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A Consumer-based Aquatic Trash Collecting Drone: A Engineering Design Case Study

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A CONSUMER-BASED AQUATIC TRASH COLLECTING DRONE: AN ENGINEERING DESIGN CASE STUDY

By

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Abstract

Trash is polluting our world's oceans and water sources rapidly. Studies estimate about 8 million metric tons of plastic enter the oceans each year with 0.8 to 2.7 million metric tons entering through rivers. ARTEMIS is designed to help mitigate the influx of trash into the ocean by cleaning up trash in our local waterways. ARTEMIS is for drone enthusiasts, hobbyists, and those who are passionate about ocean cleanup. The purpose of designing a consumer-based device is to engage a wide range of people. Through the fun activity of collecting trash using ARTEMIS, we hope to spark people's interest to learn more about the harm caused by trash in the ocean. Therefore, as people learn more, they begin to wrestle with the disparities we uphold in the global society. The effects of trash in the ocean disproportional affect the minorities and people of color. Richer countries often exploit that environment around them, while passing off the negative consequences of their actions to lower-income people. This in effect dehumanizes lower-income areas as they get passed off the negative consequences that are unwanted by the richer countries without any concern for their humanity. The goal of ARTEMIS is not only to mitigate the inflow of trash into the ocean but also awareness of how western culture's blindness to the negative consequences of their actions is dehumanizing for the people that have to take on those consequences.

Quad Chart

ARTEMIS

(Aquatic Removal of Trash for Ending Messes In Seas)

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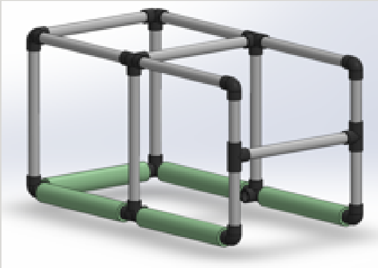
Objective:

- **To design and build an affordable, effective, and fun aquadrone that will clean up trash from oceans and local bodies of water**
- **There is a large amount of trash pollution in oceans and city waterways which harms both the environment and humans**
- **Similar methods for cleaning up ocean trash are expensive, inaccessible, or unappealing for the average individual**

Concept:

- **Small boat that can move through local waterways with a trash intake and storage system to collect trash for appropriate disposal on shore**
- **Transformed into a fun and interactive game for users via remote control and live video**



Approach:

Produce a prototype boat and demonstrate its ability to:

1. **Float**
2. **Intake trash and store it onboard**
3. **Maneuver in water via remote control**
4. **Interface with the user via an app that streams live video and GPS location**

Analyses and RRP:

Analyses:

- **Maximum volume, mass distribution, and structure**
- **Speed and motor torque/power**
- **Transmission frequency, range, and latency**
- **Power consumption and battery capacity**

RRP:

- **Prototype boat frame to demonstrate buoyancy**
- **Build remote transmission subsystem to demonstrate motor control and live video streaming**

Problem Statement and Research Summary

Ocean trash is a significant issue that is unseen to many individuals. According to NOAA, garbage patches are "large areas of the ocean where litter, fishing gear, and other debris – known as marine debris - collects" (Parker). There are six main garbage patches in the ocean, with one of the most famous ones being the Great Pacific Garbage Patch. The Ocean Cleanup found that there is 180x more plastic than biomass at the surface of the Great Pacific Garbage Patch and that 84% of plastic samples had at least one chemical pollutant in excess. Even worse, common north pacific subtropic gyre surface feeders had a ratio of over 50% plastic compared to food in their stomachs (Chen). This is concerning because of the impact on marine life and the resulting impacts on human life. Ocean plastics covering the surface of the water block sunlight from reaching autotrophs, such as plankton or algae, who form the foundation of the marine food web. According to National Geographic,

> "If algae and plankton communities are threatened, the entire food web may change. Animals that feed on algae and plankton, such as fish and turtles, will have less food. If populations of those animals decrease, there will be less food for apex predators such as tuna, sharks, and whales. Eventually, seafood becomes less available and more expensive for people" (Micalizio).

