## Prince William Sound Underwater Profiling Vehicle

## ECE4873 D1A - Senior Design Project 2

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# **Table of Contents**

Ex	ecutive Summary	3
1.	Introduction	5
2.	Project Description and Goals	7
3.	Technical Specifications	11
4.	Design Approach and Details	
	<ul> <li>4.1 Design Approach</li> <li>4.1.1 Design Concept Ideation</li> <li>4.1.2 Design Concept Constraints</li> <li>4.1.3 Design Concept Alternatives</li> <li>4.1.4 Design Concept Tradeoffs</li> </ul>	12
	<ul> <li>4.1.4 Design Concept Tradeons</li> <li>4.2 Preliminary Concept Selection and Justification</li> <li>4.2.1 Power/Energy</li> <li>4.2.2 Communication Module</li> <li>4.2.3 Processor</li> </ul>	20
	<ul><li>4.3 Engineering Analyses and Experiment</li><li>4.4 Codes and Standards</li></ul>	22 22
5.	Schedule, Tasks, and Milestones	23
6.	Project Demonstration	24
7.	Marketing and Cost Analysis	24
	<ul><li>7.1 Marketing Analysis</li><li>7.2 Cost Analysis</li></ul>	24 26
8.	Current Status	27
9.	Leadership Roles	27
10.	. References	29
Ap	opendix A	32

## **Executive Summary**

In 1989 an Exxon oil tanker ran aground, spilling more than 11 million gallons of oil into the Prince William Sound [1]. After cleanup efforts damaged the ecosystem even further, Exxon began funding research efforts in the sound that allow for monitoring of the ecosystem and restoration efforts. The scientists currently used a moored profiler that was made by Sea-Bird Scientific which they have added instruments such as a plankton camera. Sea-Bird Scientific has discontinued production and support for this profiler and the scientists have problems with the current system. They came to our professor over the summer and proposed the idea of designing a new profiler. The new system would overcome the biggest disadvantages of the current system and leave them with a system that they could extend to provide even more functionality in the years to come.

After speaking with the scientist we concluded that the biggest problems with the current design, and most important problems to solve in the new design were: first a way to remotely charge the battery, they current have to go out on a boat and pull the profiler out to charge it once a month; second lack of information that can be remotely communicated, they can only receive very simple telemetry, but would like to get scientific data.

Our group will build a prototype of a new moored profiler that will have a wave power generator that will trickle charge a 14V battery. It will have a long range radio for scientific data transmission. Finally, we will use a Raspberry Pi as the processor and include interfaces that can support the current instruments. The cost will be \$545.84 dollars. A future group will work to integrate the wench along with all the instrumentation. They will also upgrade the processor to something more fit for this application and upgrade to use a more suitable radio for communications.

### Nomenclature

LoRa: Long Range, a low power long range communications device

PWS: Prince William Sound

RPi: Raspberry Pi

## **Prince William Sound Moored Profiler Reimagining**

## 1. Introduction

The Prince William Sound autonomous moored profiler (PWS profiler) has provided vital data regarding the health of marine ecosystems in the Prince William Sound of the Gulf of Alaska. In response to the 1989 Exxon Valdez oil spill which decimated wildlife populations in the area, the PWS profiler has administered long-term monitoring to assess the still lingering effects of this environmental catastrophe [10]. Despite being an overall success, the profiler has a variety of pain points that have concerned its scientists and has prompted calls for improvement. Thus, our team: Scientific Shark is requesting \$545.84 to develop a prototype for a new moored profiler that incorporates renewable energy in the form of a wave power generator which provides trickle charging to the device's battery, as well as a communications box that will enable greater ranged data transmission capabilities.

The current system of the PWS profiler was created by Sea-Bird Scientific but has since been discontinued and support for the profiler suspended. It carries a Bluefin 1.5 kWh Subsea battery that must be manually charged by removing the entire profiler from the water once a month. This not only is tedious and cumbersome, but also takes away time from the water that may produce vital information. As opposed to the current design of the profiler, our group will implement a wave power converter based on attenuators (linear absorbers) onto our prototype. This will provide a renewable, alternative energy source to the system without the need to remove the profiler from the sound.

