolved organic matter. The stations can measure water level and the flow velocity of the steam. That information recorded by sensors is periodically uploaded to the project's database using cellular internet connection. A relevant feature is that water samples are automatically taken for additional tests in the analytical chemistry research lab as it was mentioned by the project's developers. The project also has a network of 42 anchored sensors that samples a vertical profile of the lake from surface to bottom. The project wants to set a system to create the "smartest lake in the world".

The company IBM is supporting the project, not only with the architecture and sensors but also the database and algorithms to analyze it. Researchers acknowledge the importance of getting reliable data in the long term to have a better understanding of the lake's ecosystem. The network of sensors is able to create a 3D model of the lake distinguishing solid objects from fluids.

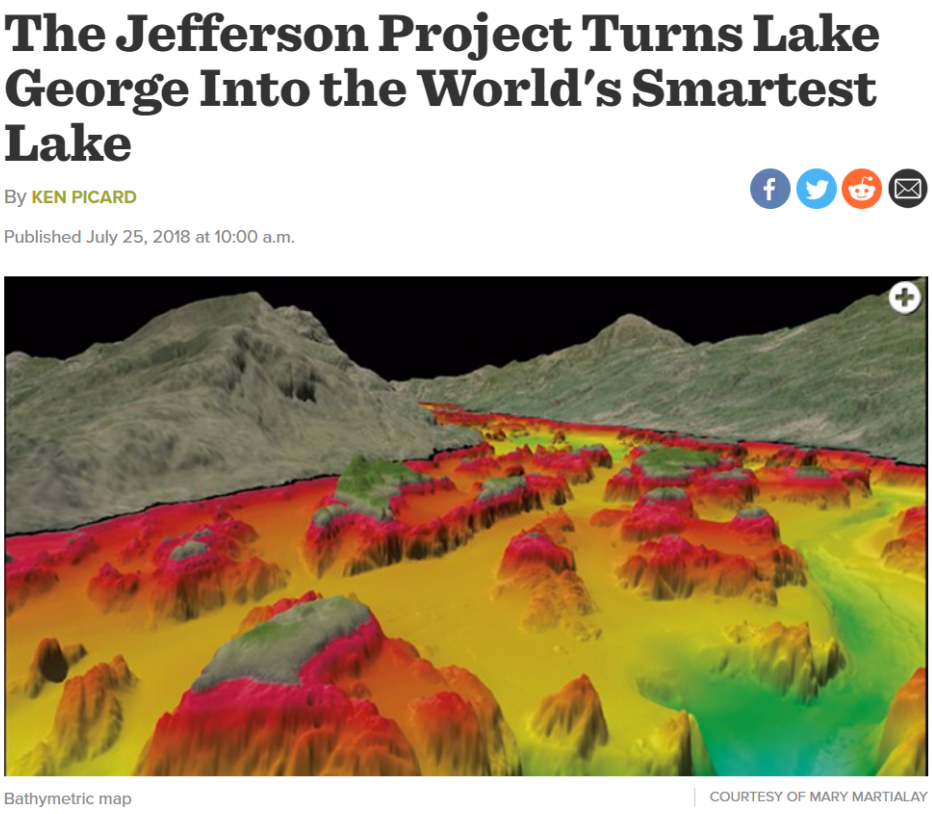

Figure 8: Lake Mapheat (picture taken from sevendaysvt.com)

From the information provided on the project's official page, the project is providing real time information about water quality, weather and potential hazards in the lake, for example toxic algae among other information such as salinity and oxygen. Where all of their sensor data can be reached from a server connected to their real time database provided by their sensor's network.

3.1.5 Lake County Water Atlas (USF)

The University of South Florida's Water Institute created a system called Lake Wateratlas which is able to provide real time information to the public domain for multiple lakes. Different parameters are measured, stored, and shared.

Table 5: Sample Data Parameter (taken from lake.wateratlas.usf.edu)

Latest Data

Sample Date	Parameter	Value	Download †
3/18/2023 12:00:00 AM	Daily Cumulative Rainfall	**0.02** in	Grouped daily, monthly
3/18/2023 10:30:00 PM	Dew Point	**50.38** deg F	Grouped daily, monthly
3/18/2023 10:30:00 PM	Precipitation	**0** inches	Grouped daily, monthly
3/18/2023 10:30:00 PM	Relative Humidity	**87.9** %	Grouped daily, monthly
3/18/2023 10:30:00 PM	Solar Radiation	**0.01** w/m2	Grouped daily, monthly
3/18/2023 10:30:00 PM	Temperature, air @ 10m	**53.55** deg F	Grouped daily, monthly
3/18/2023 10:30:00 PM	Temperature, air @ 2m	**53.87** deg F	Grouped daily, monthly
3/18/2023 10:30:00 PM	Temperature, air @ 60cm	**54.5** deg F	Grouped daily, monthly
3/18/2023 10:30:00 PM	Temperature, soil	**73.45** deg F	Grouped daily, monthly
3/18/2023 10:30:00 PM	Wind direction (direction from, expressed 0-360 deg)	**269.2** deg	Grouped daily, monthly
3/18/2023 10:30:00 PM	Wind Gust	**4.1** mph	Grouped daily, monthly
3/18/2023 10:30:00 PM	Wind velocity	**1.23** mph	Grouped daily, monthly

† Downloads of individual parameter data are available in daily or monthly groupings

3.2 Relevant Technology

3.2.1 The Eureka Water Probes Company's Sensors

The Eureka Water Probes is a company that designs and manufactures multiparameter water quality sondes which comes with software (app) to manage the system. As it can be read from their website, they have a wide variety of sensors with multiprobes capabilities that can be integrated simultaneously to the same system and managed with their software.

The company offers sensors that are able to measure conductivity, pH, turbidity, dissolved oxygen, and depth, but it also offers more specialized sensors like PAR, Total Dissolved Gas, as well as many different kinds of fluorometers which can be used for early detection of hazardous algal blooms or for dye trace studies.

The Eureka company provided high quality sensors that are reliable enough for important measurements in projects that could measure critical data, for example, the presence of dangerous algae. They have a catalog of sensors each providing high levels of reliability and quality. With one of focus being the Manta+ which is used to sense oil spills and green and blue algae growth.

3.3 Strategic Components and Part Selections

3.3.1 Microcontrollers

A microcontroller (MCU) will be important in our project because it will help with many things like sensor readings. Choosing the right one is critical since it will control many important aspects of the project like sensor readings. For the size, we are looking flexible since our waterproof container that will contain the MCU will have plenty of space inside. Microcontrollers are often referred to as mini computers since they are an integrated circuit that can do many things. An MCU typically has a central processing unit (CPU), random-access memory (RAM), read-only memory (ROM), clock, serial bus interface, input/output (I/O) ports, and more. Microcontrollers are capable of running specific and multiple operations in an embedded system. They are able to accomplish these operations by being pre-programmed, often with a response to an input using sensors. Among the most famous microcontrollers are the Texas Instrument LaunchPad MSP430 and Arduino UNO. We will be looking for a microcontroller

that is user friendly and capable of handling multiple things at the same time since we will be reading multiple things using different sensors.

3.3.1.1 TI LaunchPad MSP430G2ET (MSP430G2553)

When it comes to TI boards, the MSP430G2ET is one of the most affordable ones and is an ultra-low-power MCU. Some of its features are: 1.8 to 3.6V operation, 16-bit RISC architecture up to 16MHz system clock, 16KB of flash memory, 512 bytes of SRAM, 8-channel 10-bit ADC, 8-channel comparator, 2 16-bit timers, 24 GPIOs, one universal serial communication interface. As previously mentioned, it is among the most affordable boards offered by TI. It can be obtained for around $10.00 on Texas Instruments' website.

3.3.1.2 TI LaunchPad MSP430FR6989

The MSP430FR6989 is an MCU capable of ultra-low-power. It contains two buttons and an LCD display on the board. It is more expensive than the MSP430G2ET, however, it is still affordable for all it can accomplish compared to the MSP430G2ET. Some of its features are: 1.8 to 3.6V operation, 16-bit RISC architecture up to 16MHz system clock and 8MHz FRAM access, 128KB of nonvolatile FRAM, 320-segment LCD display, 16-channel 12-bit ADC, comparator, five timers, direct memory access, 83 GPIOs, and more. This board is a bit more expensive (can be found for around $20.00 on Texas Instruments' website) than the previous MSP430G2ET, however, it is more performant.

3.3.1.3 Arduino UNO Rev3

The Arduino UNO is a beginner friendly board that can accomplish plenty. Additionally, not only is it user-friendly, it is also open source. It is known for its short learning curve. Some of its features are: 5V operation, 16MHz clock speed, 32KB flash memory, 2KB SRAM, 1KB EEPROM, supports UART, I2C, and SPI communications, and more. This microcontroller can be obtained for around $53.80 on Arduino's website.

3.3.1.4 Arduino UNO WiFi Rev2

The Arduino UNO WiFi Rev2 has the same functionalities as the Arduino UNO Rev3. It adds the capability to connect to a WiFi network, which can be useful. Some of its features are: 5V operation, 16 MHz clock speed, 48KB flash memory, 6KB SRAM, 256 Bytes EEPROM, supports UART, I2C, and SPI communications, and more. It can be bought for around $54.00.

3.3.2 Boat

Our project will consist of a waterproof container that contains the features of the project (e.g., sensors, etc.) being hauled by a floating remote control boat. In other words, the remote control boat will be attached to the container for movement. This will help move the project to any desired location without any difficulties. The boat is important to our project because it will be what moves the container, which is our project. Without it, the container will not be able to be moved to different locations in the water at any desired time. It should be able to haul something on the heavier side without difficulties. Additionally, an important

feature is the maximum range between the remote control and the boat because it will be significant how far the boat hauling the waterproof container can go. The bigger the distance the better. When it comes to the speed of the boat, it is not a major thing we will consider. We will be looking for something with a decent speed, which means it does not have to be the slowest nor the fastest.

3.3.2.1 Contixo T1 RC Boat

The Contixo T1 remote control Boat has a cruising speed of 15 miles per hour. It uses a rechargeable 7.4v 1100 mAh Lithium Ion battery. It requires 2 hours of charge time to be able to play 20 minutes with it. In our case, the boat will not always be in movement, so 20 minutes of play is plenty since we will only move the boat to bring it to certain locations and leave it stationary. The boat has a signal range with the remote control up to 590 feet. It can be found for around $46.00.

3.3.2.2 Contixo T2 RC Boat

The Contixo T2 remote control boat is an upgrade over the previous Contixo T1 in multiple areas. It has a cruising speed of 20 miles per hour. The battery used in it is a rechargeable 7.4v 3000 mAh Li-ion battery. For 30 minutes of play, it requires 3 to 4 hours of charge. Lastly, the boat has up to 820 feet of signal range. It can be found for around $58.00.

3.3.2.3 ifollower RC Boat

The ifollower remote control boat reaches a maximum speed of around 7.5 miles per hour. It uses one 800 mAh rechargeable battery. It has around 25 minutes of play. Also, it has around 195 feet of signal range. The cost of this boat is $40.00. The ifollower boat is not a performant boat when compared to the Contixo T1 and the Contixo T2. The price difference between this one and the previous 2 remote control boats is not that big, however, the specifications are a big difference. It can be obtained for around $48.99.

3.3.3 Solar Panels

When it comes to powering the microcontroller in our project, rechargeable batteries will be used. An important question came up: how do we recharge those batteries? It is not practical to have the user open up the project, take out the batteries to recharge them, and put them back inside. With practicality in mind, the solution was to add solar panels to recharge the batteries powering up the microcontroller. This will avoid having the user open up the waterproof container to take out the batteries once they are drained. Using the sun to keep batteries charged when necessary is an environmentally friendly solution.

3.3.3.1 Semi Flexible Monocrystalline Solar Panel

The semi flexible monocrystalline solar panel is a lightweight panel weighing around 87g. It has an operating voltage of 5V, an operating current of 1A and a maximum power of 5W. This solar panel has a working temperature of

-20 °C to 60 °C (-4 °F to 140 °F). The dimensions of this product are 11.41 x 5.9 x 0.05 inches. Additionally, it is waterproof. This solar panel comes in a package of only one solar panel, which has a total cost of $25.40.

3.3.3.2 FellDen Micro Solar Panels

For these solar panels, the weight was not listed. It has an operating voltage of 5V, an operating current of 200mA, and a maximum power of 1W. The working temperature was not listed. The dimensions of this product are 4.33 x 2.36 x 0.1 inches. This model of solar panel comes in a package of 10 solar panels (10 pieces). The FellDen solar panels have a total cost of $21.00 for 10 pieces.

3.3.3.3 Treedix Polysilicon Solar Panels

The Treedix polysilicon solar panel does not have the weight listed. It has an operating voltage of 5.5V, an operating current of 181 mA, and a maximum power of 1W. The working temperature for this model is -10 °C to 60 °C (14 °F to 140 °F). The dimensions of this product are 3.74 x 3.74 x 0.12 inches. Additionally, this model of solar panel contains 3 pieces. The Treedix solar panels have a total cost of $14.00 for 3 pieces.

3.3.4 pH Sensor

One of our features for this project is providing accurate readings of pH levels of the water**.** pH is defined as a measurement of how acidic or basic a substance or solution is. And is displayed on a scale from 0 through 14 where 7 is neutral. Where readings below 7 are acidic and above 7 are basic. This measurement is important because pH measures the relative free hydrogen and hydroxyl ions in the water. And is an indicator of certain chemicals in the water like lead and copper. We will need a pH sensor that can reliably deliver quick and accurate readings. To properly incorporate this sensor we need to make sure it is compatible with our selected micro controller. This is important because the microcontroller is what is the core of our project. And from our sensor we need it to be able to be compatible with the selected microcontroller to convert the value from analog to digital signals. This will allow us to display the results of the sensor to the desired output medium. One challenge that we have to account for is periodic calibration of the sensor. Periodic calibration is required for pH sensors in order to maintain accuracy over time. And will require further research and communication with experts in the field to understand approved and tested methods. pH is an important metric in determining the quality of a body of water and including periodic monitoring of pH in our system can give researchers more data on ponds and allow for them to sample more ponds remotely.

3.3.4.1 Gravity: Analog pH Sensor/Meter Kit V2

The Gravity: Analog pH Sensor/Meter Kit V2 is designed to measure the pH of a solution with accurate readings of acidity or alkalinity. This product ships with two main components being a signal conversion board and pH probe. And

these components can be easily integrated into an Arduino. It features 3.3 ~ 5.5 wide voltage input. This signal conversion board has two connectors one for the input which connects to the pH probe and one for the output signal. The dimensions of the signal conversion board are 42mm by 32mm and have a measurement accuracy ±0.1@25℃. The pH probe is graded as laboratory grade with the ability to detect pH range from 0~14 and has a zero point of 7±0.5. with a response time of under 2 minutes. This pH sensor provides a fast enough response time with the desired detection and error range. This sensor kit is listed for $39.50 but has more advanced models that can provide different features. If we discover in prototyping and testing we need a more reliable sensor, upgrading will be possible.

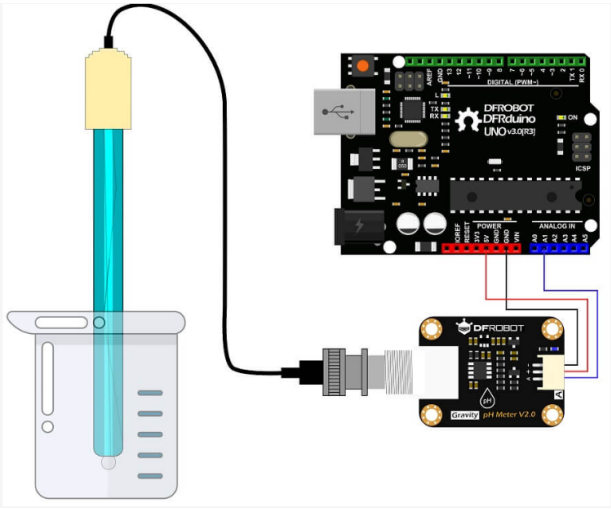

Figure 9: Analog pH Sensor (picture taken from dfrobot.com)

3.3.4.2 AnyLeaf

The AnyLeaf is designed to be a lab-grade digital pH sensor and ORP circuit. With the ability of reading temperature compensation. The AnyLeaf comes with a module and pH probe. This module is dynamic and can be used to connect to an Arduino, Raspberry Pi, or embedded system. AnyLeaf also provides a library of open-source software that can be used in calibration and reading data which will be helpful in constructing an output of data. And supports software for C++, Python, and Arduino. The module dimensions are 50 mm x 25 mm x 17 (height) mm with a weight of 14 grams. And takes an input voltage of 2 ~ 5 V. The pH probe is 155 mm x 12 mm with a weight of 24g. And for pH it can display the range of 0 ~ 14. With a digital precision of 16 bit. The module and pH probe come together for a price of $70.