The harm caused to even the smallest members of marine life can have lasting and compounding effects that must be taken seriously.

Additionally, trash pollution can have lethal effects on larger marine life and seabirds through entanglement, digestion, and chemical contamination. Animals such as sea turtles and seabirds eat larger plastic pollution like plastic bags thinking they are prey animals. If the animals eat too much plastic, they starve to death because they are unable to digest the plastic. Furthermore, studies have shown that plastics can concentrate chemicals in an animal's gut. Controlled laboratory studies have demonstrated health effects including the formation of pre-cancer cells from the ingestion of plastics (Wilcox). Large animals can also get entangled in plastic pollution such as discarded fishing nets, plastic bags, and balloons. This entanglement can lead to death from exhaustion and suffocation. Recent studies have shown entanglement is the "greatest threat to seabirds, sea turtles and marine mammals" (Wilson) regarding the effects of plastic pollution in the ocean.

This is not only an issue that harms animals but humans as well. Humans use marine life for everything from food to beauty products and medical devices and vaccines. Furthermore, the chemicals and pollutants in plastics and other trash get ingested by the same marine life that eventually gets ingested by humans. It is not fully known yet how microplastics and chemicals from the food chain impact humans, but it presents an additional concern that is actively being researched further (Parker).

So where is all of this trash coming from? National Geographic estimates that for the Great Pacific Garbage patch, about 54% comes from land-based activities in North America and Asia (Micalizio). Furthermore, The Ocean Cleanup determined that rivers are the primary culprits for transporting land-based waste out to the ocean. Based on a range of 0.8-2.7 million metric tons of global plastic emissions per year, they estimated that over 1000 rivers are accountable for 80% of these emissions, and a larger collection of 30,000 rivers are responsible for the remaining 20% of emissions (The Ocean Cleanup). However, as stated by NOAA, "prevention is the key to solving the marine debris problem over time" (Parker). While the scope of the problem has reached nearly insurmountable proportions, it can be prevented from getting worse while future solutions are developed. Our goal is to help people across the world prevent their trash from ever reaching the ocean or making it out to the garbage patches. However, we are not the only engineers seeking to address this problem.

Several companies and devices already exist to address ocean pollution from a variety of different angles. The main competitors are Seabin, TrashBot, WasteShark, and The Ocean Cleanup. The Seabin is essentially a stationary trash can that is submerged beside a dock with the rim nearly level with the water. When the top periodically becomes slightly submerged in water, plastic, oil, and other debris flow in and get trapped in the bucket and filter contained inside. The Seabin can be connected to a dock in marinas, ports, and yacht clubs. While this can play an important role in ports or marinas, it requires frequent and regular maintenance and does not involve or appeal to the general population. This limits its impact. In contrast, the two competitors that are the most similar to our project are the TrashBot and the WasteShark. The TrashBot follows a similar concept to the device we are proposing, as it is a remote-controlled aquadrone that is designed to be operated as a game. However, it is a crowdsourced, shared device that only resides in the Chicago River. This means that anyone, anywhere, at any time can log into their website and control the robot to clean up trash in the Chicago River. Although the concept is excellent and the initial deployment has been a success, the device has been expensive to develop. It also only allows for one device per waterway for several users, instead of utilizing several users with several devices. This limits larger-scale implementation and thus reduces the overall impact that can be made on trash cleanup. The WasteShark device is also similar, although it is not designed to be a game. The primary drawback is the exorbitant cost. The remote-controlled version is priced at $17,000, and the autonomous version costs $23,000. In contrast, we seek to create a device that will be significantly cheaper, within the range of typical hobby drones, and thus accessible for more people. Lastly, one of the largest ocean cleanup operations is appropriately named The Ocean Cleanup. The Ocean Cleanup is focused on actually reducing trash in the Great Pacific Garbage Patch, as well as pollution prevention through "Interceptor" devices placed in high-impact rivers. Again, it is an excellent mission and their work has led to significant breakthroughs. However, it is focused on a large-scale application which is not our focus or demographic.