To this end, a variety of other renewable energy sources were also considered, including solar and wind energy. The most prominent disincentive for using these sources, as well as a general

5

challenge to overcome with designing a new profiler is the location itself. The Prince William Sound is located in the Gulf of Alaska, which can see extreme weather and high waves [1]. Any equipment attached to the exterior of the profiler such as a solar panel or wind turbine has a high probability of being destroyed or becoming detached, although these could be used to supplement the wave power. The wave power converter was also subject to debate. While our group chose to implement an attenuator-based convertor because of its existing example application in technologies similar to our prototype, both point absorbers and submerged pressure differential wave converters could have also been employed.

In addition to the substandard battery charging methods, the PWS profiler also has a general lack of remote data transmission abilities. The current system can only communicate standard telemetry through a line of sight, high-bandwidth radio with a range of about 2-3 miles via a 900 MHz transmitter [13]. Our team will develop a prototype profiler with a communications box attached to the body of the profiler that will have high frequency and range data transmission capabilities, using a Raspberry Pi microcontroller as the processor. We will also incorporate interfaces that can support the current instrumentation. This will enable the remote transmission of data not only related to the status of the profiler, but also scientific data that has thus far been extracted from the device by taking it out of the water.

Other than introducing an alternative energy source, the aforementioned improvements that will be implemented to the prototype will most benefit the end user by making operation of the device much less hands-on. With these modifications, scientists can leave the profiler in the sound without the necessity to remove it whenever the battery requires recharging or to extract information from its sampling instruments. This would allow for greater time periods of uninterrupted data acquisition and

6

would save researchers the time and effort of physically travelling to Prince William Sound to pull the profiler out of the water.

The subsequent sections will provide a deeper understanding for our group's revised profiler prototype. A description about the project, customer requirements, and goals will offer the necessary background on the device's current operation and key issues. Next are the device's Technical Specifications followed by the Design Approach, which details our motivation to revise the current profiler, the project's constraints and tradeoffs, and quantitative engineering analyses among other key elements describing the production of the profiler. Finally, the last few sections are predominantly logistical, pertaining to the design team's development, cost analysis, and presentation of the prototype.

## 2. <u>Project Description, Customer Requirements, and Goals</u>

Our team will be redesigning a marine resource management system using an automated ecosystem procedure [13]. A PWS profiler will be prototyped, which consists of a 14.4V battery from inspired energy, a communication system supporting high bandwidth precise data, an attenuator wave generator, and a Raspberry Pi 4 processor with interfacing solutions that could be upgraded in the future to be lower power with higher processing ability. An initial prototype will be created which does not meet the exact requirements of the customer, such as including a winch, but the prototype could be expanded to meet those requirements. To allow for self-charging we will be using the attenuator method to derive the wave energy as this tactic works with the existing buoy and is potentially powerful enough to generate power for the current instruments such as the Seabird FASTCAT, RBR brevio, Seabird Eco FLNTU, Seabird SBE 63, Aanderaa Optode, Seabird SUNA, and plankton camera. The power generation required for the new system will incorporate attenuators, aka linear absorbers, which are wave energy converters oriented parallel to the direction of waves. They have a modular design and generate power by flexing its joints. In a real implementation, the power generated from these hinge joints will be connected via subsea cable to the profiler allowing a constant charge, in our prototype it will just be connected via a rubber wrapped cable. The process will involve combining wave data from the aforementioned profiler with a time-domain numerical tool for the wave attenuator to generate power source. The alternatives for attenuators are other renewable sources such as solar and wind energy, and wave power converters like submerged pressure differential and point absorber. More detailed information about power/energy for the PWS autonomous moored profiler such as technical specifications, design ideation, constraints, and design alternatives is mentioned in the following sections of this proposal.



Figure 1. Block Diagram of a fully functional moored profiler

The communication systems will be equipped with a Raspberry Pi 4 processor to allow remote accurate data collection. The RPi processor will be extended to include communication interfaces for each sensor. For now, communications will be a black box. An Adafruit LoRa Radio Bonnet module is intended to be that box and hence, alternatives were not considered. This box will allow high bandwidth and precision data that can be collected remotely instead of collecting the data directly from the profiler at the location. We picked this processor as we have worked with this platform before so rapid development will be possible. In the above block diagram a full system is shown, with a Bluefin battery, winch, and sensor suite. The prototype will use a lower powered battery and omit the winch and sensor suite. All of these things would be able to be integrated by upgrading the prototype.