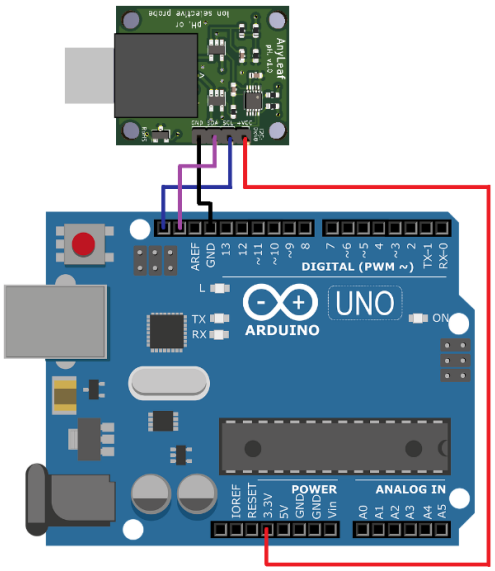

Figure 10: Digital pH Sensor (picture taken from anyleaf.org)

3.3.5 Water temperature sensor

Lake and pond water temperature sensors are an essential piece of equipment for keeping track of the stability and health of aquatic ecosystems. These sensors detect the water's temperature at different levels and can give important information about seasonal variations, thermal stratification, and the consequences of climate change. In addition to measuring the water temperature, some sensors for lakes and ponds can also measure the pH, conductivity, and dissolved oxygen levels in water. Researchers and water managers may utilize this information to create policies for safeguarding recreational activities like swimming and fishing as well as for maintaining and restoring aquatic ecosystems. One of the most delicate characteristics or parameters for industries like petrochemical, automotive, aerospace and defense, consumer electronics, etc. is temperature sensing. These sensors are included into the devices to accurately and efficiently measure the temperature of a medium under a certain set of conditions.

3.3.5.1 Gikfun DS18B20 Temperature Sensor

A digital temperature sensor with an accuracy of 0.5°C, the Gikfun DS18B20 Temperature Sensor Waterproof is designed to detect temperatures in the range of -55°C to +125°C (-67°F to +257°F). It is packaged in waterproof stainless steel, which makes it suitable for usage in a variety of conditions, including high humidity, muddy, or dusty ones. The package's compact form factor of 6mm diameter and 1-meter-long cord make it simple to deploy in confined areas.

Figure 11: Digital pH Sensor (picture taken from amazon.com)

3.3.5.2 HiLetgo K Type Thermocouple Temperature Sensor

The module is simple to employ in a range of applications because of its small form. It features a 3-wire interface for interacting with microcontrollers or other devices and is supplied by a DC 3-5V power supply. With the help of the MAX6675 module's cold-junction compensation circuit, precise temperature readings may be obtained even in settings with changing ambient temperatures. A 12-bit analog-to-digital converter (ADC) that produces a digital output for temperature readings is also included into the device. Overall, the HiLetgo DC 3-5V MAX6675 Module + K Type Thermocouple Temperature Sensor is a trusted and reliable temperature sensing solution that can be utilized in a wide range of applications, including industrial control systems, HVAC systems, and scientific studies.

3.3.5.3 The KOOKYE Temperature Sensor TMP36

This sensor has a small form factor and can be easily integrated into various electronic projects. It is perfect for battery-powered applications since it uses very little power and operates throughout the DC voltage range of 2.7V to 5.5V. The output voltage of the sensor has a slope of 10mV/°C and is directly correlated with the temperature. As a result, using it with microcontrollers or other electronics equipped with analog-to-digital converters is simple (ADCs). Due to the sensor's low output impedance, extended cables may be driven by it without experiencing severe signal degradation.

3.3.5.4 Semiconductor-Based Temperature Sensor LMT86LPM

Texas Instruments makes the LMT86LPM, a precise analog temperature sensor. With a maximum precision of 0.4°C across the temperature range of -50°C to +150°C, it is a low-power device. The sensor is appropriate for battery-powered applications since it operates from a supply voltage range of 2.7V to 5.5V and uses very little power. The LMT86LPM sensor is simple to utilize in tiny designs because of its small form factor and SOT-23-5 package size. It features a linear output voltage that is proportional to 10 mV/°C and fluctuates with temperature. A microcontroller's analog-to-digital converter (ADC) or other data acquisition devices may read the output voltage directly.

3.3.6 Waterproof Container

It is possible to store a microcontroller in a waterproof container on a small floating lab, but doing so calls for careful attention to environmental considerations. The floating lab must be stable and not prone to tipping over or capsizing, and the container must be entirely waterproof and composed of a material that is resistant to water. The microcontroller should also be shielded from harsh weather conditions and other environmental considerations. Data gathering and processing in aquatic situations are made possible by the secure storage of a microcontroller aboard a tiny floating lab.

3.3.6.1 ML-58F Outdoor NEMA Enclosure

The ML-58 Outdoor NEMA is a weather proof enclosure designed for outdoor use. It is constructed from high quality fiberglass reinforced polyester (FRP) material, which makes it highly resistant to impact, corrosion, and UV radiation. A hinged door with a padlockable latch and mounting hardware made of stainless steel are features of the ML-58F enclosure. Many applications, including wireless networks, security systems, and industrial automation, are suited with the ML-58F.

3.3.6.2 Geekworm UNO R3 Case

The Geekworm UNO R3 Case is a protective enclosure designed to house the Arduino UNO R3 board. The container is constructed of premium acrylic and is intended to offer the board strong defense from environmental risks including dust, moisture, and accidental impact. The casing has a clear acrylic design that makes the board and its components easily visible, making it simple to monitor and solve any problems. Also, it includes accurate cuts that make it simple to access all of the Arduino UNO R3 board's required ports, headers, and pins, facilitating communication with other devices.

3.3.6.3 Gratury Junction Box, IP67 Waterproof Plastic Enclosure

The Gratury Junction Box is an waterproof plastic enclosure designed to protect electrical and electronic components in harsh environments. The enclosure is made from high-quality ABS plastic material, which provides excellent impact resistance and UV protection, making it suitable for outdoor and indoor applications. The Gratury Junction Box has a snap-on cover for quick access to the enclosure's contents and a gasket seal to ensure a dust- and water-tight seal. Also, it has mounting holes and pre-drilled holes for cable entrance and exit as well as for simple installation. Because of its small size and low weight, the Gratury Junction Box is perfect for usage in confined locations. It is appropriate for a variety of uses, such as outdoor electrical installations, boats, and industrial automation.

3.3.7 Bug collector

The mosquito trap for randomized samples can be made from a net that will be hanging out during certain moments and then stored back into the Lab by the

use of an electronic switch. It is a simple net structure that has a mild source of heat in the center that attracts random mosquitoes into the trap. The selective trap would be similar but with the capability of emitting different wavelengths of light which could potentially attract one family of mosquitoes more than others, but this feature is more advanced and would have to be developed with the support of an entomologist, specialized in mosquitoes.

3.3.7.1 Benvo Mosquito Net Mesh

The amazon product “Benvo Mosquito head net mesh” fits multiple requirements to be used for the capturing process of mosquitos during missions. The requirements are important to be met so that this subsystem of our project works as intended. The design of this net mesh from Amazon makes it a reasonable choice for mosquito capturing net traps. The shape and size of the net mesh can be easily modified so that we can make it applicable for our net trap subsystem in our project. Also, the weight is an important factor in the selection of such a net mesh. Therefore, this amazon product is a good option because of its ultra light weight which is less than 36g (the weight includes the bag which is not needed for our project).

3.3.7.2 Mosquito Capture Tool

The Walmart product “Mosquito capture tool” is a good option for the net trap subsystem in our project. The mosquito capture tool can be used in the net trap subsystem because of multiple good features in this net. The shape of the net mesh is cylindrical and it can be added to the project. The material used in the manufacturing of the net mesh is environmentally friendly. So, the net mesh of this type won’t be a threat for the environment and lakes during missions. The size of the net mesh is big enough so it can be modified based on our needs.

3.3.7.3 “Insect Protection Netting” product

The product “insect protection netting” is a net bag that is used to prevent mosquitoes from entering into fruits. This product comes with 5 individual pieces of nets that are made of high quality Polyethylene material and environmentally friendly. There is a wide use for this product. For example, it is excellent for mosquito and bug prevention to get into fruits, flowers, and plants. Also, The product is reusable and durable against multiple types of bugs. There are three different sizes for the product. The small size is 15x10cm, medium size is 25x15cm and finally the large size 30x20cm. The shape of the net enables it to be a good option for the net trap in our project.

3.3.8 Power Supply

Our project consists of multiple individual subsystems that need to be powered efficiently during each mission. The power supply ensures that each and every subsystem in our project functions as intended and supplied with the needed and required amount of power to operate the subsystems in a safe manner. One of the main goals of our project is the convenience of use of the system by scientists and users. The user of this product should be able to use the product with peace in mind and not to worry about the discharge of the

battery and losing the power supply of the product. Therefore, losing the product and the important data that have been gathered from the project. As a result, the project needs to draw its power from a rechargeable battery rather than a non-rechargeable battery. In addition, rechargeable batteries are a good fit for our project's requirements regarding the use of solar panels as a source of energy. An infinite energy source that supplies our project with solar power is a feature that can help in increasing the convenience of using the product.

There are multiple types of rechargeable batteries with different chemistry that can be used as the power supply for our project such as lithium-ion battery, (NiMH) battery, and Lead acid battery. Lithium Ion batteries are one of the most commonly used batteries in electronics projects. High efficiency, a long cycle life, high energy density, and high power density are all features in this type of batteries.

3.3.8.1 REACELL lithium-ion 3.7v Battery Connected in Series

The single Lithium ion rechargeable battery is a 3.7 Volt 3000mAh. The lithium ion battery has a higher capacity and a longer lasting power. This rechargeable battery can be bought in multiple quantities such as 4-pack for $20.99.

3.3.8.2 Tenergy (NiMH) Battery Pack

The Nickel Metal Hydride (NiMH) from Tenergy is a battery pack that is 12 Volts and 2000mAh high in capacity. The battery is a secondary battery which means it is a rechargeable battery. The battery is portable, used for RC models and DC devices, and it costs $20.00.

3.3.8.3 SHENMZ lithium ion battery (Li-Ion)

The lithium ion battery (Li-Ion) from the SHENMZ store is a 3.7 Volts 3400mAh flat top battery. The battery is rechargeable and it comes in 4 single batteries. The 4-pack battery comes with an additional charger and it can be bought for $38.88.

3.3.8.4 Swanlake (NiMH) rechargeable battery

The Nickel Metal Hydride (NiMH) battery from Swanlake brand is 3.6 Volts and 2500mAh. The battery is rechargeable, and it is used for many applications. The product comes in a four pack protected battery, and it costs $24.99.

3.3.9 Data Transmission

The main focal point of our project is our ability to provide a wide array of accurate metrics of ponds and have these readings be able to be displayed in a way that can be remotely accessed. To achieve this for our project we need a way to transmit the data from the microcontroller to our server. Data transmission is the transfer of data from one digital device to another. And occurs via point-to-point data streams or channels. There are two main ways of data transmission: wired and wireless. With the nature of this project we are limited to only using wireless data transmission. Where wireless transmission is a form of

unguided media that has no physical link between two or more devices. This method works because the lab kit will be isolated in the body of water. And will need to send the data in the form of signals across the water. Three different ways of achieving wireless transmission include connection of cellular, over WiFi, and transmitting local radio waves to a receiver. Each of these methods could achieve the desired result of transmitting data because they all achieve the ability to transmit a signal to a receiver. And deciding which technique to implement depends on the surrounding area and the potential reliability of the signal being sent. Since we are periodically sampling the bodies of water, sampling speed is not an issue because we can scale that back accordingly. Resulting in the focus needing to be shifted on reliability of our data so we are able provide recurrent readings. Location will be a factor in choosing the method because commonly ponds are in remote Floridian areas. Making it challenging to get cellular signals because of the lack of cell phone towers and seldom having a local WiFi set up in the surrounding areas. Coupled with potential pond size where it could cause trouble depending on the strength of the signal being sent across a large distance. No matter what medium we choose to send the information over we will still need to structure the data that is being taken. The information we want to send needs to be organized in custom arrays that will be decoded by our selected method of reception and then uploaded to our web server. This custom array should consist of all the sensor results that have been taken from the lake. Eventually further into development we could potentially find a way to make each lab tool kit modular for data transmission. Depending on the surrounding factors of location different methods of transmission could be used.

3.3.9.1 ESP8266 WiFi Module

The ESP8266 WiFi is a self contained SoC that can give microcontrollers access to WiFi networks. Where it is capable of WiFi direct (P2P) enabling easy direct connection among WiFi devices using 2.4 GHz WiFi. To achieve this I²C serial communication protocol is used. This module is capable of hosting an application or offloading WiFi network functions from another application processor. For storage it has 4MB of flash memory and can wake up and transmit packages in under 2 ms. With a standby power consumption of 1.0mW. This module also has huge community support providing a backlog of examples of how to integrate it into different microcontrollers. The maximum voltage that it can take is 3.6 V which means depending on the microcontroller and power supply the voltage might need to be shifted. The price of this component is listed at $7.50.

3.3.9.2 SIM900A GSM Module

The SIM900A GSM Module is a module that allows for GPRS/GSM communication. Where GPRS/GSM are the technologies that allowed 2G and 3G networks to be functional by providing the ability for data packets to be sent at high speeds using simple wireless access. This module uses 900 and 1800 MHz frequency bands to allow connection to be made using SMS. Where it can be connected to all sorts of embedded systems with easy accessibility to Arduinos.

Because input data can be sent or received through the UART interface. This component can be found being sold for $7.47.

3.3.9.3 SparkFun LTE CAT M1/NB-IoT Shield (with Hologram SIM Card)

The SparkFun LTE Cat M1/NB-IoT Shield is designed to connect Arduino or Arduino-compatible microcontrollers to connect to LTE networks across the globe. The SparkFun LTE is capable of sending communication over UART to a microcontroller via a simple command set. And has the ability of sending SMS text messages to communicate with servers over a TCP/IP connection.
With the price of this component being $96.50.

3.3.9.4 Speed RF Transmitter and Receiver Link Kit - 315MHz/ 433MHz

The Speed RF Transmitter and Receiver is an ultra-long distance 315mHz or 433mHz radio frequency link set that provides stable frequency and strong anti-interference ability. This Speed Link Kit allows for wireless data transmission and potential use as a remote control. The Speed Link Kit consists of a pair of electronic RF transmitter and receiver. These are used to send and receive radio signals between two devices, typically microcontrollers. The RF signal has a frequency of 315Mhz or 433MHz and is propagated through the air. Where data is sent by the transmitter module to the receiver transmitter. Transmission works by employing Amplitude Shift Keying. Where the module for the transmitter receives serial input from a microcontroller and transmits it by radio frequency. This module can be integrated with any microcontroller. When selecting the RF 433MHz there has to be a focal point on the distance of transmission and with the Speed Link Kit it has listed a long emission distance of 2km (1.24 mi) in open area without interference. With the price of this component being listed at $17.