Instead, our solution is different from these competitors because it seeks to address the problem through prevention by prioritizing affordability and customer engagement on a small, but reproducible scale. We recognize that we do not have the resources or time to develop a solution that could significantly address the existing garbage patches in the ocean. Instead, we want to prevent the trash from ever reaching the ocean gyres where it will break down into microplastics and have the greatest impact on wildlife. Furthermore, we acknowledge that solutions exist for those who have the resources and passion to make a significant investment in the various technologies. However, we believe that if we empower individuals to take accountability for the health and cleanliness of their local waterways, collectively we can help prevent the problem from worsening. Our solution seeks to address both the technological challenges of efficiently collecting trash in areas that are inaccessible to humans without a boat, as well as the behavioral problem of engaging users who may not have the resources or passion for ocean clean-up. We will accomplish this through a product that will be capable of collecting floating trash, easy to use, affordable, fun, and educational for users as they participate in cleaning up the ocean and prevention more pollution.

Initial Project Statement and Critical Features

Initial Project Statement: Design, build, and test a water-cleaning robot. We want to build an electrically propelled, floating water robot that will collect trash as it moves through the water with a mouth connected to a form of a storage container. The trash can then be properly disposed of onshore once it is collected. Furthermore, it will be remote-controlled and have live video, as well as the GPS location, streamed to an app. This will allow customers to enjoy it as a game while they clean up their local waterways! Additionally, the project will account for safety concerns such as visibility/interference with other watercraft, maintaining the appropriate range for control, and monitoring battery life to minimize the risk of losing the drone in the water.

Critical features:

1. *Moves* – The drone must demonstrate the ability to move via remote control from a user on-shore.
2. *Collects trash* – The device must demonstrate the ability to intake trash and store it until it can return to the user.
3. *Water-based* – The drone will float and be best suited to maneuver on a body of water in non-harsh conditions.

Customer Description and Priorities

Who

ARTEMIS is for drone enthusiasts, hobbyists, and those who are passionate about ocean cleanup. There are currently more expensive or government-supported projects that exist, but we aim to make a fun and affordable product for families and people everywhere who desire to make a meaningful difference in the health of our planet.

What problem

Trash is polluting our world's oceans and water sources rapidly. Once trash enters a river, it inevitably ends up in the ocean. We recognize that the open ocean has a large amount of trash, which is not feasible for us to address in the scope of this project. Therefore, ARTEMIS is designed to help mitigate the influx of trash into the ocean by cleaning up trash in our local waterways.

Where

ARTEMIS is designed specifically for low-intensity water climates, such as harbors, gentle rivers, and lakes. Due to the remote-controlled operation, the device must stay within range of the shore. It will also have safety precautions implemented so that it can be used in areas where other boats are present. ARTEMIS is <u>not</u> fit for the open ocean or river rapids, as both can be extremely harsh environments.

When

Now – our oceans and waterways are severely polluted and need immediate mitigation, both in prevention and treatment.

What price

Other aquatic trash-collecting mechanisms exist, each with its market and customer. To make ARTEMIS compelling to drone enthusiasts, ARTEMIS will be offered at a competitive price to existing flying drones, within the range of several hundred dollars to a thousand.

CUSTOMER DESIGN PRIORITIES

Feature	Weight
Reliable	20
Low Environmental Impact	20
User Cost	15
User Friendliness	15
Durability	10
Safety	10
Size	5
Maintainability	5
TOTAL	100

Reliable – Tied for the highest rank, reliability is critical to this product. Customers want the assurance that the product will work every time – they do not want to worry about it stalling, becoming lost in the water, or becoming a piece of floating trash itself.

Low Environmental Impact – Also tied for the highest rank, customers are highly concerned about the impact of the product on the environment. Customers are interested in helping clean up the ocean and want to ensure that the product does so effectively while not contributing to any other environmental harm (disruption of wildlife, leaking trash or chemicals back into the water, etc.)