There are quite a few challenges involved in this procedure such as the intricacy of the marine ecosystem, unavailability of renewable energy sources, insufficient communication systems, and interfacing solutions. Also, the RPi4 processor has a tradeoff as it consumes a comparatively high power of 540mA (2.7W) at idle and 1280mA(6.4W) at 400% CPU load [7]. Furthermore, the attenuator method used to generate power and energy can only be generated by ocean waves. Using wave energy can be expensive and difficult to use because of its current location in the Gulf of Alaska but it is still preferred compared to solar or wind energy sources. A future implementation could combine wind, solar, and wave energy.

Based on customer's requirements, it is necessary to replace the current energy source that requires charging every month, with the wave power generator, and have a system that allows precise and remote data collection. There might be software, hardware, and standard constraints associated with the project that we are currently not aware of. But we believe that executing the following changes in the profiler will save time and energy of scientists, as they won't have to travel up to the Prince William location in the Gulf of Alaska to charge the profiler every month, and get the accurate scientific data remotely. Due to the nature of this project, the customer does not have a target price for the final product, but the prototype budget is \$700. The stakeholder's chart in Figure 2 shows the internal and external stakeholders for this project. The internal stakeholders include Professor West, and our team of electrical and computer engineering students working on the prototype while the external stakeholder include Dr. Campbell. The QFD chart showing the customers' needs and engineering requirements is shown in Table 1 below.

	Wave Power	Communications	Processor	Total
Size	6	4	5	15
Weight	4	4	4	12
Power	5	5	9	19
Usability	10	5	7	22
Total	25	18	25	

<b>Table I.</b> The QFD cha	rt
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Figure 2. Stakeholder chart for Prince William Sound Profiler

# 3. <u>Technical Specifications</u>

Table 2. Target technica	l specifications o	of the system
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Specification	Min	Max
Target Functional Temperature	-2 C	14.4 C
Target Power Generation	60 W	350 W
Power Supplying	6.5 W	40 W
Target Communications Range	300 m	3 Km
Communications Frequency	860 MHz	915 MHz

The proposed technical specifications can be seen in Table 2 above. These specifications are subject to change as development of the product progresses. However, they will serve as ideal guidelines in order to encourage an organized development process. The functional temperature specification relates to the temperature that the entire system should be able to operate at, which is relative to the location of the Prince William Sound. The power generation specification refers to the power being produced by the proposed generator. With the proposed generator, the team theoretically would want to produce a minimum of 60W worth of energy to the battery to charge. On the low end of power supply we would just be supplying the RPi doing processing and the LoRa radio, on the high end is powering all sensors. Next, the communications range is the range that the profiler should be able to transmit data. Finally, the communications frequency specification is determined by the operation frequency of the LoRa radio bonnet which can range between 860 MHz and 915 MHz depending on the specific unit we receive.

## 4. Design Approach and Details

### 4.1 Design Concept Ideation, Constraints, Alternatives, and Tradeoffs

### 4.1.1 Design Concept Ideation

#### **Power/Energy Source for the PWS Autonomous Moored Profiler**

Attenuators, or linear absorbers, are wave energy converters that are oriented parallel to the direction of wave travel. The majority of the time they're modular in design and rely on the flexing of joints to generate power. Their design looks similar to two barges that are linked together, or in some cases, a sea snake. These devices try to capitalize on several different translations of motion; such as

surge, sway, and heave as examples [15]. These converters are placed parallel to the force and direction of a wave. The motion of the device from the crest and trough of the wave exerts force on a turbine that then feeds energy into the grid [5].



Figure 3. Example of attenuator



**Figure 4.** The top view of the attenuator [3]



Figure 5. The side view of the attenuator [3]

#### **Communication Module**

Communication is not the main focus of this project, but is an aspect that is important to be present in the final product based on the needs of our customer. As a result, we have looked for an easily accessible option that can be rapidly implemented to our current design. The component we have decided to employ is the Adafruit LoRa Radio Bonnet with OLED - RFM95W @ 915MHz - RadioFruit. The device adds a LoRa / LoRaWAN radio to the RPi. It also includes a 128x32 OLED display to ease debugging. The device allows for 868MHz or 915MHz transmission/reception and can be tuned dynamically. It can transmit up to two kilometers away with simple antennas, so this is a part that would have to be upgraded in a future deployment. With directional antennas it could transmit up to 20 kilometers. Another major reason we have decided to use the Adafruit LoRa Radio Bonnet is there are ready-to-go CircuitPython libraries to aid in software development for this device [17].