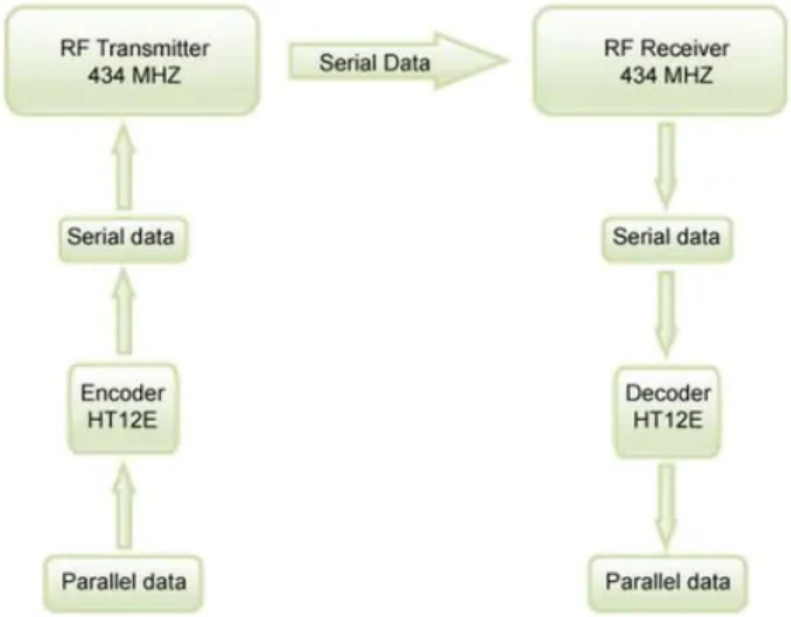

Figure 12: How 433 MHz RF Module Works (picture taken from robocraze.com)

3.3.10 Server Configuration

After the data has been collected, transmitted, and decoded it will need a way to be displayed. To achieve this we will have a server that will store, send, and receive the data. This can be done in a multitude of ways with two main focal points on the type of server stack and the location of the server. It is important to have

3.3.10.1 Server Stack

The first component of server selection is the server stack that will be used. A server stack is the collection of software that forms the operational infrastructure on a given machine. Our application like this will have four tiers. Which are the client tier, web tier, business tier, and database tier. The client tier is the component that is loaded in the browser for the user. The web tier consists of the web server or HTTP server. The business tier consists of the application server, development platform, frameworks and server-side programming languages. And lastly the database tier consists of the type of database used to store information.

3.3.10.1.1 LAMP Stack

A LAMP stack consists of four components: the operating system in Linux, the web server being Apache, the database server operating in MySQL, and the programming language consisting in PHP. LAMP stacks are commonly used to build websites and web applications.LAMP stacks have been used since 1998, making them efficient, regularly maintained and updated, and very widely supported by the community.

3.3.10.1.2 MERN Stack

A MERN stack consists of four components: MongoDB for the document database, Express.js which is used for the web framework, React.js for the client-side JavaScript framework, and Node.js as the JavaScript web server.

3.3.10.1.3 MEAN Stack

A MEAN stack consists of four components: MongoDB used for the document database, Express.js for the web framework, Angular.js which is used for the client side JavaScript framework, and lastly Node.js for the JavaScript web server.

3.3.10.2 Server Location / Provider

The second component of server selection is the physical location and provider that will be used to host it. A server provider is a company providing the data center and server hardware. And is used for Amazon Web Services and Digital Ocean.

3.3.10.2.1 Local Hosted Server

A local hosted server refers to a server that is physically located within an organization's premises, as opposed to being hosted in a remote data center.

Local hosted servers can be used for a variety of purposes such as hosting websites, storing data, and running applications. One of the primary advantages of a local hosted server is that it provides complete control over the server environment, allowing organizations to customize the server to meet their specific needs. Additionally, local hosted servers can offer faster data access and processing speeds, as well as enhanced security, as the data is not being transmitted over the internet. However, local hosted servers require a dedicated physical space, power supply, and maintenance, which can add to the overall cost of ownership.

3.3.10.2.2 Amazon EC2

Amazon Web Services is a cloud computing platform offered by Amazon.com that provides a wide range of cloud-based computing services to individuals and organizations. Amazon EC2 (Elastic Compute Cloud) provides resizable computing capacity in the cloud. And can be used to launch virtual private servers.

3.3.10.2.3 Digital Ocean Droplet

DigitalOcean is a cloud hosting provider that offers cloud computing service and Infrastructure as a Service (IaaS). One feature of Digital Ocean is their service of a Droplet. A DigitalOcean Droplet is a virtual private server that is created and hosted in the cloud. This allows flexible server configuration that can be easily scalable depending on the CPU, memory, storage, and network options depending on the needs.

3.3.11 Air Quality Sensors

Air Quality Sensors are an important part of the project because by detecting the presence and concentration of gasses over the lake, it is easier to have some idea or educated guess about the possible microorganisms and processes happening in the lake that could produce those types of gasses. For example, when there is a high number of fish dying simultaneously and the presence of cyanobacterias in the lake is high as well, not only the pH and water quality changes, but the air over the lake and nearby areas is affected as well. Air Quality Sensors are important in terms of detecting gasses that could be harmful for human beings or animals if found in concentrations above the permitted limits according to regulations for human safety.

The sensors searched for this section of the project will be used in the first prototype which will be functional but not the actual deliverable as a final product. The first prototype will be managed by an Arduino UNO WiFi REV2 board which has SPI, I2C and UART communication protocols. Most sensors found in the market are rated for indoor use. However, it is possible to build a small case that passes the surrounding air by emulating an acceptable approximation for indoor conditions in terms of temperature and humidity. Sensors can be found in the original manufacturer's websites, and they can also be found in other vendors' websites for example Digi-Key, Mouser Electronics, Ultra-Librarian or Amazon among others.

3.3.11.1 Adafruit SGP30 TVOC /eCO2 Gas Air Quality Sensor.

The Adafruit SGP30 sensor is able to detect a wide range of volatile organic compounds (VOCs) for example H2, alcohols, aldehydes, organic acid, and CO2 among others in the air. This sensor comes with a built-in feature for calibration, for example, temperature and humidity compensation which provides a set of more reliable measurement over a wider range of operating conditions. This sensor is rated for indoors, but its compensation feature could make it more suitable for adaptations to outdoor by creating a small case that emulates an approximate indoors environment while the sensor uses the feature to auto calibrate.

3.3.11.2 MQ-135 Air Quality, Gas Sensor Module

The MQ-135 Gas Sensor has an analog output hooked from the AO pin and the digital output hooked from the DO pin (the project considers digital output only but it has the analog option as well). The sensor's mechanism comes inside a steel exoskeleton that is soldered over the sensor's board. It is capable of detecting the following gasses NH3, NOx, Alcohol, Benzene and smoke among others. This sensor has been commonly used in arduino projects.

3.3.11.3 Digilent Pmod AQS: Digital Gas Sensor for Air Quality

The Pmod AQS sensor is made by Digilent Company (well known for producing a variety of digital electronic products including high quality FPGA boards). The sensor is capable of detecting a wide variety of volatile organic compounds (VOCs), CO, NO2, and even PM2.5 (particulate matter) which can be dangerous if inhaled. The is rated for indoors but could be adapted inside the floating lab to work under approximate indoors conditions. This sensor has a wider range of operation in terms of temperature when compared to the other sensors, but it doesn't have the temperature and humidity compensation (autocalibration) feature that the Adafruit SGP TVOC sensor has which makes it more convenient.

3.3.11.4 MIKROE - 1630

The MIKROE sensor is made over a MQ-135 air quality sensor, but it is installed over a compact board which optimizes its portability across development boards and intrinsically enhances the possibility of power management if it is correctly installed by the user. It is made by MikroElektronika company and distributed by various vendors. This sensor has no Low-power mode or average power consumption rated; it is important to limit the current to avoid damage and to use power managing techniques, for example, duty cycling or manage it directly with the microcontroller, limiting its power consumption.

3.3.12 Water Sampling Devices

It is important to implement a system that scientists can use to take reliable samples of water in the lakes, avoiding cross contamination or uncertainty related to the depth, and having the location or time when the

samples were taken. Some sampling mechanisms that are currently being used in the market were searched and listed below, but certainly if used for the project, must be adapted or a new mechanism must be developed, using the same principles of fluid dynamics and sample fidelity. All parts searched will be confronted against regulations according to what the State of Florida Water Quality Laws have established or common standards that might be used in the industry.

Not only the mechanism of sampling but the size and weight when fully loaded must be considered to avoid overloading the floating lab or not distributing the weight uniformly while loading the samples which could result in sinking the lab or water infiltrations that could compromise the integrity of the electronic devices and the reliability of measurements taken.

3.3.12.1 Manual Deep Water Sampler

The Manual Deep Water Sampler was designed to be used working with gravity. A technician extends an arm from an elevated position, for example, a bridge or a hill and lets the sampler descend into the water. The depth is measured by managing the length of the rope as it is shown in their website. It is made of robust Plexiglass (plastic), it comes with a 15 meters rope and comes in two different sizes for volumes of 1000 milliliters and 2500 milliliters.

3.3.12.2 Water Sampler (United Scientific)

The water sampler is made by the company “United Scientific”, and it is made of PVC. It comes with waterproof rubber seals; the sampler is able to hold about 1.5 liters of liquid that is collected with a manual signal (jerk the line to close the apparatus). It includes a 20-meter line of Styrofoam winding floats. The size of the sampler is 300 mm in height and 100 mm in diameter, and it weighs 907 grams. It seems to be a well designed tool for a much better price than the other options.

Figure 13: Water Sampler (picture taken from unitedsci.com)

3.3.12.3 Vernier Water Depth Sampler (Fisher Scientific)

The Vernier Water Depth Sampler is our second best option after United Scientific. It has very similar characteristics including the volume storage capacity, but the price of Vernier is around $25.13 higher than United Scientific's for a similar product. It also comes with a 15.24 meters of nylon drop cord which unfortunately is 4.75 meters less than what is offered by United Scientific.

Figure 14: Water Depth Sampler (picture taken from fishersci.com)

3.4 Part Selection

3.4.1 Microcontroller Selection

Microcontrollers are small and powerful devices because they can accomplish plenty. Selecting the right one is an important task for it can be seen as the brain of a project. When it comes to our project, the microcontroller is important because it will accomplish multiple important tasks like controlling the sensors that will read certain things in the water and in the air like the temperature and more. After researching multiple microcontrollers, our team has selected the three we thought would suit our needs for this project the most. Afterward, we compared their features to see which would be the best to use.

The following table shows a comparison of some boards we have researched. It is then followed by a figure of the Arduino UNO WiFi REV2, the microcontroller we chose.

Table 6: Microcontroller Boards Comparison

	MSP430G2ET	**MSP430FR6989**	**Arduino UNO Rev3**	**Arduino UNO WiFi REV2**
Operation Voltage	1.8 to 3.6V	1.8 to 3.6V	5V	5V
System Clock	Up to 16MHz	Up to 16MHz	16 MHz	16MHz

Memory	-16KB Flash memory -512 Bytes SRAM	-8MHz FRAM access -128KB non volatile FRAM	-32KB Flash memory -2KB SRAM -1KB EEPROM	-48KB Flash memory -6 Bytes SRAM -256 Bytes EEPROM
Communication	UART, IrDA, SPI, I2C	UART, I2C, SPI	UART, I2C, SPI	UART, I2C, SPI
LCD Display	No	Yes (320 segments)	No	No
Manufacturer	Texas Instruments	Texas Instruments	Arduino	Arduino
Price	$10.00	$20.00	$27.60	$53.80
Size (Length x Width)	N/A	76.2 mm x 50.8 mm	68.6 mm x 53.4 mm	68.6 mm x 53.4 mm
Weight	N/A	28g	25g	26g

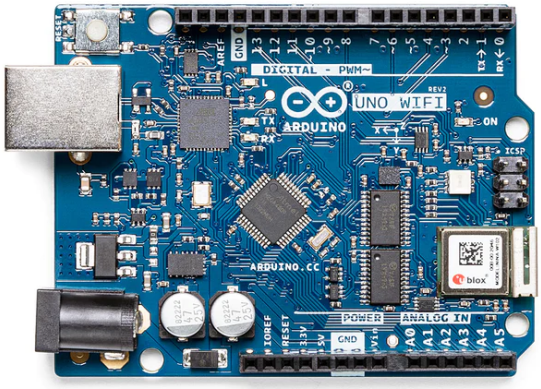

Figure 15: Arduino UNO WiFi Rev2 (picture from store-usa.arduino.cc)

The MSP430G2ET, manufactured by Texas Instruments, is a simple MCU capable of plenty. One advantage it has among the three MCUs is the cost, for it is the cheapest out of the four. Its system clock can go up to 16 MHz. The memory associated with it seems to be reasonable with 16KB of flash memory and 512 Bytes SRAM. Something it lacks is an LCD display like the MS430FR6989 contains. However, the LCD display is not important in our project because the microcontroller will be inside a waterproof container that we will not be able to see. When it comes to communication, it is able to support UART, IrDA, and SPI with its serial communication interface A (USCI_A). Additionally, its serial communication interface B (USCI_B) does support SPI and I2C. In order to not waste resources, this board is capable of being in low power mode, which is

a way of optimization to save battery life. The size and weight were not available online when trying to find them.

Moving on to the MSP430FR6989. This MCU is an upgrade over the previously mentioned model and is more powerful. It is also manufactured by Texas Instruments. Its system clock can also go up to 16 MHz. When it comes to its memory, it has 8MHz FRAM access and 128KB non volatile FRAM. For communication, the user guide of this board only mentioned UART. However, in our Embedded Systems class at UCF (EEL4742C), we did use this board with SPI and I2C communication in labs. A plus it has over the other boards is that it has an LCD with 320 segments. This MCU is also capable of low power mode to save battery life, which is important for our project because the MCU will be powered on by a battery. Its price is in the middle range when compared to the other boards. The size of it is 76.2 mm x 50.8 mm, and its weight is 28g.

The Arduino UNO Rev3 is another popular MCU. The manufacturer of this board is Arduino, which is a change from the previous two MCUs discussed. It has a system clock of 16 MHz. It has good memory with 32KB flash memory, 2KB SRAM, and 1KB EEPROM. This board does not have an LCD display, which again, is not a big issue when it comes to our project because of the location of the MCU. Communication wise, the Arduino UNO Rev3 is capable of supporting UART, SPI, and I2C. It is capable of low power mode, which is important to save battery as much as possible. It is reasonably priced at $27.60. Its price makes it more expensive than the previous 2 models discussed, however, it is still reasonably priced. The size of this board is 68.6 mm x 53.4 mm. Additionally, it weighs 25g, making it less heavy than the MSP430FR6989.

The Arduino UNO WiFi Rev2 is an interesting board, and it is the one we will be using in our project. It is capable of accomplishing everything the Arduino UNO Rev 3 is able to do. However, it is able to be connected to a WiFi network, and it has bluetooth too. For its system clock, it has 16 MHz. The memory on it is reasonable; it has 48KB flash memory, 6 Bytes SRAM, and 256 Bytes EEPROM. Like the Arduino UNO Rev3, it does not have an LCD display. When it comes to communication, it is capable of using either UART, SPI, and I2C. This board is also capable of having low power mode activated to save as much battery as possible. Out of all the boards, this one is the most expensive at $53.80 on Arduino's website. Compared to the other boards, this one is expensive. For instance, it is 5 times the cost of the MSP430G2ET. Its size is exactly the same as the Arduino UNO Rev3 at 68.6 mm x 53.4 mm. Also, it weighs 26g.

Moving on to why we chose the Arduino UNO WiFi Rev2. After taking a look at all the MCUs mentioned, we found that the LCD display was not an important feature for our project since the MCU will be inside a waterproof container, making the LCD display not useful. Additionally, we could not find a use for it even if it was not inside a container. We wanted something with decent memory, which the Arduino UNO WiFi Rev2 has. Additionally, communication wise, the chosen board is capable of using all these different communication protocols, which makes it a good choice. The board had to have low power mode. The reasoning behind this is that our MCU will be powered on by a

rechargeable battery that gets recharged using solar panels. By having low power mode, we would be able to save as much battery as possible, which in this case is important. After researching all these boards, we have learned that Arduino are a lot more user friendly, for they are easier to understand and program. They use C/C++, which a lot of us in the team are familiar with thanks to previous experience in courses taken at UCF. Arduino boards also have a lot of libraries available to them to help control sensors, motors, and more. Also, Arduino has a big active user community which promotes open-source. This fact is helpful because a lot of work could have been done and optimized already and that would make our project easier to implement compared to if we try to create the same thing that is not optimized. A big feature that made us unanimously agree on the Arduino UNO WiFi Rev2 is that it is capable of WiFi and bluetooth. The sensors in our project will make readings, and we want to send those numbers to a cloud preferably. For this to happen, the device needs to have a connection. Because this board can be connected to a WiFi network, sending our sensor readings should not be an issue once we have it connect to a WiFi network.