User Cost – Several products already exist that attempt to solve the problem of water pollution, but they cost a lot of money. Customers are interested in a way to personally contribute to ocean clean-up efforts without breaking the bank or being reliant on government funding/programs.

User Friendliness – Customers want to enjoy using the product! They also want to be able to use the product with their families, so users can be of all ages. Thus, simple and intuitive controls along with an engaging interface are a significant priority.

Durability – The product will have frequent exposure to water which can be corrosive as well as present a variety of obstacles (trash, natural features, other aquatic vehicles, etc.). Thus, customers want durable materials to be used to increase the longevity of the product.

Safety – Customers want to use this product with the assurance that it will not injure themselves, other people, or wildlife.

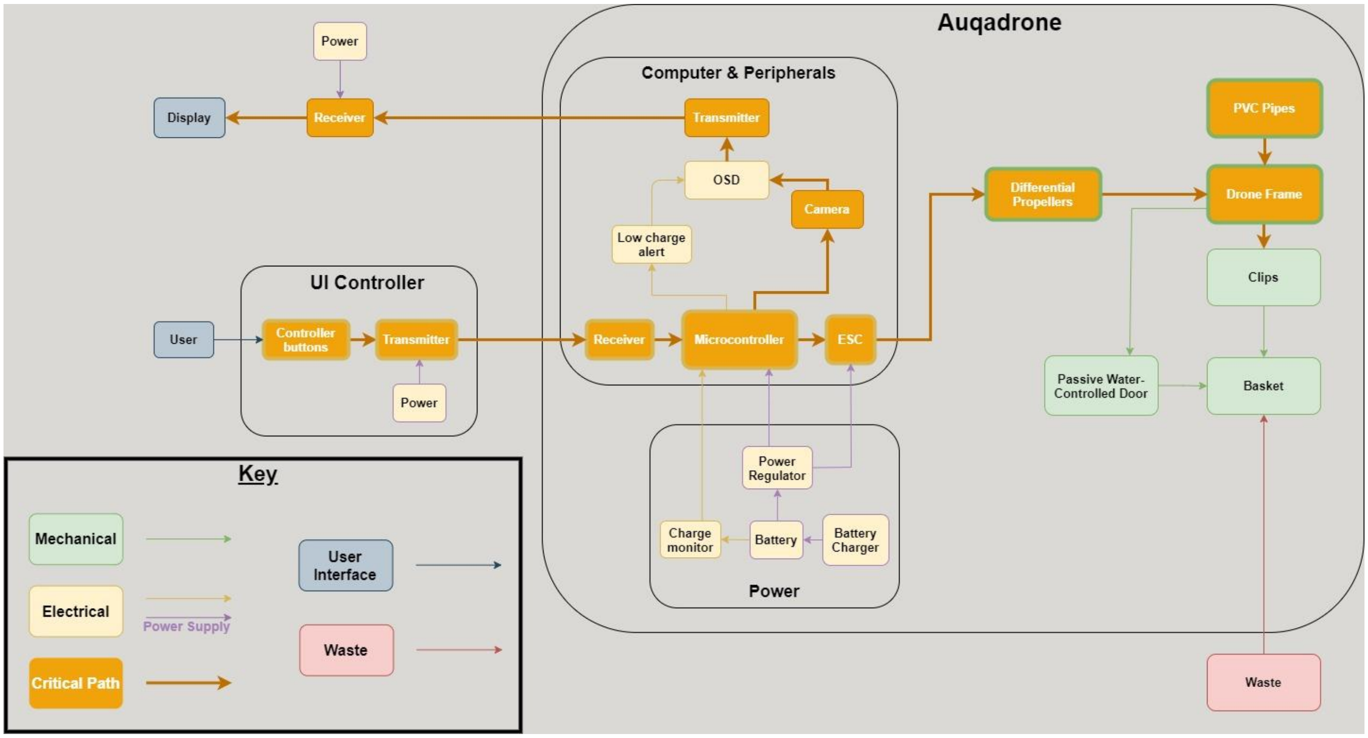
Size – The customer has some flexibility in the desired size, but there is an ideal balance. Too big, and the product will become difficult to transport and power effectively. Too small, and the product will not be able to collect a substantial amount of trash or larger pieces of trash.