#### Processor

The Raspberry Pi 4 has been chosen for this project. We have considered other processors such as the ODROID, and other RPi models, but have ultimately decided to use the RPi 4 because of our past experience with RPi and the wealth of publicly accessible knowledge and examples that exist for the RPi platform. The upgraded processor on the RPi 4 was attractive for this application due to the machine learning that would be integrated in the future as well as the number of serial connections available.

### **4.1.2 Design Concept Constraints**

**Power/Energy Source for the PWS Autonomous Moored Profiler** 

Using an attenuator as a method to generate power/energy to the PWS Autonomous Moored Profiler could have the following constraints:

- The power from the attenuator is dependent upon wave motion.
- The waves made during experimentation may not be strong enough to push the pistons into the generator; therefore, the power generated from prototyped attenuator may not be enough.

#### **Communication Module**

The Adafruit LoRa Radio Bonnet module has many constraints and could not be used as the final module for communication, but serves as a good example for a prototype:

- By itself can only transmit 2 Km in line of sight
- Not as fast as WiFi or Bluetooth
- Does not maintain a link/pairing like WiFi or Bluetooth

#### Processor

The RPi processor does not have as much computing power as other systems like the ODROID-C4.

### 4.1.3 Design Concept Alternatives

There are many alternative methods that the PWS Autonomous Moored Profiler can be recharged with other than using an attenuator for a wave power converter. Besides attenuators, we can also employ other wave power converters, such as point absorbers and submerged pressure differentials.

#### **Point Absorber**

Point absorbers are floating structures that have a small horizontal dimension compared to their vertical dimension and utilize the wave action at a single point. Most designs for point absorbers resemble a typical buoy, at least from the surface. Generally one end of the absorber is fixed (or relatively fixed compared to the water surface) while the other moves in a vertical motion, the resulting reciprocating action is used to pump a fluid or drive a linear generator, which in turn can provide usable power. Point absorbers are one of the most common design types in the industry today [15].



Figure 6. Example of point absorber [15]

A point absorber utilizes the motion of the surface waves to generate electricity. A point absorber will experience many external loads, (such as winds, waves, and currents) and internal loads (such as shifting masses in the device). It should be stable enough to be able to withstand these loads and prevent itself from turning over [6]. We did not choose to make the point absorber as it would involve modifying the current buoy or creating another one.

#### Submerged Pressure Differential

Submerged pressure differential comes in two different types. In one type, the device rests on or near the seafloor and relies on pressure fluctuations as a wave passes overhead to flex a pliable material such as an air bladder and squeeze a fluid to drive a turbine or some other power take-off unit. The other type is similar to a point absorber, but the submerged, like that shown below. In this type, a buoyant, submerged float is actuated by passing waves and this reciprocating motion is converted to energy with a linear generator [15]. The reason the team did not pursue this topic was because this model would require the prototype to be in shallow water and rest on the seafloor.



Figure 7. Example of submerged Pressure Differential

Other than using wave energy, the PWS Autonomous Moored Profiler can be recharged with different renewable energy methods, such as solar energy and wind energy, which we have also considered as well.

#### **Solar Energy**

Solar energy is not our primary choice for generating energy because there are many limitations and disadvantages compared to the wave power converters. For example, solar energy is very weather and time dependent. Therefore, energy cannot be generated at night or when there is a snow or rain or storm. In addition, a solar panel degrades over time; therefore, a solar panel can usually be used between 20-25 years before the panel has lost all of its efficiency [2]. The efficiency of a solar cell will degrade around 5-10% each year [8]. Furthermore, the solar panels can be easily damaged in the environment proposed. However, solar energy could be implemented in conjunction with wave energy in a future design to generate more power.

#### Wind Energy

Wind energy is also not our primary choice because it would require significant modifications to the nearby buoy, which is not in the scope of this project. A large turbine could also lead the buoy to be less stable. Wind energy is also less consistent than wave energy [8]. However, wind energy could be implemented in conjunction with wave energy to produce more power in the future.