3.4.2 Boat Selection

Having the waterproof container float on the water is an interesting idea. However, what if someone wants to move it to another location? This is where the boat comes from. Our waterproof container that has the sensors and more will be attached to a remote control boat, making it easier to move around the water. Any user will be able to grab the remote control, move the boat, and the container will follow. Having the container move adds an improved level of user experience since a user can now move the project strictly using the remote control without having to go in the water themself. Selecting a good boat is important since this will be how our project will be moving around in the water. After looking at multiple remote control boats online, we have selected three to compare their features and see which is the best one to fit our needs.

The following table shows a comparison of some boats we have researched. It is then followed by a figure of the Contixo T2 Boat, the boat we chose.

Table 7: Boat Comparison

	Contixo T1 Boat	**Contixo T2 Boat**	**ifollower Boat**
Speed	15 miles/hour	20 miles/hour	7.5 miles/hour
Charge time per play time	2 hours for 20 minutes of play	3-4 hours for 30 minutes of play	Charging time N/A, 25 minutes of play
Battery Type	Rechargeable 7.4v 1100 mAh Lithium Ion	Rechargeable 7.4v 3000 mAh Li-ion	Rechargeable 800 mAh

Range	Up to 590 feet	Up to 820 feet	Up to 195 feet
Manufacturer	Contixo	Contixo	ifollower
Price	$46.98	$58.00	$48.99
Size	387 mm x 288.036 mm x 109.98 mm	463.55 mm x 114.3 mm x 88.9 mm	238.76 mm x 60.96 mm x 78.74 mm
Weight	1057g	616.89g	405.4g

Figure 16: Contixo T2 boat (picture from theaccessoriesplaceonline.com)

The Contixo T1 boat, manufactured by Contixo, is capable of going around 15 miles per hour. It requires around 2 hours of charging for the user to be able to play 20 minutes with it. When it comes to the battery, it is equipped with a rechargeable 7.4v 1100 mAh lithium ion battery. The maximum range the boat can distance itself from the remote control and still function is up to 590 feet. The Contixo T1 can be obtained online for around $47.00. Additionally, for its size, it is 387 mm x 288.036 mm x 109.98 mm. For the weight, it is on the heavier side weighing around 1057g. The features of this boat are very reasonable for its price when compared to other options.

Moving on to the Contixo T2 boat, which is also manufactured by Contixo. This remote control boat model is an upgrade over the previously discussed Contixo T1, and we shall analyze the specifications. The speed of this boat is around 20 miles per hour, which is a 5-mile increase in speed when compared to the previous model. To get 30 minutes of play time, the battery needs to be charged for 3-4 hours. Compared to the previous model, we would get 10 minutes of extra play time, but we would have to charge the battery 1-2 hours more for that. The boat is equipped with a rechargeable 7.4v 3000 mAh Li-ion battery. The Contixo T2 boat has almost a battery that is 3 times the capacity of the previous model (Contixo T1 has a battery of 1100 mAh). However, play time

is not tripled when compared to the previous model. The Contixo T2 boat can be obtained online for around $58.00. The size of the boat is 463.55 mm x 114.3 mm x 88.9 mm. Its weight is 616.89g.

Last but not least, the ifollower boat. The manufacturer of this boat is ifollower. This boat has a speed of 7.5 miles per hour, which is deceiving when compared to the previous two models discussed. After searching for the charging time of the battery, it was not specified on any website. However, we did extract that the boat can be played with for 25 minutes, which is good when compared to the other models. It comes with a rechargeable 800 mAh battery. The battery is small when we look at the Contixo T1 that has a battery of 1100 mAh and the Contixo T2 with a battery of 3000 mAh. Additionally it has a deceiving range of 195 feet. We say deceiving since the Contixo T1 has a range of up to 590 feet, and the Contixo T2 has a range of up to 820 feet. The price of the ifollower boat is around $48.99. Its size is 238.76 mm x 60.96 mm x 78.74 mm, and it weighs 405.4g.

Moving on to why we decided to go with the Contixo T2 boat. The Contixo T2 boat offers the most value for its price after comparing it to the other two models. With 20 miles per hour of speed, it is the boat that can go the fastest of the three. The speed can be seen as a nice feature to have, however, it is not that important. We do not want the user to be stuck with a slow boat that takes a while to move the project around. So, we were looking for something with a reasonable speed. The play time of 30 minutes is also the most out of the three models, meaning the user can have more time to move the boat around in the water. The bigger the play time the better because users will have to take the boat out of the water less to recharge it. Play time can be seen as more of a convenience thing. One thing to note is that the boat will not be constantly moving with our project; the user will move it to a certain location(s) in the water and leave it there to get readings from the sensor, and more. However, a downside of this model is that it takes the most time to charge the battery with 3-4 hours of charge time. An important feature we all agreed on is the range of the boat because it means the boat can go up to a certain distance without the user having to move from their initial location. Having a big range is important as every pond is of different size, so a big range means a bigger area is covered. The Contixo T2 offers the biggest range out of the three models with a range of up to 820 feet. Lastly, even if the Contixo T2 has the best speed, play time, and range out of the three models, it is only $10.00 more expensive than the other two models.

3.4.3 Solar Panel Selection

In our project, having solar panels will be a convenience to the user. Having rechargeable batteries means taking them out to recharge them and then putting them back. Solar panels will make the rechargeable batteries recharge using the sun, meaning users will not have to take them out to charge them. The rechargeable batteries will be powering on the MCU, which means we need to select a good solar panel since the fate of the MCU rests in having the batteries

powering it recharged. Additionally, having solar panels is an environmentally friendly solution.

The following table shows a comparison of some solar panels we have researched. It is then followed by a figure of the semi flexible monocrystalline solar panel, the one we chose.

Table 8: Solar Panel Comparison

	Semi Flexible Monocrystalline	**FellDen Micro**	**Treedix Polysilicon**
Operating Voltage	5V	5V	5.5V
Operating Current	1A	200 mA	181 mA
Power	5W	1W	1W
Weight	87g	277.8g	99.7g
Working Temperature	-4 °F to 140 °F	N/A	14 °F to 140 °F
Manufacturer	DFRobot	SuniAde	Treedix
Dimension	289.8 mm x 149.86 mm x 1.27 mm	110 mm x 60 mm x 2.5 mm	95 mm x 95 mm x 3.05 mm
Pieces Included	1	10	3
Cost	$25.40	$21.00	$14.00

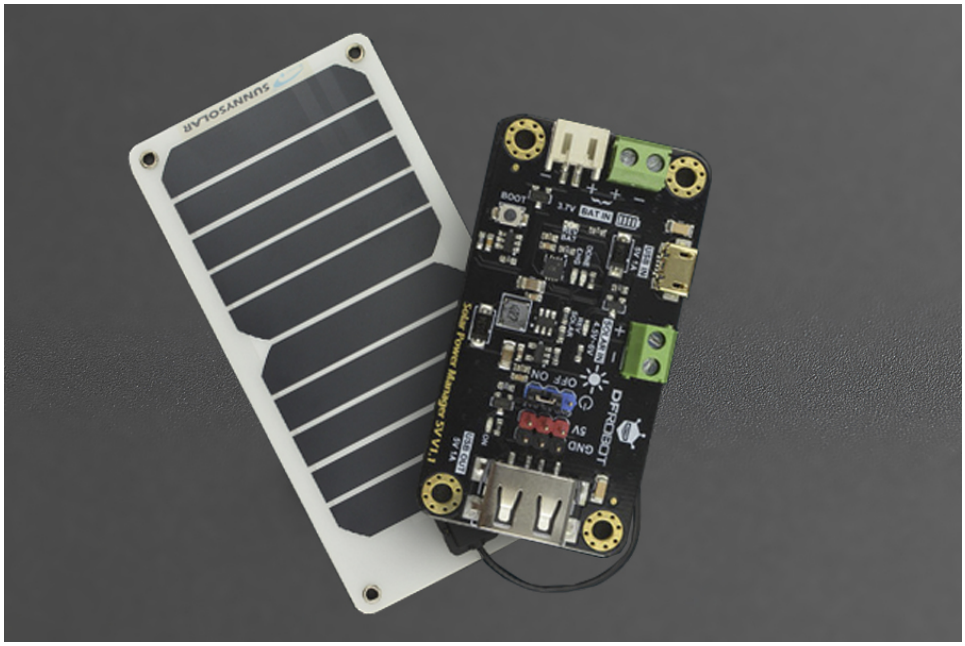

Figure 17: DFRobot (picture from dfrobot.com)

The semi flexible monocrystalline solar panel is manufactured by DFRobot. It is a solar panel that has an operating voltage of 5V and an operating current of 1A. It has a listed power of 5W, which can also be deduced using the electric power formula P=VI. The weight of this model is 87g. For its working temperature, it works in temperatures between -4 °F and 140 °F. It can work in either very hot or very cold temperatures. The dimensions of it are 289.8 mm x 149.86 mm x 1.27 mm. When one buys this solar panel, only one will come in the box. If something happens to that solar panel like if it stops working or it gets damaged, the user would have to buy another one completely.
The listing price of this semi flexible monocrystalline solar panel is $17.50 on DFRobot's website.

Moving on to the FellDen micro. This model is manufactured by SuniAde. It has an operating voltage of 5V, and its operating current is 200 mA. It has a power of 1W, which is a lot less than the previously discussed model. The FellDen micro solar panels have a listed weight of 277.9g. However, the seller fails to mention if that is the weight of one panel or if it is of the whole pack of ten. Another thing the seller fails to do is list the working temperature of this model, so we do not know the range of which this model would work in. The dimensions of one panel are 110 mm x 60 mm x 2.5 mm. The listing price of the FellDen micro solar panels is $21.00. An interesting thing is that they come in a pack of 10. In other words, when the whole pack is bought, the price of one panel comes down to $2.10. Having multiple panels is convenient because we might keep some as spare if one fails or gets damaged.

Last but not least, we have researched the Treedix Polysilicon solar panels. This model is manufactured by Treedix. The Treedix solar panels have an operating voltage of 5.5V and an operating current of 181 mA. It has a power of 1W, which is also a lot less than the first discussed model. This solar panel

has a listed weight of 99.7g. The working temperature is from 14 °F to 140 °F, so it will work in both hot and cold weather. The dimensions of a panel are 95 mm x 95 mm x 3.05 mm. The price for a package of three is $14.00. One panel would then cost around $4.67. Again, the advantage of having multiple ones in a pack is that if one gets damaged or something happens to it making it not function correctly, there would be spare panels available for replacement.

Moving on to why we decided to go with the semi flexible monocrystalline by DFRobot. Before getting into the details, our team wanted to focus on the output power, weight, working temperature, and dimensions of the panel. The semi flexible monocrystalline was the online model that offered a power of 5W. The two other models offered 1W. Having more output power is the best option to pick since it will be capable of better recharging rechargeable batteries. Additionally, we liked that it was a light weight panel because we do not want to add too much weight on something that will be floating on the water. With its 87g, it is not heavy compared to the other two options. When it comes to the working condition, it is the model that gets to the colder temperature (-4 °F). For instance, the Treedix model can work from 14 °F. For hot weather, both this model and the Treedix polysilicon can work up to 140 °F. Up to here, the selected model is the best for the output power, weight, and working temperature like our team wanted to focus on. We also were interested by the dimensions, however, the selected model seems to be the worst out of the three researched ones; it is the largest panel. Also, it only comes in a package of one, when the other options come in either a package of three or ten. With our selection, if something goes wrong with the panel, we will have to purchase a second one. Or, we might just have to buy two panels from the beginning to have one as spare, which will increase our costs. Despite those disadvantages, we judged this model to still be the best one out of the three we have researched for all the reasons mentioned above.

3.4.4 pH Sensor Selection

For this project one of the main data points is pH. pH is an extremely important metric when tracking the quality of a pond or lake and will be a focus of anyone using our Lab toolkit. For this reason we need to focus on the quality of the sensor and the readings it provides. And making sure that we are able to extract the reading of pH. When selecting a ph sensor we needed to focus on key factors that are shown in the table below.

The following table shows a comparison of some pH sensors we have researched.

Table 9: pH Sensor Comparison

	Gravity: Analog pH Sensor	**AnyLeaf**
Range	0-14	0-14
Accuracy	< 0.2pH	<.01ph

Communication	I2C	I2C
Dimensions	43mm×32mm	60 x 27 x 17 (height)
Weight	15 grams	14 grams
Input Voltage	3.3-5.5 V	2-5 V
Response Time	<2 Minutes	N/A
Price	$39.50	$70

The Gravity: Analog pH Sensor is a laboratory grade sensor and the cheaper of the options with a price of $39.50 while still providing an accurate reading of the pH. And supports full 0-14 readings of pH with less than .2pH of error. This pH sensor is well equipped for use with our selected microcontroller of the Arduino Uno REV2 and is capable of using I2C communication to talk to the microcontroller. And it has a response time of <2 minutes which would be suitable for our project.

The AnyLeaf lab-grade digital pH and ORP circuit which is designed for use with Arduino, Raspberry Pi, or embedded systems could be a great fit for our pH sensor. With a light weight design of 14 grams it could be integrated into our desired microcontroller because of its use of I2C communication. And provides step by step instructions for connecting to an Ardunio on their website. Also providing resources in C++, Python, and Rust to get the readings of the sensor to be transmitted.

With both of these pH sensors being suitable for our project. We decided to go with the AnyLeaf sensor. Even though it is more expensive than the Gravity: Analog pH sensor the overall quality of the readings combined with the support and examples in the community make a more suitable design choice. With our desired goal of collecting the most accurate data the difference from .2 and .01 in accuracy was more than enough to make our decision. Combined with the amount of example code and projects made us favor the AnyLeaf sensor.

3.4.5 Data Transmission Selection

Data Transmission is an important part of our project. This is because our lab tool kit is designed to stay in the body of water for an uncertain time period. And since that, we need a wireless way to provide the readings from the sensors to the person using it. To achieve this we need a way to transmit the readings to our server. Since our main deployment of this project is in stationary bodies of water in Florida, we have to look at potential different methods of transportation of this data.

In the table below 4 different methods are listed out each specifying the method of data transmission for comparison. The table is then followed by a figure of 4G LTE coverage in Florida.

Table 10: pH Data Transmission Comparison

	ESP8266 WiFi Module	**SIM900A GSM Module**	**SparkFun LTE CAT M1/NB-Iot Shield**	**Speed RF Transmitter and Receiver Link Kit**
Method	WiFi	2G or 3G cellular	4G LTE cellular	Radio Waves
Frequency Range	2400-2484 MHz	900 and 1800 MHz	698 MHz - 960 MHz or 1.7 GHz - 2.7GHz	200 KHZ
Distance of Signal	Global	Global	Global	2 KM
Input Voltage	3.3V	4.5V - 12V	3.3 V	3.3V - 9V (Transmitter) 3V - 5V (Receiver)
Hot Spot Needed	Yes	No	No	No
Communication Method	Data	SMS	Data	Data
Comes Included with Arduino Uno REV2	Yes	No	No	No
Price	$7.50	$7.47	$96.50	$17.00

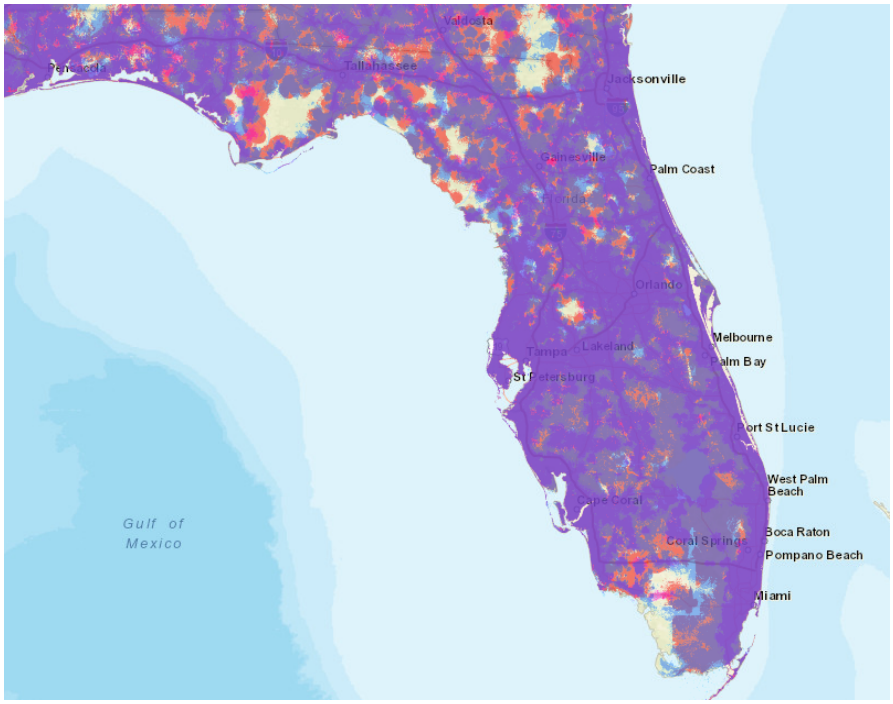

Figure 18: 4G LTE Cellular Coverage Map Of Florida (picture from fcc.maps.arcgis.com)

Each of these solutions provide answers to different challenges that our project might face. With our underlying goal of finding a cheap and reliable method of data transmission that can be integrated with our desired methodology of microcontroller and server configuration. With more factors being the implication of the location of where ponds and lakes usually appear in Florida. Where they can reside in remote areas, which would limit the amount of noise that interferes with the signal.