Maintainability – Customers are hobbyists and non-engineers with a desire for fun trash-collecting, so they want to maximize the time spent using the product and minimize the time spent maintaining the product. However, simple, off-the-shelf repairs and maintenance are acceptable

Team Final Design

The final design is a remote-controlled aquatic drone that floats, can intake trash and store it, can maneuver in the water, and will interface with the user over a PC application that streams live the first-person video. ARTEMIS will have an RF controller that will allow a user to control the electric propulsion and steering system on the drone within a visual line of sight (VLOS). It will also have a low battery alert to minimize the risk of losing the location or control of the drone. It will be designed with a buoyancy and trash intake system that will maximize the trash collection effectiveness.

Block Diagram



Risk Reduction Prototype

Description

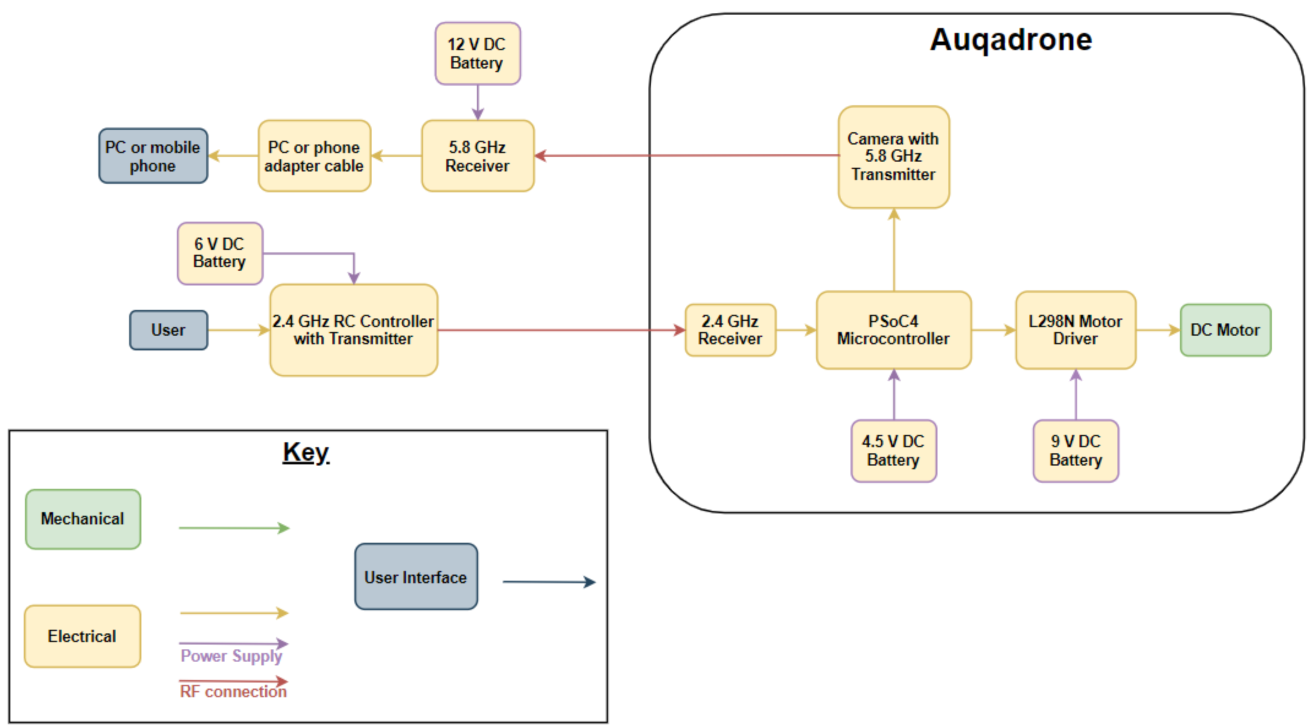
Mechanical – Buoyancy:

To succeed, the aquadrone must be able to float in the water. We have never constructed an aquadrone before, and the structure and buoyancy of the drone will help determine analysis for the movement control. Thus, this subsystem is both essential and risky. **For the RRP, we propose to build a prototype boat that will demonstrate it can float with the maximum predicted volume of trash.**

Electrical – Movement Control:

To succeed, the user must be able to remotely control the movement of the aquadrone through the water. This will require the successful remote transmission of both control commands and video, which involves the risk of crosstalk and interference. Furthermore, we have not previously used radio transmitters and receivers for remote control or video streaming, making this risky. **For the RRP we propose to build a remote transmission subsystem to demonstrate that we can control the movement of a motor while simultaneously streaming live video from a remote location.**

Summary of code: Code will be required for the motor driver. The program will use PWM to control the speed of the motor according to instructions received by the user controller. No code should be required for video transmission, as a 5.8 GHz camera receiver can be purchased with an included adapter cable and app for interfacing with a mobile phone or PC.



Specifications

Critical Features:

1. Moves
2. Collects Trash
3. Water Based

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method	Why this threshold value	Relates to critical feature(s)
RRP001	Flotation Dimensions	1ft Max below the surface	6in. Max below the surface	Measurement	Demonstrates the ability to float on the water's surface with a limited depth below the water to float in shallow bodies of water	3
RRP002	Mouth Dimension	No Larger Than 3ft	No Smaller Than 1ft	Measurement	Demonstrates the ability to collect trash passively, accounting for an appropriate range of sizes of plastics and microplastics (ranging from milk jugs and down in size).	2
RRP003	Trash Volume	3 gallons	15 gallons	Observation & Measurement	Demonstrates the ability to hold trash collected from the body of water and maintain flotation status.	2
RRP004	Remote Controller	Actuate a motor using a remote signal (min. 3 feet).	Actuate a motor while simultaneously streaming live video.	Observation	Demonstrates the ability to send, interpret, and act on a remote signal from the operator for motor control.	1
RRP005	Remote live video	Stream live video to a mobile device or PC (min. 3 feet)	Stream live video and simultaneously actuate a motor.	Observation	Demonstrates the ability to stream live video from the drone to an operator to aid in maneuvering for trash collection.	1, 2

<u>Engineering Analyses Overview</u>

Mechanical Engineering

MEA.003: Structural Analysis – Compute the stress to ensure the aquadrone will not undergo catastrophic failures while collecting trash. Dependent on mass distribution and possible external forces from the environment.

> *MEA.003.1: Buoyancy Analysis* – Estimated the buoyancy capability of the 3-inch ABS piping to be 67 pounds.

MEA.006: Wind Conditions – Free Body Diagram Analysis based on the rated thrust of propellers and full trash load.

> *MEA.006.1: Propellor Thrust* – In our thrust test, the maximum reading was 0.41 kg.
> *MEA.006.2: Net Drag Force* – Theoretical drag force on the trash intake net was 14.48 N.

Electrical Engineering

EEA.001: Transmission Frequency – Selected transmission frequencies of 2.4GHz for controls and 5.8GHz for video.

EEA.002:Range – The range is identified as 800+m from the datasheet, however, experimental testing needs to be completed to confirm this.

EEA.003: Latency – The video latency is 62.4 +/- 1.3ms video latency from a distance of 1 ft.

EEA.004: Power Consumption – The current power draw is estimated at 11A per battery.

EEA.005: Battery Capacity – The battery life is 27 minutes with the existing 3s2p battery system and a 3s9p battery is needed to reach the 2-hour threshold.

EEA.006: Microcontroller – Selected the Raspberry Pi 3 for the user interface and the Arduino for the aquadrone.