### 4.1.4 Design Concept Tradeoffs

Attenuator vs. Point Absorber and Submerged Pressure Differential							
Pros	<ol> <li>Design is much simpler to implement</li> <li>Considerably easier to use</li> <li>Little to no alterations to pre-existing buoy; therefore, simply an add-on to existing buoy</li> </ol>						
Cons	<ol> <li>Less horizontal space on the surface of the water required</li> <li>Structure could be eroded and degraded by saltiness of seawater; therefore, damaging the system</li> </ol>						

Table 3.	Attenuator	Pros	and	Cons
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Wave Power vs. Solar and Wind Energy							
Pros	<ol> <li>Relatively more safe to be installed in the ocean</li> <li>Waves are hardly interrupted and almost always in motion; therefore, more reliable</li> <li>Potential amount of power that comes in waves are huge (roughly 30-40 kW for every meter)</li> </ol>						
Cons	<ol> <li>Harder to maintain as wave energy converter is larger in scale</li> <li>Due to the scale of the wave energy converter, engineers would potentially have to disassemble the attenuator by pieces to do maintenance</li> <li>Costs of wave power are generally very high</li> </ol>						

Based on the pros and cons listed in Table 1, the attenuator wave power generator has a more feasible design to manufacture and experiment upon with the given constraints surrounding this project. With the skillset of the group and resources at hand, the attenuator seems to have more of an advantage compared to the other alternatives as it will not require us to innovate pre-existing systems currently in place; therefore, it'll be theoretically be an add-on that can easily be held by the buoy.

	<b>RPi 4</b> [7][18]	<b>RPi 3 B+</b> [7][18]	<b>RPi 3</b> [7][18]	Odroid C4 [9]	BeagleBone Black [4][18]
Power at idle	540 mA (2.7 W)	350 mA (1.9 W)	260 mA (1.4 W)	1.9 W	290 mA (1.45 W)
400% CPU load	1280 mA (6.4 W)	980 mA (5.1 W)	730 mA (3.7 W)	3.1-3.3 W	-
Clock Speed	1.5GHz	1.4GHz	1.4GHz	2.0 GHz	1.0 GHz
RAM	1GB/2GB/4GB	1GB	1GB	4GB	512 MB
Serial Connections	6	2	2	2	5

 Table 4. RPi Tradeoffs

Overall, based on Table 4 above, the ODROID C4 has a higher clock speed and more RAM by default, but no one in the group is familiar with the system and the learning curve, and possibly lead time, could be significant. The other advantage of using a RPi denomination is that both the senior design lab and The Hive have Raspberry Pi 3, 3B+, and 4 in stock so we can begin development immediately. The Hive also has BeagleBone Black's, but the set up is more difficult and the performance is lower.

#### **Computing Aspects**

A Raspberry Pi 4 microcontroller will be employed along with a pair of LoRa radio bonnets to communicate battery information to a receiving device. The LoRa radio has a 2km, line-of-sight range to communicate this information, but can be extended with directed antennas. The RPi will receive power from the battery via trickle charging from the wave power generator. It will interact with both the LoRa radio and a battery board through code running on the RPi in order to transmit data. The hardware/software interfaces are through RS232 (serial) and SPI. RFM9x LoRa radio will be used along with Adafruit CircuitPython RFM9x module and CircuitPython. This technique will allow the sending and receiving of packets of data.

### 4.2 Preliminary Concept Selection and Justification

#### 4.2.1 Power/Energy for the PWS Autonomous Moored Profiler

After carefully reviewing all the options for this proposed project, the team has decided to develop according to the attenuator method because out of all the options it would simply be an add-on to the currently existing buoy.

From current commercial inventions and research, the main design aspect of this component would be that it's essentially a tube with hinged joints that is made of material that is not conductive and has buoyancy properties that will allow the attenuator to stay afloat. Power is generated in the hinge joints that connect its cylindrical tube sections with hydraulic rams that drive an electrical generator. Theoretically, this device would be connected to the profiler via a sub-sea cable for a constant charge while also tethered to the buoy.

For contingency plans, if our method does not meet the specifications given, we will go forward with the point absorber method as it is more proven in the real-word with several devices already built upon this methodology. Some potential risks that the team foresees in this project is not enough resources and time to complete everything as a lot of the attenuator's work is theoretical; therefore, a lot of trial and error could happen. In addition, due to the nature of the attenuator, problems could arise from the team attempting to scale it down from its industry sized predecessor to a miniature one that meets the design specifications.

#### **4.2.2 Communication Module**

Communication is not the focus of this project, so we found a solution that maximized ease of use over performance. The LoRa radio is intended to be a black box so alternatives were not considered.