With the ESP8266 WiFi Module, it comes standard with our selected microcontroller of the Arduino UNO WiFi REV2. Which is nice because it is already integrated in our desired microcontroller mitigating time debugging or implementing. It also has a built-in low-power 32-bit cpu. And has I/O features like integrated TCP/IP protocol stack. Power consumption has a standby of 0.9 uA, running consumption from 60~215mA, and an average of 80mA. This module is well implemented in embedded devices resulting in wide community support. And a low price of the module being $7.50.

SIM900A GSM Module is an interesting approach to solving this solution. It is the cheapest solution of being listed for $7.47. And definitely could be put into use, but there is an underlying problem with the solution. This being that since our target demographic is Floridian stationary bodies of water 2G and 3G network has been shut down starting in 2022 to make room for faster communication. Making using 2G or 3G networks virtually impossible for our project. If our project were to expand we would be able to add this option to provide support in communities that still have this technology in use.

SparkFun LTE CAT M1/NB-Iot Shield is the most expensive solution to this challenge listed for $96.50. And provides a solution that is reminiscent of the

SIM900A but with a more modern cellular connection. This Shield allows for multiple ways of serial communication with the options of using UART interface, USB interface, SPI interface, SDIO interface, and DCC interface. This combined with the wide coverage of 4G LTE networks in Florida are reasons to use this in our design.

The Speed RF Transmitter and Receiver Link Kit offers a different approach to solving this problem. Instead of having any sort of global connection it implements local signals. And can be used to send data up to 2 Km making it a viable option because of the distance the signal can travel. Making it a potential way of wireless data transmission.

When deciding which methodology to implement, the driving factor relates to our selection of microcontroller. With our desired microcontroller being an Arduino Uno WiFi REV2 it already comes standard with the component ESP8266 WiFi module. And with this factor it is hard not to use this component, when it is already there. If we use the Arduino Uno WiFi REV2 it drastically reduces the level of complexity when integrating. We do not have to worry about input voltage or soldering connections. And to make it work in remote locations we are able to purchase a wifi hotspot to make sure the module can communicate.

3.4.6 Server Configuration Selection

Server selection is a critical aspect of our project. This is because there are many different combinations of different aspects that could be used to get a working server configured. The two main aspects in our project is the web stack being implemented and the server's location and / or provider.

3.4.6.1 Server Stack Selection

The Web Stack that is used will determine the underlying functionality and feel of our project. The web stack is important because it will drive the software side of the project. Fundamentally all three of these Stacks are capable of being implemented on any server location or through any provider but each use different technologies to achieve the desired result.

The following table shows a comparison of some server stacks we have researched.

Table 11: Server Stack Comparison

	LAMP Stack	**MERN Stack**	**MEAN Stack**
Database Type	MySql	NoSQl (MongoDB)	NoSQl (MongoDB)
Ability To handle Dynamic Content	Partially	Yes	Yes
Mobile	Minimal	Included	Included

Compatibility			
Group Experience	Minimal	Some	Some

The LAMP stack is a popular open-source web development platform that is used to create dynamic websites and web applications. It stands for Linux, Apache, MySQL, and PHP, and each component plays a critical role in web development.

The MERN stack is a popular web development stack that uses four technologies: MongoDB, Express, React, and Node.js. Each component of the MERN stack is designed to work together seamlessly, making it a powerful tool for creating modern, full-stack web applications.

The MEAN stack is a popular web development stack that uses four technologies: MongoDB, Express, Angular, and Node.js. Each component of the MEAN stack is designed to work together seamlessly, making it a powerful tool for creating modern, full-stack web applications.

We decided to use a MERN stack for two main reasons. With one of these being the focus on scalability and user interfaces. Using either the MERN or MEAN allows for future proofing the design and easier ability to convert to a mobile experience if wanted in the future. And the other factor being with relative group experience and of learning when comparing using React or Angular. With designing a product of this sort it would be beneficial if multiple people could be working on and updating the source code and React is generally easier to learn than Angular, resulting in code being created faster.

3.4.6.2 Server Location / Provider Selection

There are many different aspects when looking into hosting a server. With the functionality of the server being designed to handle Post requests from our desired microcontroller to propagate and display information on the website into a MERN stack Three different methods of handling this achieving this are laid out in the table below.

Table 12: Server Location / Provider

	Local Hosted	**Amazon EC2**	**Digital Ocean Droplet**
Hosting Price	Free	Not Listed	$4 per Month
Operating System	Any	Amazon Linux, Windows, and Ubuntu	Linux
Hosting Machine	Laptop	Virtual Machine	Virtual Machine

Hardware Price	$200	Free	Free
Server Location	Local	Cloud	Cloud
WiFi or Cellular Necessary	No	Yes	Yes
Familiarity with Group	Some	None	Some

When looking into locally hosting a server on premises it is definitely an interesting idea and can easily support a MERN stack. This concept could function extremely well in an extremely remote environment. Providing a solution if a network signal is hard or extremely inconsistent. Also locally hosting a server provides greater flexibility over the server and complete direct access. But this does come with a cost of having to have more technical expertise and maintenance of the server. An underlying fact that hampers this option would be that each server would need its own dedicated piece of external hardware. Increasing the cost of the product to enable functionality.

Amazon EC2 is a branch of Amazon Web Services that allows for users to access cloud computing to quickly and easily access virtual machines in the cloud. And can easily be used to support a MERN stack. Amazon Web Services also provides a larger ecosystem of products that can help with such as S3, RDS, and Lambda. But with this ecosystem it will take longer to learn the features of each product. Amazon EC2 allows for scalability for a server. And allows for deployment on three different kinds of operating systems.

Droplet's are a part of the DigitalOcean family that allows virtual servers to be spun up. And can easily support a MERN stack. DigitalOcean Droplet provides flexibility and scalability for a server. Providing straightforward and easy access to the virtual server. Allowing for the user to SSH directly into the server to make changes, configuration, maintenance, or whatever is necessary. The one drawback is that it is only compatible with a Linux operating system,

We selected to go with a Digital Ocean Droplet for three main reasons. This being because of our expected data transmission method of using ESP8266 WiFi Module, this rules out the idea of locally hosting a server because if the data is being transmitted on a network then we would prefer to have the ability to have it be received globally instead of locally. Allowing for more access to the data that was being collected. Secondly the features and capabilities of a Digital Ocean Droplet and Amazon EC2 are fundamentally the same for a project of our caliber. But using Digital Ocean is a more simple and user-friendly product. Compared to using Amazon Web Services which has more features overall which could add more complication to our project by also including a steeper learning curve. And lastly group familiarity with the product. In previous experience group members have used Digital Ocean Droplets to configure and manage servers in the past. Making setup, managing, and configuration easier.

3.4.7 Waterproof Container Selection

For a floating lab tool kit, a waterproof microcontroller container is essential for many reasons:

1- Protection against water damage: Electronic components can be harmed by water, which can result in errors or complete failure. The microcontroller may be protected from water damage using a waterproof container, keeping it functional even after becoming wet.

2- Protection from additional elements: A waterproof container can shield the microcontroller from additional elements, such as salt, sand, or wind, that can be present in a maritime environment.

3- Safety: If water were to get into touch with the microcontroller, it might result in electrical shorts or other risks. A waterproof container can help avoid these risks.

There are a number of things to take into consideration when choosing a waterproof container for a microcontroller in a floating lab tool kit that collects data from lakes. First and foremost, the container needs to be waterproof and able to resist prolonged contact with water. To prevent water from leaking in, it should have a tight seal or closure mechanism. The container should also be tough enough to stand up to the challenges of being on a boat. It should be constructed from a substance that can withstand collisions, scratches, and UV light. For this use, a durable plastic or metal container could be appropriate. The container's size is still another major element. It needs to have enough room for the microcontroller and any extra sensors or parts that could be required for data collecting. It should also be small enough to readily fit in the tool kit and not take up too much room. Using a container that is simple to open and access may also be beneficial since it will be simpler to recover the microcontroller and carry out any required maintenance or repairs. For this use, a container with a movable lid or snap-on closing could be a good choice. Overall, careful consideration of the container's material, size, and accessibility is necessary when choosing the appropriate waterproof container for a microcontroller in a floating lab tool set. You can assist make sure that your microcontroller is safe and working in the demanding water environment by selecting a container that complies with these specifications.

The following table shows a comparison of some waterproof containers we have researched. It is then followed by a figure of the UNO R3 case, the container we chose.

Table 13: Waterproof Container Comparison

	ML-58F	**UNO R3 Case**	**IP67**
Material	ABS plastic	ABS plastic	ABS Plastic
Dimensions	8.75 x 5.25 x 3.30 in / 222.25 x 133.35 x 83.82 mm.	Case Size: 7.5cm x 6cm x 2cm (2.95inch x 2.36inch x 0.78inch)	290×190×140mm (11.4"×7.5"×5.5")

Weight	6.4 ounces	1.3 ounces	7.7 ounces
Waterproof	yes	yes	no
Color	Clear ; Gray	Black	Gray
Price	$36	$5	$31

Figure 19: UNO R3 Case (picture taken from amazon.com)

In order to safeguard electrical devices in challenging settings, such microcontrollers, the ML-58F is a waterproof container. ABS plastic, which is strong and high-quality and can withstand impacts, scratches, and UV rays, was used to create this container. It is a good size for holding small to medium-sized microcontrollers and sensors since its external dimensions are 6.5 x 4.5 x 2.8 inches (165 x 114 x 71 mm) and its interior dimensions are 5.8 x 3.6 x 2.4 inches (148 x 91 x 61 mm). The ML-58F is portable and lightweight, weighing just around 6.4 ounces (181 grams). It is available in a stylish black color and features a safe snap-on latch to guarantee watertightness. Depending on the provider and the amount bought, the cost of the ML-58F waterproof container varies, but it usually ranges between $25 and $35.

A protective case made especially for the Arduino Uno R3 microcontroller board is called the Uno R3 case. High-quality acrylic used in the construction of this case offers great resistance to impacts and scratches. It is a great match for the Arduino Uno R3 board because of its external measurements of 3.6 x 2.5 x 1.4 inches (92 x 64 x 36 mm) and internal dimensions of 2.9 x 1.9 x 0.8 inches (73.7 x 48.3 x 20.3 mm). At only 1.3 ounces (37 grams) in weight, the Uno R3 case is light and convenient to carry. It comes in a translucent clear and black color that makes the Arduino board inside easily visible. The case's simple snap-together structure makes it quick and simple to put together. Depending on the provider and the amount requested, the cost of the Uno R3 case varies, but it normally ranges from $5 to $10.

A tough and long-lasting container, the IP67 waterproof container is made to safeguard delicate electronic equipment in challenging settings. It is constructed from high-grade, lightweight ABS plastic that is scratch, UV, and impact-resistant. This container has an IP67 rating, which means it is totally waterproof and can withstand being immersed for 30 minutes in water up to one meter deep. Its interior dimensions are 5.9 x 3.1 x 1.8 inches (150 x 80 x 45 mm),

which is more than enough room for small to medium-sized microcontrollers and other electrical equipment. Its external measurements are 6.7 x 3.9 x 2.3 inches (170 x 100 x 58 mm). Black and gray are just a few of the color options for the container. It is lightweight, weighing only at roughly 7.7 ounces (220 grams), making it easy to travel. The IP67 waterproof container's cost varies based on the provider and the number of units bought, but it normally costs $25 to $35.

We selected to go with the UNO R3 Case for many reasons and the main reason is that this case was made especially for Arduino UNO WIFI Rev2. The UNO R3 Case is the ideal solution for securing an Arduino UNO WIFI Rev2 board in a floating lab tool kit because it is water-resistant. The case is perfect for usage in moist or humid conditions since it is constructed from high-quality materials that offer a reliable and long-lasting protection against water damage. The Arduino UNO WiFi Rev2 board's ports and pins are all easily accessible thanks to the case's precision-cut holes. The Arduino UNO WIFI Rev2 board may be safely and securely placed in the UNO R3 Case, offering a solid and dependable base for use in a floating lab tool kit.

3.4.8 Water Temperature Sensor Selection

An essential part of a microcontroller in a floating lab tool kit used to gather data from lakes or other bodies of water is a water temperature sensor. As it influences many physical and biological processes that take place in water, such as absorption, metabolic rates, and species dispersion, temperature is a crucial element in aquatic environments. Researchers can monitor changes over time caused by natural or human effects and get insights into the health of aquatic ecosystems by monitoring the temperature of the water. An electrical resistance, voltage, or other change in physical qualities brought on by temperature fluctuations is normally how a water temperature sensor operates. Certain sensors could also have other capabilities, such the capacity to gauge ambient factors or depth. Data can be sent to a microcontroller by connected or wireless methods, depending on the type of sensor being used, and then saved for subsequent analysis or real-time monitoring. Overall, including a water temperature sensor in a floating lab tool kit can assist researchers in gathering more thorough data on aquatic ecosystems and informing their choices for management and conservation initiatives.

The following table shows a comparison of some water temperature sensors we have researched.

Table 14: Water temperature sensor

	Gikfun DS18B20	**KOOKYE TMP36**	**HiLetgo MAX6675**	**LMT86LPM**
Power supply range	3.0V to 5.5V DC	2.7V to 5.5V DC	3.0V to 5.5V DC	2.2V to 5.5V DC

Dimensions	5.8 x 0.6 x 3.9 inches	2.1 x 2 x 0.5 inches	4.5 x 2.5 x 0.3 inches	3 x 1.6 x 1.15 inches
Weight	2.4 Ounces	0.634 ounces	0.71 Ounces	0.4
Temperature range	-55°C to +125°C (-67°F to +257°F	-40°C to 150°C / -40F to 302F 2°C accuracy	C20Degrees Celsius ¨C 85Degrees Celsius	-50°C ~ 150°C
Accuracy over the range	: ±0.5°C	±2°C	±2°C	±0.4°C
waterproof	yes	yes	no	yes
Price	$12	$10	$8	2$

For detecting water temperature in a range of applications, the Gikfun DS18B20 temperature sensor is a well-liked and dependable choice. As it can operate between 3.0V and 5.5V, this sensor is suitable with the majority of microcontrollers and other electrical equipment. It is simple to include into any size project due to its outward measurements of 0.6 x 0.2 x 0.2 inches (16 x 5 x 5 mm) and weight of only 0.1 ounces (3 grams). The temperature range of the DS18B20 temperature sensor, which is suited for most aquatic settings, is -55°C to +125°C. It can measure temperature in steps of 0.0625°C and has a high precision of 0.5°C between -10°C and +85°C. Moreover, this sensor has an IP68 classification, making it waterproof and suitable for usage in submerged situations. The Gikfun DS18B20 temperature sensor has a variety of prices depending on the provider and the quantity bought, but it is normally between $5 and $10.

A well-liked and reasonably priced choice for detecting water temperature in many projects is the KOOKYE TMP36 temperature sensor. It works between 2.7V to 5.5V and consumes little power, making it perfect for use with microcontrollers and other low-power gadgets. With exterior measurements of 0.3 x 0.2 x 0.1 inches (8 x 5 x 3 mm) and a modest weight of about 0.01 ounces (0.3 grams), the sensor is sufficiently compact and portable to be employed in a range of applications. With a temperature range of -40°C to +125°C, the TMP36 temperature sensor may be used in a variety of settings. At room temperature, it has a high accuracy of 2°C. It is simple to use with most microcontrollers since the KOOKYE TMP36 temperature sensor is an analog sensor that provides a voltage proportional to the temperature. Its small size and simple wiring make it simple to include into projects as well. Depending on the seller and the quantity requested, the cost of the KOOKYE TMP36 temperature sensor varies, but it normally ranges from $2 to $5.