Mechanical Analyses

MEA.003 – Structural Analysis

Compute the stress to ensure the aquadrone would not undergo catastrophic failures while collecting trash. Dependent on mass distribution and possible external forces from the environment.

Initially, the purpose of this analysis was to ensure that the drone frame would not fail while the consumer was using it. For this analysis, we assumed there were two possibilities for these failures. First, the stress created from the various mechanical loads, identified in MEA.002. Second, the stress created from the force of hitting objects such as other boats, piers, or other such objects the drone may encounter while in use. For this quarter we determined the first group of stresses from the mechanical loads to be the greater risk as the results from this analysis would inform our purchasing. Unlike the stresses caused by external forces, if the stresses from the mechanical loads caused the frame to fail the entire drone would need to be redesigned. Thus, we determined it would be important to ensure that the electronics selected would not cause failures. Moreover, failures caused by external forces could be mitigated reactively using padding and not a complete structural redesign. Therefore, we chose to focus on the stresses caused by the mechanical loads.

Table 1. The estimate of the Mechanical loads identified in MEA.003

Material	number	Weight (lbs)	Combined Weight (lbs)
Wood frame	2	3.6	7.2
Side Panels	4	1.053	4.212
Top Panels	2	1.2636	2.5272
3" ABS Pipes	2	2.5	5
Signal Flag	1	0.75	0.75
battery	2	0.55	1.1
Current Electronics	1	1	1
Additional	1	1.25	1.25
Propellers	2	0.5	1
		Total (lbs)	24.0392

The weights of the siding panels and top panels are based on the density of ¼ marine-grade plywood.

$$\rho = \frac{m}{V}$$

$$m = \rho V$$

Table 2. Estimate of the Marine Plywood weights based on the Density.

Marine plywood			
	Density (lb/in^3)	Frame Volume (in^3)	Weight (lbs)
Top Panel	0.0234	54	1.2636
Side Panel		45	1.053

Reviewing the Mechanical Load Analysis, most of the weight for each of the designs is the frame and other structural parts. The total weight for the mechanical loads identified is approximately 24 pounds with most of this weight resulting from the mechanical structure.

Hence, since the mechanical load weights are minimal, we have determined the stresses they create will not be a major risk for this quarter. The stress created from a few pounds would not be a potential risk for failure. Furthermore, based on our research and previous experience rigid ABS shows very little creep and is superior to other plastics in this way. Nevertheless, this analysis will be a part of our final design to ensure the structural integrity of the product. This analysis will be completed experimentally with the final design. We were unable to complete the initial test Winter Quarter due to the delay caused by the free range of motion along the piano hinge. Once we solved this by attaching a chain along the bottom there was not enough time to test. Nevertheless, the risk from the stress caused by the mechanical loads is negligible, there will still be external forces causing stresses on the drone frame and walls.

Instead of the Structural Analysis, we determined that the buoyancy of the device was a greater risk. Successful flotation of our load drone is a critical component, and the drone would fail if it were unable to float. These calculations informed both the design process and material list. Thus, we calculated the buoyancy force and the amount of displaced water for a series of different ABS diameters based on the design. The mass of water an object displaces is equal to the amount of mass it can float. Hence, we could calculate the theoretical maximum mass our design could successfully float based on the mass of water it displaces.

Table 3. Estimate of the Buoyancy forces and mass of displaced water when submerged completely (upper line) and halfway (lower line) for ABS diameters from 1inch to 4 inches.