#### 4.2.3 Processor

Overall, the ODROID C4 has a higher clock speed and more RAM by default, but no one in the group is familiar with the system and the learning curve, and possibly lead time, could be significant. The other advantage of using a RPi is that both the senior design lab and The Hive have Raspberry Pi 3, 3B+, and 4 in stock so we can begin development immediately. The Hive also has BeagleBone Black's, but the set up is more difficult and the performance is lower. Additionally in past courses such as ECE 4180 embedded development has been performed on the RPi, so we know this kind of development is possible. Finally, for future sensor integration the RPi lends itself better to sensor integration because it has the highest number of serial connections available, plus USB connectors that could be integrated with RS232 to USB connections. The chart in the appendix shows the current sensors and their communication protocols, showing that seven serial connections are needed, which is possible on the RPi 4 through the use of hats and USB connections.

### 4.3 Engineering Analyses and Experiment

After acquiring the wave size and frequency in PWS we will calculate the exact amount of power our wave power generator will produce based on the chosen piston and generator.

When we successfully waterproof the prototype, testing will be accomplished using water tanks in Georgia Tech labs that will replicate the environment that the proposed attenuator will be in. The miniature attenuator will be placed into these water tanks, which machine-made or man-made waves will be created in order to produce the necessary waves to generate power within the attenuator that will be connected to an arbitrary device to measure the amount being produced. Based on these experimental measurements, changes will be made to the device accordingly to ensure proper design meets specifications.

As a contingency to not waterproofing the device, we will manually move the device to replicate waves and connect it to a device to measure the amount of power being generated. Again, based on these experimental measurements, we will make changes to the device.

22

### 4.4 Codes and Standards

Relevant codes and standards include:

- LoRa, which short for long range, is a long range, low power wireless platform that is used widely in the Internet of Things applications [16]
- SPI, Serial Peripheral Interface, is the communication interface for the chosen communications module
- Serial (RS232) is the standard that will be used for communication with the battery pack along with many of the future sensors



## 5. <u>Schedule, Tasks, and Milestones:</u>

Figure 8. PERT Chart of the flow of the development process

Task Name	Anning	Daves	Clast	ETA	Differente	17 Aug	24 Aug	31 Aug	7 Sep	14 Sep	21 Sep	28 Sep	5 Oct	12 Oct	19 Oct	26 Oct 2020	2 Nov	9 Nov	16 Nov	23 Nov
Task Name	Assigned	Days	Start	EIA	Difficulty/risk	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
Submit bid on Project	All	5	17 Aug	22 Aug	1															
Research energy, processors, and comms	All	22	22 Aug	13 Sep	2															
Project Proposal	All	2	14 Sep	16 Sep	2															
Order Parts	All	30	19 Sep	17 Oct	3															
Define communications and processing aspects	CompE	30	19 Sep	17 Oct	3															
Define wave power generator and power aspects	EE	30	19 Sep	17 Oct	3															
Finalize design	All	3	18 Oct	21 Oct	2															
Website	All	30	18 Oct	15 Nov	1															
Wave power generator construction	EE	30	18 Oct	15 Nov	5															
RPi and LoRa Radio Integration	CompE	30	18 Oct	15 Nov	3															
Bill of Materials finalization	All	1	14 Nov	15 Nov	2															
Capstone Expo Preparation	All	7	16 Nov	23 Nov	2															
Capstone Expo	All	1	23 Nov	23 Nov	2															

Figure 9. GANTT Chart with definitive dates during development

Based on our proposed schedule the probability that we will finish before the design expo is 90%. There is some risk associated with the wave power generation, but we believe we have allocated enough time for testing and development.

## 6. <u>Project Demonstration</u>

We are planning to build a miniature model of the proposed project with the resources at hand to demonstrate virtually at the Fall 2020 Virtual Expo. This tentative way of demonstrating the project would validate the project specifications as it will demonstrate that the model works on a scaled version. Furthermore, it will provide validation on how the project would work in ideal conditions given different circumstances and numbers. Additionally, we will include video of the wave power generator creating power during our prototype testing

Overall, a demonstration will consist of a battery connected to the RPi and the wave power generator, along with the LoRa radio connected to the RPi. We would manually make waves to show the wave power generator generating power and the LoRa radio transmitting to the other side of the radio some distance away.