High-precision thermocouple-to-digital converters like the HiLetgo MAX6675 are frequently used to measure temperature in a range of projects. It may be used with the majority of microcontrollers and other electrical devices because of its operating voltage range of 3.0V to 5.5V. With exterior measurements of 0.7 x 0.6 x 0.2 inches (18 x 15 x 5 mm) and a low weight of only 0.02 ounces (0.5 grams), the MAX6675 temperature sensor is a small and portable solution for temperature monitoring. With an accuracy of +/- 2°C and a temperature range of -200°C to +700°C, this sensor may be used in a variety of applications. The type K thermocouple interface MAX6675 has an SPI digital output that makes it simple to connect to other devices. The HiLetgo MAX6675 temperature sensor is a cost-effective solution for people who want to monitor temperature properly and precisely. Its price varies based on the provider and the quantity bought, but it normally ranges from $5 to $10. The HiLetgo MAX6675 temperature sensor is, all things considered, a dependable and reasonably priced alternative for temperature sensing in a number of applications, including those that need high precision and accuracy.

Texas Instruments produces the high-precision analog temperature sensor known as the LMT86LPM. It is perfect for usage in tiny designs because to its small form factor and SOT-23-5 package size. With a high precision of 0.4°C, the LMT86LPM sensor has a broad temperature range of -50°C to +150°C (maximum). It features a linear output voltage that is proportional to 10 mV/°C and changes with temperature. The sensor is suited for battery-powered applications since it operates within the 2.7V to 5.5V power supply range and requires very little power. Fast reaction time and a shutdown mode on the LMT86LPM sensor let it consume less power when not in use. The sensor's light weight and small size make it simple to utilize in a variety of applications. The cost of the LMT86LPM temperature sensor varies depending on how much is bought and from whom, but it is often reasonable and economical. In general, the LMT86LPM temperature sensor is a great option for uses where high accuracy and low power consumption are critical.

The DS18B20 temperature sensor is among the greatest water temperature sensors compatible with Arduino Uno WiFi Rev2. It is a very precise digital temperature sensor that works with most microcontrollers and electronic devices because to its wide working voltage range. Also, because of its waterproofness, it may be used in submerged areas. The one-wire protocol of the DS18B20 temperature sensor makes it simple to link it with the Arduino Uno WiFi Rev2 and include it into your project. The sensor is also ideal for monitoring water temperature in a variety of applications since it can measure temperature in steps of 0.0625°C with an accuracy of 0.5°C between -10°C and +85°C. Overall, the DS18B20 temperature sensor is a reliable and cost-effective option for measuring water temperature in projects using the Arduino Uno WiFi Rev2.

3.4.9 Bug Collector Selection

The collection of bugs is an additional feature that makes the product more effective in gathering data from lakes and ponds. We will be able to help scientists in the analysis of mosquitos to understand the possible newborn

disease or illness that can be caused by the captured mosquitos, illnesses such as Malaria and West Nile virus. There are many methods of Mosquito capturing. Due to the movement nature of mosquitos it was necessary to choose one of the guaranteed ways of capturing mosquitos to be used as samples. After researching multiple methods of mosquito capturing, we decided that the selected method of capturing mosquitos is the use of a net trap capable of capturing mosquitoes in a way that we ensure the capture when needed with high accuracy. The net mesh needs to follow multiple requirements so it can be used in the net trap subsystem for our project and then this will enable the product to be as efficient as possible in achieving the required goal which is collecting bugs and mosquitos for further analysis. For example, the type of fabric used in the manufacturing of the net mesh needs to be effective in the capturing process of mosquitos if it was used in water bodies such as lakes and ponds. The net mesh should function as needed if it was put in water, and should not alter or change the shape of the net to the point where it is not useful in the capturing process.

Also, the tiny spaces and holes in the net mesh need to be in the required shape and size so the net mesh can trap the mosquitos without letting them escape through the holes in the net mesh. If we have larger holes in the net mesh this will result in the escape of the mosquitos we are trying to capture. On the other hand, a smaller size of holes might not be a good option either because a smaller size of holes could result in capturing water and other unwanted objects using the net mesh. So, the net mesh holes need to have the perfect size for this application. The average size of mosquitos is 3.81mm-10.16mm, with this information in mind the net mesh size of holes should be in that range.

The following table shows a comparison of the net traps we have researched and found.

Table 15: Bug Collectors Comparison

	“Benvo Mosquito Head Net Mesh”	**“Mosquito Net”**	**“Insect Protection Netting” Product**
Manufacturer	Benvo store	Echenor store	Hemlock store
Size	54 cm height, bottom perimeter 96cm, top perimeter is 40 cm	N/A	large(30x20 cm)
Weight	23g	Lightweight	Lightweight
Material	Nylon	N/A	Polyethylene

Color	Grey, Black, white	Green	white
Price	$9.99	$8.68	$6.09

The first option was “Benvo Mosquito Head net mesh”. This net mesh is manufactured by Benvo store. This product is used as a face and neck fly netting hood from bugs, gnats, and mosquitos. It was designed and built for the purpose of having a better outdoor activity. Many outdoor activities involve reaching to places and wandering in areas where there are many lakes and ponds where it is the perfect place to find Mosquitos. So, this product can be used to trap mosquitoes for our project. The fabric and material of this product is made of 100% nylon which makes it durable and flexible. There are different sizes for this product. The dimensions of the bigger size of the product is 54 cm in height, bottom perimeter is 96 cm, top perimeter is 40 cm. The product is lightweight, because it weighs around (23 grams). The product comes in a variety of colors such as gray, black, and white. The price of this product is $9.99.

The second option is manufactured by the Echenor store. This product is used as a trap for capturing mosquitos. The product is durable and has sunscreen properties. The trap net is environmentally friendly and it is cylindrical in shape. The fabric of this product is flexible and not fixed in one shape. As a result, It can be modified into the shape we need so it does the intended function during missions.

The third option is “insect protection netting” and it is manufactured by Hemlock store. The product is a net bag that is used to prevent mosquitoes from entering into fruits. The product is made of environmentally friendly material. The features of this product are reusable and durable. The product comes with three different sizes: small, medium, and large. The dimensions of each size are as follows: small (15x10cm) , medium (25x15cm), large(30x20 cm). This product comes with pieces and it is less expensive than others which costs $6.09.

Considering the fact that there are many possible objects other than mosquitos that could be found floating on the bodies of water such as lakes and ponds, we decided to choose the first option which is the **“**Benvo Mosquito Net Mesh**”** product. There are some features that sets this product apart from other options. We are trying to build a trap that could be modified into the desired shape and not be impacted by the contact of water. The product also shows its ability to capture mosquitoes effectively without capturing other objects which is what we need. Also, this product demonstrates its ability to be modified and added to UV lights in future versions which can attract mosquitoes even more and make the capturing process more efficient.

3.4.10 Power Supply Selection

Each subsystem in our project needs to be supplied with the required amount of power to be efficient in doing its functionality. The microcontroller which is the brain of the system has a specific requirement in terms of the voltage to operate with. The MCU usually operates in a range of voltage like 5v-12v. Also, each subsystem and part that is connected to the MCU needs to

withdraw a specific amount of current to operate efficiently, and it is essential to consider it.

The following table shows a comparison between different types of batteries with different chemistries and specs to choose the needed and suitable type of battery for the project. The table is then followed with figures of the different power supplies.

Table 16: Power Supply Comparison

	REACELL lithium-ion 3.7v battery	**Tenergy(NiMH) battery pack**	**SHENMZ lithium ion battery (Li-Ion)**	**Swanlake (NiMH) rechargeable battery**
Voltage	3.7v	12v	3.7v	3.6v
Capacity	3000mAh	2000mAh	3400mAh	2500mAh
Chemistry	lithium ion	NiMH	lithium ion	NiMH
Weight (one battery)	0.7ounce (20g)	7.9ounce (225g)	0.7ounce (20g)	1.58 ounce (45g)
Size(height x width)	(67x18.67mm)	(5.36 x 7.3cm)	(2.2 x 7.2cm)	(65 x 18mm)
Top	Button type	Flat top	Flat top	Flat top
Brand	N/A	Tenergy	N/A	PUNILM
Number of batteries included	4	10	4	4

Protection	No	Yes	No	No
Manufacturer	REACELL	Tenergy	AexPower	Swanlake
Price	$20.99	$20.00	$38.88	$24.99

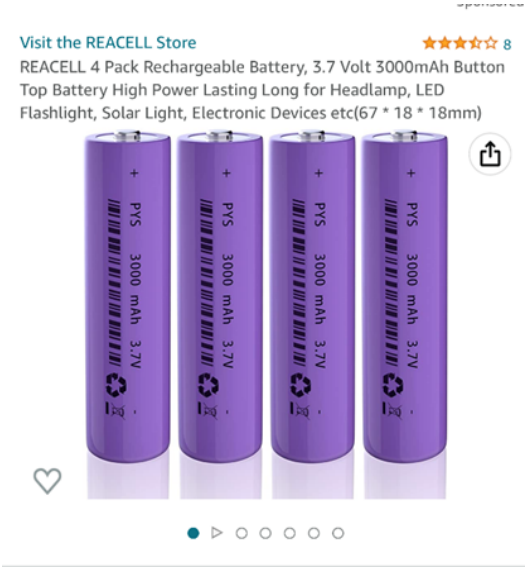

Figure 20: REACELL lithium-ion 3.7v battery (picture taken from Amazon.com)

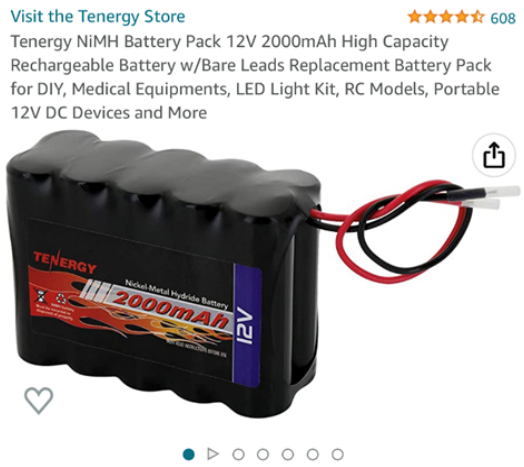

Figure 21: Tenergy(NiMH) battery pack (picture taken from Amazon.com)

Figure 22: SHENMZ lithium ion battery (Li-Ion) (picture taken from Amazon.com)

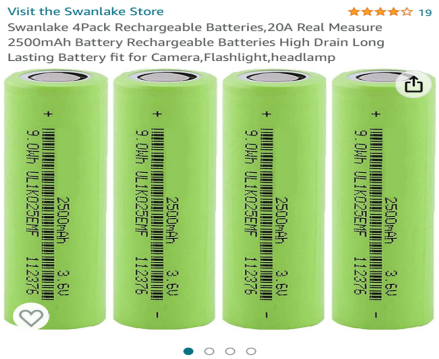

Figure 23: Swanlake (NiMH) rechargeable battery (picture taken from Amazon.com)

The first option for our power supply is the lithium-ion 3.7v battery from the company REACELL shown in figure 21. There are some requirements that our projects need these types of batteries to follow and one of them is reusability of the battery. It was important to consider this option because of its ability to recharge and be used in sync with our power management system (PMS) that regulates the power and connects the power produced from the solar panels to the rest of the system. The 3.7v option is a suitable option for the power source because of the battery's ability to be connected in series to produce the desired voltage that is suitable to supply power to the microcontroller board (MCU).

The second option for the power supply is the Nickel Metal Hydride (NiMH) battery pack from the company Tenergy shown in figure 22. The battery is a 12Volts and 2000mAh high in capacity. This NiMH battery has an advantage over other batteries. This specific battery has a very interesting feature included which the ability to modify the shape of the terminals in the positive and negative connecters . The battery is protected and it is able to be modified when needed. On the other hand, this battery's weight is significantly more than other batteries and the weight of it is 7.9 ounces (225g). The specs of this battery indicates that the battery’s performance would be suitable for our project which makes it a good option to consider.

The third option for the power supply is the lithium ion battery (Li-Ion) from the company SHENMZ shown in figure 23. The battery is 3.7Volts and 3400mAh high in capacity. There are a lot of similarities between the first battery and this battery, but the main difference is in the capacity of the battery. The battery has a better discharge rate and performance. Also, it can be connected in series to obtain the desired amount of voltage needed to power the board and the parts connected to the system.

The last option for the power supply is the Nickel Metal Hydride (NiMH) rechargeable battery from the company Swanlake shown in figure 24. The battery is 3.6Volts and 2500mAh high in capacity. This battery has a lower capacity than the other two lithium ion batteries and weighs more, weighing around 1.58 ounce (45g). In addition, the dimension of the single battery is (65 x 18mm).

All of the mentioned batteries are good options. The fact that we need to modify the battery to be used more in series might add an extra section of work in the project. As a result, we have decided to choose the second option of the batteries mentioned which are the Tenergy(NiMH) battery pack. The reason behind the decision is because it already has a built in series of batteries connected together to form the voltage and capacity needed. In addition, the battery leads and connection wires of this battery are easily modified to the desired connector for various applications.

3.4.11 Air Quality Sensor Selection

The following table shows a comparison of some air quality sensors we have researched. It is then followed by figures of some of those air quality sensors.

Table 17: Air Quality Sensor Selection

	MQ - 135 Gas Sensor	**Adafruit SGP30 TVOC Sensor**	**Digilent Pmod AQS, Digital Sensor**	**MIKROE 1630 Digital Sensor**
Operating Voltage	3.3V to 5V ± 0.1	3.3V to 5V ± 0.1	1.8 V to 3.3 V ± 0.1	3.3V to 5V ± 0.1
Operating Current LPM	N/A	0.05 mA	2.5 mA	N/A
Operating Current CM	160 mA	4.5 mA	6 mA	200 mA
Power	< 800 mW	< 225 mW	< 198 mW	< 1 W
Weight grams	11 g	1.3 g	9.07 g	3 g
Working Temperature	-10 °C to 45 °C	-40 °C to 85 °C	-40 °C to 85 °C	-10 °C to 50 °C
Manufacturer	Winsen Electronics Technology Co, Ltd	Adafruits, Sensirion AG	Digilent	MikroElektronika
Dimension	32 mm x 22 mm x 30 mm	20 mm x 20 mm x 4 mm	31.75 mm x 20.32 mm x 25.4 mm	25.5 mm x 20.0 mm x 4 mm
Cost	$3.00 - $5.89	$17.50 - $22.00	$26.00 - $30.00	$16.50 - $20.00
Gasses detected	NH3, NOx, Benzene, smoke, CO2, more	(TVOC) eCO2, CO, Ethanol , Butane, Acetone, more	(VOCs) CO, NO2, PM2.5, more	CO, NO2, NH3,H2, CH4, C3H8, C4H10, more
Parts per Million (ppm)	10 to 1000 varies per gas	0 to 60,000 varies per gas	1 to 1000 varies pee gas	10 to 1000 varies per gas

Figure 24: Air Quality Gas Sensor (picture taken from quartzcomponents.com)

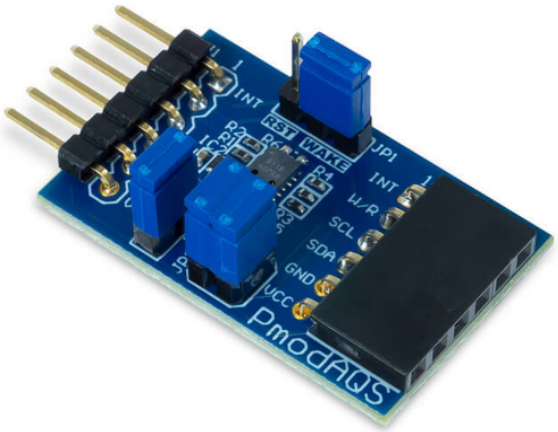

Figure 25: Digilent Pmos AQS (picture taken from digilent.com)

Figure 26: MIKROE 1630 (picture taken from my.element14.com)

In order to select the best option for an air *quality sensor* that satisfies the project's needs, each sensor will be explained on its advantages and disadvantages pursuing that objective. It is important to note that the hardware that has been selected in this report will be used to build the first fully functional

prototype which will be tested on its performance and functionality but will most probably be different from our final delivery in terms of hardware selection. Although the system will operate the same way, seeking to measure the same parameters, there might be constraints from the government side about the type of hardware they can use.

The idea is to have a functional prototype to show and discuss it with the experts in water quality; from that design we will start with customization to what is actually needed by them to perform a professional work in the field of Limnology; that might be higher quality sensors and hardware that we must confront against standards but specially regulations. As engineers it is important to comply with what is mandated by State laws, for example if the maximum concentration of a gas that is permitted for neighborhood lakes (where people live) needs to be measured to certain parts per million and ±1% precision by law and ethical reasons as well, but the selected sensor doesn't' have enough resolution and its precision is around ±10%, it would not satisfy the minimum requirements for State regulations. (The final product delivered must be re-designed and tested with the experts on board to build something professional and functional with the same principles of our first toy model but with sufficient precision, reliability and quality, that it can used to conduct a professional work)

The MQ - 135 Gas sensor is an analog device but most versions come with digital and analog outputs as well, which makes it very convenient. As it is analog it doesn't have different power modes; it is somehow harder to manage than digital sensors, it is suggested to work with power management techniques, also to protect the device from pulling more current than needed by setting up limiting components in the hardware if needed. This sensor could be a good option because the price is the most competitive and availability as well but the capability of sensing gasses parts per million is not the best of all the options, the working temperature windows is the narrowest of all options and the embedded power consumption security is very low compared to the digital sensor options. (It doesn't have Thermal Shutdown in the case excessive current passes through the device which could cause catastrophic failure and even a fire) Device Picture taken from Quartz Components' website.

The Digilent Pmod AQS, Digital Sensor is the second best option after the Adafruit SGP30 TVOC sensor because both have similar working temperature windows which are the widest of all options (The widest the temperature window is, the better it is to be adapted for reliable performance in outdoors applications). It has the disadvantage that it works with a 1.8 V to 3.3 V ± 0.1 voltage which is different from our standard of 3.3V to 5V ± 0.1 including the Arduino microcontroller. (It is just a preference for consistency and minimizing the number of devices working at different voltages) The range of prices for this sensor is the highest, which is a disadvantage with respect to the other opinions. The sensor's picture was taken from Digilent's Website.

The MIKROE 1630 is an analog sensor; it is built over the functional structure of the previously mentioned MQ - 135 analog sensor. It has a slightly

wider working temperature window than the MQ, around 5 °C more but it has the same challenges related to power management than its parent device. Working with analog sensors over digital environments, usually results on additional challenges related to hysteresis and calibration, analog to digital conversion and specially power management techniques, but it wouldn't be a bad option if it wasn't because the price is in a similar range to the digital sensors, and it is more than twice higher than its analog parent device.

Considering that air quality is an important parameter to consider in lake research, choosing the best option is key for producing reliable data that can be stored and used. ***Adafruit SGP30 sensor*** was selected not only because the price is competitive with respect to the other options, but for its reliability, the wide range of projects that are currently using it which translates to robust community support (it has been tested and debugged many times). It also counts with low power mode features and is native for Arduino which makes it more attractive for our prototype.

3.4.12 Water Sampler Devices Selection

The following table shows a comparison of some water sampler devices we have researched. It is then followed by a figure of a water sampler.

Table 18: Water Sampler Devices Comparison

	Deep Water Sampler_1	**Deep Water Sampler_2**	**Water Sampler United Scientific**	**Vernier Water Depth Sampler**
Height mm	280	320	300	452
Diameter mm	100	130	100	109
Volume mL	1000	2500	1500	1500
Part Number	5079A-1000	5079A-2500	USS-UNWTRSMPL01	S16031ND
Price	$735.00	$773.68	$75.87	$101.00
Weight grams	850 g	1200 g	907 g	900 g
Manufacturer	Sampling Systems	Sampling Systems	United Scientific	Fisher Scientific

Figure 27: Water Sampler (picture taken from samplingshop.com)

The Vernier Water Sampler was selected over the other options because choosing a water sampler mechanism that is not too expensive and could be customized for the project are two of our top priorities. Each sampler will describe the reasons why it was discarded or selected will be explained according to what is expected for the project's objectives.

The Deep Water Sampler_1 is made of plastic and is capable of handling a sample of 1000 milliliters of lake water. Unfortunately the price is very elevated with respect to other similar tubular samplers found online. The price is $735.00 dollars which makes it not competitive at all compared to the Vernier Water Depth sampler for a price of $101.00 which makes a big difference of about $634 which is an excessive amount of money to spend on a prototype.

The Deep Water Sampler_2 is made by “Sampling Systems” which is the same company that made Sampler_1; they used the same materials and similar characteristics but made Sampler_2 bigger, it is able to store a larger volume: 2500 milliliters of water and the price is also higher; it costs $773.68 which is $38.68 more than its smaller version. Both samplers appear to be good quality tools but are not the best option for the project, especially because of the excessive high cost. The image for the Samplers was taken from the Sampling Shop Website.

The Water Sampler from United Scientific is our selected component because it has the best price of all, $75 which is very competitive compared to the first options, it has a larger volume capacity than sampler_1 and the same volume capacity than its counterpart Vernier which is our second best option for an also reasonable price of $101.00. The United Scientific Sampler not only has similar characteristics to those found in the other options, but it also has the best price and a longer rope to access deeper waters.

The Vernier Water Depth Sampler has a 4.75 meters long rope while Water Sampler from United Scientific comes with 20 meters of rope which is

more than 4 times the length that is included with Vernier. When acquiring the sampler, the mechanism will be studied in order to build our own samplers and customize them to the project's needs. For example: the sampling trigger in all samplers is signaled by a human being pulling the string but the project would have to create an electronic switch that could activate an electromechanical device to operate the sampler's trigger signal instead of being pulled by a person directly.

Thinking about building our own samplers, based on known principles, there is a list of materials that can be used, for example: different kinds of PVC tubes, ropes, and rubber seals. It is also possible to 3D print some parts if needed. The Lowes PVC browsing tool was consulted in their website, from where the image below was taken. The characteristics listed in the PVC selection table was made with values that were found there as searched on 20 March 2023 current prices.

3.4.13 PVC Selection to Build Customized Water Sampler Device

The following table shows a comparison of some PVC we have researched. It is then followed by some figures of some PVC we found.

Table 19: PVC Customized Comparison

	Charlotte Pipe 6 in - dia	**Charlotte Pipe 3 in - dia**	**Charlotte Pipe 4 in - dia**
Height m	3.05 m	3.05 m	3.05 m
Diameter mm	152.4 mm	76.2 mm	101.6 mm
Part Number	#PVC 04600 0600	#PVC 07300 0600	#S/M 06004 0600
Price	$69.16	$37.96	$32.86
Manufacturer	Charlotte Pipe and FOUNDRY COMPANY	Charlotte Pipe and FOUNDRY COMPANY	Charlotte Pipe and FOUNDRY COMPANY
Color	White	White	Green

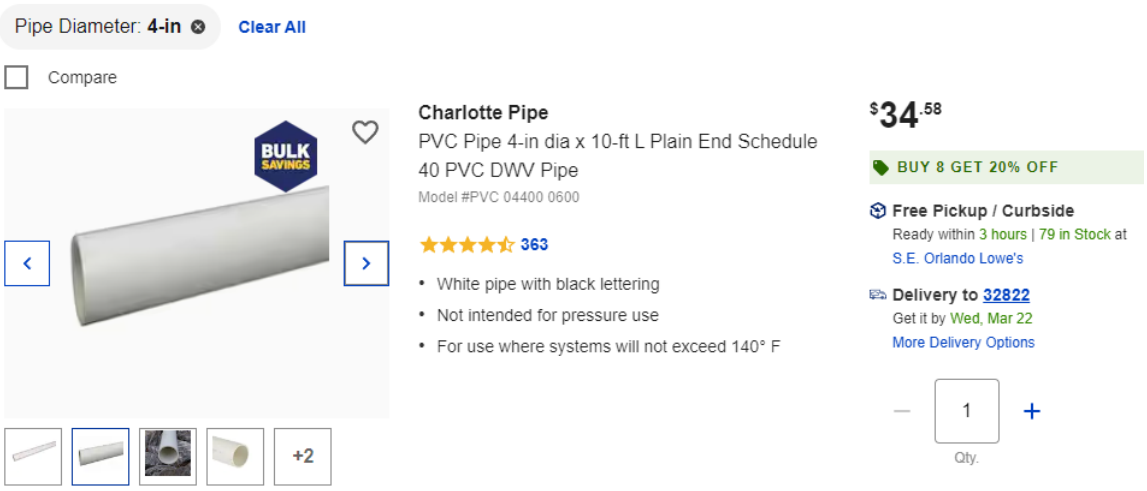

Figure 28: Charlotte Pipe (picture taken from lowes.com)

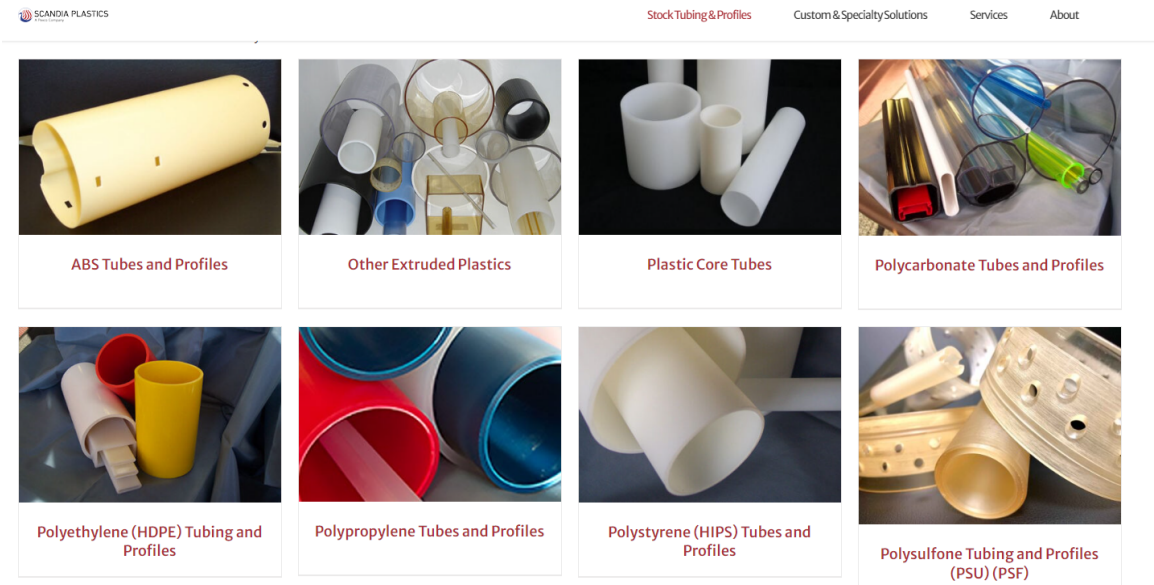

Figure 29: Tubes (picture taken from scandia-nh.com)

It was found that Charlotte Pipe and Foundry Company is a well known and established pipes manufacturer and distributor in the United States, it supplies a wide variety of Tubes and plumbing materials to mega stores for example Lowes and others. Their website is listed below, but the prices were recorded from Lowes' website on 20 March 2023.

A variety of diameters were found for PVC tubes. Studying the Water Samplers, the pipes with closest diameters were chosen for the table. The parameter volume is (dia x height) because it depends on the height that we determine our samplers to have according to design constraints. Each PVC tube is 3.05 meters long, then it would be enough material for 10 samplers if we

choose the 300 mm, same height that the United Scientific Water Sampler has. The difference in price between 3 inches and 4 inches for the same total tube length is not considerable but it scales at approximately double the cost for 6 inch diameter. The 4 Inches Green PVC tube was selected because it has the similar characteristics to its white counterpart but the piece is slightly lower. ($1.72 savings) Since the difference is not too big, the 4 inches white pipe is also a great option at the same level of the 4 inches green pipe.

If the project needs a more specific material design for the water sampler's tube due to weight constraints, density, hardness or other property that would need higher customization, the company "Scandia Plastics" does an excellent job with a variety of plastics including transparent materials too. The image below was taken from "Scandia Plastics" website; it shows the diversity of materials and extrusion capabilities that the company offers.

4.0 Related Standards and Design Constraints

This section covers the standards that apply to the technology that will be used in this project as well as the limitations on creating this floating lab tool kit. This has a significant impact on both the selection of different components and the creation of the floating Lab Toolkit overall design. The floating lab must comply with these in order to function properly, and doing so will make developing and improving the design simpler. So every good engineering project must adhere to standards and constraints.

4.1 Related Standards

4.1.1 IEEE 829-2008

In a person's day to day It is almost impossible to not interact with some sort of software system. And with these guaranteed interactions because of the rapid expansion of software driven systems there is an importance to make sure these systems have been designed and tested correctly. This is because these systems could result in major catastrophes if something were to go wrong or have not been properly tested. This led to the creation of the IEEE standard 829-2008. Where the IEEE 829-2008 Standard for Software and System Test Documentation is a standard that applies to all software-based systems and software being developed, acquired, operated, maintained, and/or being reused. "With the purpose of this standard to establish a common framework for test processes, activities, and tasks in support of all software life cycle processes, including acquisition, supply, development, operation, and maintenance processes." (IEEE Standard for Software and System Test Documentation)

With this standard IEEE lays out a test plan structure method that can be followed. Including the steps of test plan identifier, introduction, test items, features to be tested, features not to be tested, approach, item pass/fail criteria, suspension criteria and resumption requirements, test deliverables, testing tasks, environmental needs, responsibilities, staffing and training needs, schedule, risk and contingencies, and approvals. These steps provide a solid framework for complete understanding of how to design and quantify the risks of software.

Table 1— Consequence-based integrity level scheme

Description	Level
Software must execute correctly or grave consequences (loss of life, loss of system, environmental damage, economic or social loss) will occur. No mitigation is possible.	4
Software must execute correctly or the intended use (mission) of system/software will not be realized causing serious consequences (permanent injury, major system degradation, environmental damage, economic or social impact). Partial-to-complete mitigation is possible.	3
Software must execute correctly or an intended function will not be realized causing minor consequences. Complete mitigation possible.	2
Software must execute correctly or intended function will not be realized causing negligible consequences. Mitigation not required.	1

Figure: 26 Consequences-based integrity level scheme (14,IEEE Std 829-2008)

The figure above is an example of integrity in software design and serves as a good practice when designing software with multiple components. Integrity is defined as the quality of being honest and having strong moral principles. Making integrity an important aspect of this standard. Where the designer of the software must recognize the inherent risk that the system they are designing might impact . And attempt to mitigate the potential damages a system can do. Combined with this expectation of integrity this standard also pushes for intensity and rigor applied to testing tasks depending on the level of integrity a task has. Focusing harder on the systems that have a higher integrity level.

Test Processes determine whether the development products of a given activity conform to the requirements of that activity and whether the system and/or satisfies its intended use and user needs. These process tasks determine the appropriate breadth and depth of test documentation and differ for each element of the product. And encompasses the scope of testing software-based systems, computer software, hardware, and their interfaces. And content the processes of management, acquisition, supply, development, operation, and maintenance.

With the scope of our project we have two software systems that have to communicate with each other making it important to implement this standard. This is because we need to test to make sure each software system is working as intended with proper documentation and course of action. And determine what features and functionality are important to implement and what is not. Where we can properly advance the features and desired results by following the framework that is designed to give software systems structure. And then we are able to test our expectations with our results allowing for completion of our software. This method should allow for an easier combination of the two systems because we will know that both can function independently.

Our first software system design approach is to read in the inputs from our external sensors then combine the information into a user constructed object or array. This software system design is important because we are gonna need a way to combine different input sources into one controlled output source. With a need to make sure the information is being passed in a reliable and proper way. Our second software system involves taking the information passed from the collection side and displaying it onto our web server. We will need to use this standard to help us organize and determine the functionality of how we will achieve this. By properly testing the functionality of the servers ability to receive input data and display it properly. To make our project successful we will follow then combine the two software systems into one. And with the plan of adhering to this standard enforcing proper planning and testing the two systems should be able to combine with relative ease.