## 7. Marketing and Cost Analysis

### 7.1 Marketing Analysis

#### 7.1.1 Power/Energy Source for the PWS Autonomous Moored Profiler

In this project, we are planning to design our own attenuator in order to prove the concept of being able to charge the Bluefin battery, a 1.5 kWh battery, on the PWS Autonomous Moored Profiler on a small scale using smaller parameters that will be able to manipulate in future uses with the actual project. With that being said, there are several existing ideas and products that work the same as the attenuator the team is proposing.

The most popular existing product of the attenuator is the Pelamis Wave Energy Converter, manufactured by Scottish company Pelamis Wave Power (formerly Ocean Power Delivery). Pelamis is a semi-submerged, articulated structure composed of cylindrical sections connected with hinged joints. The wave-induced motion of the joints is resisted by hydraulic rams that pump high-pressure fluid to drive hydraulic motors, which in turn power electrical generators to produce electricity [15]. This product was the world's first commercial scale machine that generated electricity to the grid from offshore wave energy and the first to be used commercially. It was designed to produce 2.5 MW of energy. The first devices of the Pelamis Wave Energy Converter deployed in Portugal had a rated power of 750 kilowatts. A typical Pelamis 'farm' would span one square kilometer, providing 30 megawatts of power in an optimal setting [5].

Due to the fact that the profiler requires very low energy, 1.5 kWh, to operate, our designed project will only need to generate a smaller amount of the energy. Therefore, our design of the attenuator will be much smaller in size than the products from the current market.

### 7.1.2 Communication Module and Processor

In future versions of this product a higher range version of a LoRa radio would need to be implemented, currently it requires line of sight which will not be possible in PWS. Additionally, a more specialized processor for this application will need to be implemented.

## 7.2 Cost Analysis

Part	Count	Distributor/ Part Num	Cost per Unit	Total Cost
Raspberry Pi 4	1	adafruit/4295	\$30	\$30
LoRa Radio Bonnet	2	adafruit/4074	\$32.50	\$75
Piston	2	Piston Connecting od X/ 545081864	\$40.59	\$81.18
Generator	1	T-Tech Innovations 12V/24V DC Permanent Magnet Motor	\$75.95	\$75.95
8" diameter PVC Pipe (5ft)	1	McMaster-Carr/48925K26	\$82.59	\$82.59
14v, 5Ah Li-Ion Battery (PVC)	1	Aegis Battery	\$70	\$70
Caps, Female Socket Connect 8"	4	McMaster-Carr/4880K142	\$32.78	\$131.12

Table 5. (	Cost for	each	part
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The total budget of this project is \$700. Based on our prices, we are under budget with a total cost of \$545.84.

## 8. <u>Current Status</u>

### Power/Energy Source for the PWS Autonomous Moored Profiler

- Find the best method as the power/energy source for the PWS Autonomous Moored Profiler:

100% Complete

- Have the final product
  - Design our own attenuator: 20%
  - Find and order the parts for the attenuator: 20%
  - Build the attenuator: 0%
  - Testing the product: 0%

### **Communication Module and Processor**

- Find the module we will use as a black box communication box: 100%
- Decide on a processor that will fit the needs of the design: 100%
- Understand how to integrate integrate the LoRa radio with the RPi: 10%
- Integrate the LoRa radio with the RPi: 0%

## 9. Leadership Roles

Our currently defined leadership roles are

- Group Leader: Celeste Smith
  - Coordinate meetings and serve as spokesperson
- Webmaster: Nicholas Nguyen

- Have the key to the website and be in charge of deploying information to the website
- Documentation Coordinator: Srushty Changela
  - In charge of making sure we are taking and maintaining the necessary documentation
- Expo Coordinator: Rahil Ajani
  - Coordinate everything for our group to present at the expo
- Financial manager: Richard Nguyen
  - In charge of reimbursements and keeping track of costs
- Power Lead: Kombundit Chitranuwatkul
  - Lead on the electrical engineering/power engineering side of the project

## 10. <u>References</u>

- "About Prince William Sound Science Center." Prince William Sound Science Center. <u>https://pwssc.org/about/</u> (accessed September 14 2020).
- "About Solar Energy | SEIA." Solar Energy Industries Association.
   <u>https://www.seia.org/initiatives/about-solar-energy</u> (accessed September 13, 2020).
- "Attenuator Analysis of Cost Reduction Opportunities in the Wave Energy Industry." University of Strathclyde.

http://www.esru.strath.ac.uk/EandE/Web\_sites/14-15/Wave\_Energy/attenuator.html (accessed September 14, 2020).