4.1.2 IEEE 802.11

The way we connect to the internet has been completely transformed by the IEEE 802.11 Standard, generally known as Wi-Fi. With the help of this standard, wireless communication technology has become dependable, quick,

and widely available. Without the need of cables or other physical connections, we can quickly access the internet from our smartphones, computers, and other devices thanks to the IEEE 802.11 Standard. As the IEEE 802.11 Standard works in unlicensed frequency ranges, anybody may use it without submitting an application for a license. Without the need for costly equipment or licensing fees, this has made it easy for small enterprises and individuals to build their own wireless networks. The IEEE 802.11 Standard makes it simple to set up a wireless network in our homes, workplaces, or public areas and link many devices to the internet at once. Over time, the IEEE 802.11 Standard has gone through a number of updates and revisions, with each bringing faster speeds, longer ranges, and more dependability. In high-density areas, the most recent version, 802.11ax, is intended to deliver faster data rates, lower latency, and improved performance. The IEEE 802.11 Standard will continue to be essential in delivering quick and dependable wireless connectivity to people all over the world as the demand for wireless communication increases. It's important that we understand the description supplied with the additional information in the standard as we build wireless communication in order to integrate the IEEE 802.11 standard's usability with the implementation of the floating lab tool kit. Moreover, part four of the standard attempts to describe how WLANs vary from conventional wired LANs. For example, according to the standard, cable LAN designs are different from wireless ones because they implicitly presume that an address is comparable to a physical location, but in wireless networks, the addressable unit is a station (STA). Along with discussing the effects of a wireless network, the standard also talks about how the PHYs used in this standard differ from those used in wired media, which has an influence on design and performance. Additionally, this standard examines PHY's implementation variations in terms of things like how it utilizes a medium that appears to lack absolute or clearly discernible boundaries outside of which STAs with PHY transceivers are known to be unable to receive network frames, is unprotected from other signals sharing the medium, is less dependable than wired, has dynamic topologies, lacks full connectivity, and may be subject to interference. Because of this, WLANs designed to cover a realistic geographic area may be constructed from fundamental coverage building pieces. Wireless PHY range restrictions. The IEEE publication begins with a broad overview of the architecture before going into more detail into, among other topics, MAC service definition, layer management, DS SAP specification, PHY service specification, frame formats, MAC sublayer functional description, MLME, and security.

For the reasons indicated earlier in the sections on technical investigation, the floating Lab Toolkit is largely dependent on wireless communications, thus it is crucial that we appreciate the significance of the IEEE 802.11 standard. For example, the standard makes sure to include crucial Wi-Fi information, such as the frequency range allocated by the regulatory, the operating frequency range is discussed as the DSSS PHY is allowed to operate in the frequency range 2.4 GHz to 2.4835 GHz allocated as in China, United States, and Europe, while the 2.471 GHz to 2.497 GHz frequency band is allocated by the regulatory authority in Japan.

Since wireless communication eliminates the need for physical connections or wires to transmit data and information from the lab to other places, it is essential for floating labs. This is crucial for a floating lab because it enables scientists to collect and transfer data in real-time as they carry out experiments and gather samples. Wireless connectivity also makes it possible to monitor and manage lab-based scientific equipment from a distance. This entails that scientists may remotely manage and modify the settings of sensors and apparatus, which can speed up the process and work more effectively. Moreover, wireless communication can provide users access to a greater variety of channels, including satellite and cellular networks. The floating lab's experts may be able to connect with researchers at other institutions, access internet databases, and even get weather reports in real time thanks to this. Overall, wireless communication is a crucial component of a floating lab because it enables researchers to efficiently collect and transmit data, remotely operate scientific equipment, and access a wider range of communication channels—all of which are essential for conducting research in challenging and remote environments.

4.2 Design Constraints

4.2.1 Budget

When it comes to any project, the budget is among the most important things to consider. It is significant because it gives the amount of financial resources that is available for a particular project. Not only is it significant for the previously mentioned reason, it is also significant because it can change the shape of the project; having a bigger budget for a project could lead to acquiring better components that are, for instance, more accurate than other similar and cheaper parts. In other words, a bigger/generous budget will allow the team to buy more advanced parts that are a lot better. A more limited budget would mean the team would have to opt for less expensive material hoping that can sometimes be less effective than the expensive ones. Having the budget helps the people working on a project understand to what extent they can buy parts.

The budget is also seen as a limitation, since it should not be exceeded. Exceeding the budget can make the whole project be shut down because it goes beyond the resources someone or a company was willing to pay for the development of that project. It is not rare to hear in the news that developing a project (e.g., a bridge) is exceeding the initial estimated budget. In some cases like that, the budget can be revisited and increased to accommodate the higher costs due to some unforeseen events like weather damage to the material. However, revisiting the budget is not always guaranteed, and as previously mentioned, the whole project could be shut down if it turns out implementing it will cost more than the allocated budget for it.

Another reason why budgets are important is for the customers. When developing a product that will be released for customers to be able to buy them, a research has to be made. Companies need to research at what price competitors are selling similar items. Doing that would give an idea at what price the item should be priced or even trying to develop an item for cheaper than the

competitors to sell more. Then, companies have to establish a percentage they aim to obtain as profit from the product. For example, a company could say we want 30% profit margin on the following item we are selling. This is where the budget is important because it should be able to respect those numbers. If the budget goes overboard, the project might not sell at the wanted profit margin, and it could lead to a price increase of the product to achieve the specific profit margin. If the price of the item needs to be significantly increased, this could mean that its price could be more than the item of a competitor. Selling an item at a significantly higher price than a competitor would not make sense because customers often try to look out for the best deal, and customers are most likely to buy the cheaper item from the competitor. With that being said, this is a reason why projects could be shut down. Companies could see that it is not possible to develop a product with a high budget because with a specific profit margin they need to make, it would cost too much at the end for the customer and will not sell. It is then important to establish a budget and not go over it. By doing so, the research done before development will be successful, and the product will successfully be available to the intended target like planned.

Having a budget can promote innovation as well as creativity. Sometimes, something needs to be done/implemented, however, it would cost too much to do and will exceed the budget. Designers can then think of a way of arriving at the end goal by using their creativity to come up with another way with the budget.

When it comes to our project, a budget of $1,000 was set for the material. Our first constraint is “The system shall not exceed $1,000 in cost”. The budget will affect our project in all the previously mentioned ways; it is the amount of financial resources available for the development of the project. The budget is a limitation set that should not be exceeded. Additionally, the budget will make us think of certain decisions regarding the parts; some parts may be too expensive, so we will need to look for another part that can achieve the same thing as the expensive one but for less money. Having a budget will also make us creative. If a part is too expensive and there is not another available part for cheaper that can achieve the same thing, our team members will have to be creative; the team members will have to think of a creative solution by creating something that does what the expensive part does but for a lot less money. The budget also affects our project because it will determine at what price range we can list our item if it was to be sold to a customer or a company. Our goal was to come up with a reasonable budget. By reasonable, we mean a budget that could let us get good parts without limiting us too much to only cheaper parts. Additionally, we were not searching to have a big budget because we wanted to be able to build a project that does not require a lot of money to do. The things mentioned are different ways how a budget may affect our project.

It is important to mention the thought process that went through our minds when we decided on a budget of $1,000. We wanted to make sure our budget would be enough to get parts that are not necessarily the cheapest but reasonably priced. After getting the parts, we wanted to have spare money just in case we find a part that is interesting to implement in the project while we are building it. Additionally, when coming up with the budget, we assumed that we

will not have any sponsorship. In other words, the money would come out of our team members' pockets. With that in mind, we all agreed on an amount that we could split among us. We are a team of five with a budget of $1,000, meaning we would all have to put $200.

To finish with the budget constraint, it is among the most important constraints because it directly affects the implementation of the project. If the price of implementation remains under or at the budget exactly, the project can be developed. However, if the money to implement the project starts to exceed the budget, the project development could be shut down. In a perfect world, our budget will be more than enough to build our project, and we would even have some money at the end that is unused and will be just-in-case funds.

4.2.2 Ethical, Health, and Safety Constraints

Designing and implementing devices that will be used for scientific research and public health or safety, has an ethical responsibility. As engineers we must design tools and systems that comply with all State and Federal regulations, also to provide excellent quality and reliability to the best extent of our knowledge. Although we are just achieving the entry level engineer status with our senior design project, we must show the same standards of professionalism and responsibility as if we were fully grown experienced engineers.

The main purpose of our Senior Design project is to design and build a Lab Toolkit that will facilitate the process of recording important parameters from Florida lakes, that will not only be used for research and having a better understanding of lakes ecosystems, but it will also have the function of detecting hazardous material and organisms in the lakes that could affect human health negatively, that is why reliability and complying with regulations is a must.

The project went through an initial design process where the objective was defined and the functionality was laid out with block diagrams. At this point, the parts selection was made for our first fully functional prototype which will perform all the tasks but it will not be the final delivery. The reason is that there is an ethical responsibility when designing tools that are capable of saving lives or preserving public health by providing accurate readings to scientists and technicians. If the tool provides misleading information or readings below the precision that is needed to determine if health and safety regulations for lakes are met, then people could be affected.

As Senior engineering students we must work on the project, having in mind to accomplish a product that will protect people and benefit scientific research, our ethical responsibility is to have our work revised by professional engineers who are currently working on Florida's State Water Quality to verify that our product satisfies all what is needed to be used by the State, it includes reliable sensors, approved electrical and software design and testing the precision under various operation circumstances. We will also customize our initial idea to better serve first the immediate needs that the industry might need at this moment and then taking care of additional features that will add up to a more comprehensive and convenient tool.

The early detection of green algae and cyanobacteria in Florida lakes is part of preserving peoples health. It is important to provide a basic guideline to the public in the website and maybe install physical posts close by the lakes, explaining about wildlife and how to visually check for green algae, odors or other signs of danger in the lake. A contact email or number could be provided for people to report those observations, which would help to the project's improvements and also encourage people to use their own sense to avoid danger and protect others.

Although sensor detection systems are reliable for many applications, there always exists a non detection probability that fluctuates with time, weather and other variables, that is why it is important to teach people to double check what with their own judgment and to write that information in the website.

Something like: "Our detection system is providing quality information for research and water quality but there could be a margin of error. Before entering the lake please read these health and safety guidelines and if you believe that something is wrong, please call to this number or write to this email to report inconsistencies".

It is important to consult from the perspective of law, how to provide information to people without being directly implicated on their decision of entering the lake or not. (This is a very vital topic to discuss) although we will build the best product possible, the way information is managed is fundamental to avoid misunderstandings and to preserve people's health and safety. The way information will be presented to the public and delivered to the scientist will be soon discussed. We also will determine what is the best protocol of calibration and periodically verifying pression of the tools in order to comply with regulations but also fulfill our ethical obligation of developing products that will benefit society and to protect public health and safety.

We have as a model, the National Society of Professional Engineers (NSPE) code of ethics. Their website has information about Professional Engineers (PE) educational resources, how to get and maintain the professional license, an immense set of peer review articles, magazines and publications, communities and memberships for professional engineers and the code of ethics which is shown in the website and has a downloadable file as well.

4.2.3 Environmental Constraints

There are many important factors in determining the environmental constraints in our project. Regularly, the environmental constraints are closely related to the regulations made by agencies responsible for the protection and preservation of the environment. The U.S Environmental Protection Agency (EPA) is responsible for setting the rules and enforcing them to protect the environment and track the activity of operated engineering projects that could impact the sustainability and the health of the environment directly or indirectly.

During The process of designing a project and building it, engineers are responsible for following the rules and regulations enforced in the state and country they are located in. Our project has the potential of helping scientists and researchers obtain reliable data from lakes and ponds. As a team of engineers

we are determined to follow the environmental constraints and use them to our advantage. The result of us following the regulations will make it easier for this product to be approved for the use by a variety of consumers in different areas and making sure that this engineering project is capable of providing the desired functionality without being a source of harm to the environment. Many engineering project were incredible in design and functionality but the fact that the engineers building these projects did not follow the rules and environmental constraints that resulted in lowering the chance of their project to be implemented in more areas and reach a world wide reputation and impact positively a larger number of consumers who are in need for such a technology. Following the regulations and rules created by the U.S Environmental Protection Agency (EPA) creates a good deal and great number of benefits for the project owners and engineers, the project itself and most importantly the environment.

There are many benefits from following U.S Environmental Protection Agency EPA regulations and these benefits are various and have a real noticeable impact. For example, the EPA sets certain regulations for aquatic life to be protected including their habitats. Our toolkit project is designed and made sure that it would be capable of not harming the ecosystem of lakes or ponds during missions and while gathering data from lakes and ponds. And we were able to do that by enabling the floating boat to only be used in areas of the lakes and ponds during the day because most of the animals are active during the night where not a lot of people visit the place. So, the use of the boat is specified for during the day only preferably. The main goal of our project is studying lakes and ponds and gathering its data. As a result, it would be reasonable that our project also complies with regulations created by the EPA and protects the ecosystem in lakes and the habitat around them as well.

Another example of the benefits that would come from following the EPA regulations for our toolkit boat project is the preservation of water quality. We intend to use our project as a method of ensuring the safety of water and its quality. Detecting possible contamination in lakes and ponds is crucial in the project. Therefore, the project should not be impacting the lakes and ponds negatively during missions. The negative impact to water quality while using our project in lakes and ponds could result from the type of material used in the building of the project. The team made sure that the project should be built out of environmentally friendly material and not cause contamination to the water in lakes and ponds during the missions of gathering data. Many parts and subsystems in our project were designed with the intention of making the whole project an environmentally friendly product that does not cause contamination to the water in lakes.

As engineers we are trying to make our project as efficient as possible. So, we made the project to be energy efficient and designed to minimize the consumption of energy during missions in lakes. A renewable energy source will be a good fit for our project because it will help in making it efficient and useful for remote areas where energy is not abundant. As a result, the project is powered by harnessing the power of the sun. All the subsystems in the project

gain their power from the solar panels attached to the designed project. It should be built with the intention of consuming less energy to power each subsystem in the project.

The use of hazardous material is also one of the most important areas that we focused on during the selection process of parts used for the project. We made sure that the material used in building the project is not hazardous material to the environment and to people. For example, in the power supply subsystem, we are intending to use batteries such as Lithium-Ion and Nickel Metal Hydride(NiMH). Those batteries could cause harm if it was disposed of incorrectly and thrown out to the environment. So, the project is powered by batteries that are rechargeable which means that it can be disposed off, but it would be done by the user of the product in a very long time meaning that they won't need to add a new battery every time when the capacity is down in the previous battery because of the use of solar panels.

Noise pollution can also be an issue if the project is not designed and built properly. Many machines and engineering projects result in a loud volume of noise that could disturb the residents near the area and also the animals in that area. The project we are building is taking this issue seriously because in order to make our project an easy to use product for the consumer it is necessary to select parts that are less noisy and do the intended function with as little noise as possible. The user of the product won't be disturbing the people and animals around the area during missions because of the quite operational nature of the project.

5.0 Conclusion

By creating an “Analysis Lab Toolkit”, it will be possible to collect reliable and relevant data from lakes and stationary bodies of water remotely. This data is an important area of study for the ecosystems, microbiology, and biology of Florida. This information can then later be analyzed by AI or a preferred method by scientists to expand knowledge and prevent the development of dangerous bacteria or mosquito-borne illnesses.

Our project consists of a floating device “Analysis Lab Toolkit” that can measure multiple parameters outside and inside the water using equipped sensors. Additionally, it will be able to collect water samples that could be brought to a lab for analysis and a better understanding of the water. It will also have a system to collect mosquitoes and bugs that can be taken back to the scientist’s lab to verify if they are infected with any contagious pathogen that could affect Human being's health, for example, Zika virus, Dengue, or the Nile River Virus among others. The device will be able to navigate through the waters thanks to a remote control, which would help the user bring it to any desired location for sampling.

By analyzing the current system and methods of Limnology, specifically the lakes in Florida and comparing it to the most updated sensors and technology systems in the United States and the world, there could be areas of improvement that can be addressed by implementing smart sensor systems to the lakes in a way it is customizable for Florida needs.

Although there exist projects that study Limnology in lakes and their ecosystems using sensors and big data, there is a possibility of actually contributing to the field by practicing the Research and Development methodology which is a subset of Applied Research. By conducting a deep state of the art search, not only in the internet and academic databases, but primary sources (consulting the experts in water quality directly and asking high quality questions) it is possible for the us to better understand the current state of Limnology in Florida, the challenges that the people in field might be facing and starting from there, customize our initial design to meet the regulations, requirements and actual needs in the field.

6.0 Works Cited

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