- "BeagleBone Black." Beagle Board. https://beagleboard.org/black. (accessed September 15, 2020).
- "Energy And The Environment-A Coastal Perspective Attenuators." Coastal Energy And Environment.web.unc.edu.

http://coastalenergyandenvironment.web.unc.edu/ocean-energy-generating-technologies/waveenergy/the-pelamis-wave-energyconverter/ (accessed September 13 2020).

- Faizal, M., Ahmed, M. and Lee, Y., "A Design Outline for Floating Point Absorber Wave Energy Converters," *Advances in Mechanical Engineering*, vol. 6, Feb. 15, <u>https://journals.sagepub.com/doi/10.1155/2014/846097</u> (accessed September 13, 2020).
- J. Geerling. "Power Consumption Benchmarks." Raspberry Pi Dramble. <u>https://www.pidramble.com/wiki/benchmarks/power-consumption</u> (accessed September 13, 2020).

M. Talaat, M.A. Farahat, M.H. Elkholy., "Renewable power integration: Experimental and simulation study to investigate the ability of integrating wave, solar and wind energies," *ScienceDirect*, vol. 170, pp. 668-682, Mar. 2019,

http://www.sciencedirect.com/science/article/pii/S0360544218325453.

- "ODROID-C4." ODROID. <u>https://www.hardkernel.com/shop/odroid-c4/</u> (accessed September 15, 2020).
- 10. "Prince William Sound Recent Marine Data" NDBC.
   https://www.ndbc.noaa.gov/maps/Alaska\_inset.shtml (accessed September 14, 2020).
- 11. R. Campbell, "A Profiling Observatory for High Resolution Oceanographic, Biogeochemical, and Plankton Observations in Prince William Sound." *Prince William Sound Science Center*.[Online]. Available:

https://drive.google.com/file/d/1uin5A8rl6\_Gcp6-w-3mS5BZkiQ6HwGLV/view (accessed September 14, 2020).

12. "The Basics of Wind Energy | AWEA." American Wind Energy Association.

https://www.awea.org/wind-101/basics-of-wind-energy (accessed September 13, 2020).

13. "The Prince William Sound Plankton Camera: a profiling in situ observatory of plankton and particulates." ICES Journal of Marine Science.

https://drive.google.com/file/d/1-PuFgZ\_EeXKMH\_uZcOuvVcdq-dWTjals/view (accessed September 14, 2020).

14. "Thetis Profiler." Sea-Bird Scientific.

https://www.seabird.com/systems/thetis-profiler/family?productCategoryId=54627869948 (accessed September 13, 2020). 15. "Wave Energy Converters - The Liquid Grid." The Liquid Grid.

https://theliquidgrid.com/marine-clean-technology/wave-energy-converters/ (Accessed 13 September 2020).

- "What is LoRa®?." Semtech. <u>https://www.semtech.com/lora/what-is-lora</u> (accessed September 13, 2020).
- "Adafruit LoRa Radio Bonnet with OLED RFM95W @ 915MHz." Adafruit. https://www.adafruit.com/product/4074 (accessed September 13, 2020).
- 18. "UART Configuration." UART Configuration Raspberry Pi Documentation.

www.raspberrypi.org/documentation/configuration/uart.md (accessed September 16, 2020).

# Appendix

Instrument	Link	Communication Protocol
Seabird FASTCAT	https://www.seabird.com/asset-get.download.jsa ?id=54627862103	RS-232
RBR brevio	https://rbr-global.com/products/standard-loggers /rbrbrevio	RS-232
Seabird Eco FLNTU	https://www.seabird.com/combination-sensors/e co-flntu/family?productCategoryId=547580543 52	RS-232
Seabird SBE 63	https://www.seabird.com/oxygen-sensors/sbe-6 3-optical-dissolved-oxygen-sensor/family?prod uctCategoryId=54627869933	RS-232
Aanderaa Optode	https://www.aanderaa.com/productsdetail.php? Oxygen-Optodes-2	CANBus and RS-232
Seabird SUNA	https://www.seabird.com/nutrient-sensors/suna- v2-nitrate-sensor/family-downloads?productCat egoryId=54627869922	Serial
Plankton cam		Serial