New Design									
Material	Diameter (in)	Number	Length (in)	Volume (in^3)	Volume (m^3)	Mass (kg)	Mass (lbs)	Bouyant Force (N)	Bouyant (lbf)
4 in ABS pipe	4.237	2	24	2707.123308	0.044361803	44.22871749	97.50763104	433.8837186	97.54094054
		2	24	1353.561654	0.022180901	22.11435875	48.75381552	216.9418593	48.77047027
3 in ABS Pipe	3.5	2	24	1847.25648	0.03027111	30.18029684	66.53616508	296.068712	66.55889445
		2	24	923.6282402	0.015135555	15.09014842	33.26808254	148.034356	33.27944723
2 in ABS Pipe	2.375	2	24	850.586211	0.013938611	13.89679484	30.63718826	136.3275574	30.64765421
		2	24	425.2931055	0.006969305	6.948397422	15.31859413	68.16377871	15.3238271
1.5 in ABS Pipe	1.9	2	24	544.375175	0.008920711	8.8939487	19.60780049	87.24963675	19.61449869
		2	24	272.1875875	0.004460355	4.44697435	9.803900243	43.62481838	9.807249346
1.25in ABS Pipe	1.66	2	24	415.5346904	0.006809394	6.788965385	14.96710665	66.59975042	14.97221956
		2	24	207.7673452	0.003404697	3.394482692	7.483553327	33.29987521	7.486109778
1 in ABS Pipe	1.315	2	24	260.7609867	0.004273107	4.260287657	9.392326536	41.79342191	9.395535041
		2	24	130.3804934	0.002136553	2.130143828	4.696163268	20.89671096	4.697767521

Based on these calculations we selected the 3-inch ABS piping, which will give us a significant margin of approximately 17 pounds above our shall specification of 50 pounds for the General Specification G2.1.

EEA.006 – Wind Conditions

We conducted a wind analysis to discover the maximum wind conditions that ARTEMIS would be able to handle while still being able to get back to the user on shore. This is extremely significant because if the user took ARTEMIS out with wind speeds that were too high then ARTEMIS would become a piece of floating trash. Due to the unpredictability of wind, we decided that this may be a tough specification to physically test. Therefore, we chose to do a Free Body Diagram (FBD) analysis for the forces acting on ARTEMIS as shown in Figure 1 to come up with a theoretical value for a maximum wind speed.

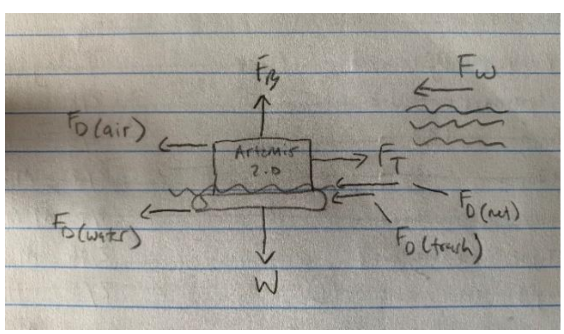


Figure 1.1. Free body diagram of the forces acting on ARTEMIS.

$$\sum F_x = 0$$

$$F_{thrust} - 2 * F_{drag\,(hull)} - F_{drag\,(artemis\,frame)} - F_{drag\,(trash)} - F_{drag\,(net)} - F_{wind} = 0 \; [1]$$

If the equation above is true, then ARTEMIS will not be able to provide enough thrust to overcome the opposing forces acting on it and therefore will not be able to move. If this were to happen then ARTEMIS would not be able to get back to the user onshore and would become floating trash.

From the thrust experiment we conducted, the maximum reading we got was 0.41 kg. This figure seemed to be off by a factor of about 10 and we're unsure of the reason why. However, from observation, it was clear the propellers were providing more thrust than that, but we still could not get a reading that matched the 3-5 kg-f rating. Hence, for this analysis, I am going to use 4 kg-f for the calculations.

Conversion from kg-f to N:

$$(4\,kgf)\left(\frac{9.81\,N}{1\,kgf}\right) = 39.24\,N$$

Drag force on the hull using an experimental drag coefficient on a long cylinder of 0.82:

$$F_{drag\,(hull)} = \frac{1}{2}(0.82)\left(1000\frac{kg}{m^3}\right)\left(1.03\frac{m}{s}\right)^2 (0.00456\,m^2) = 1.983\,N$$

$$2\left(F_{drag\,(hull)}\right) = 2(1.983\,N) = 3.967\,N$$

Drag force on the frame using an experimental drag coefficient on a rectangular prism of 2.05:

$$F_{drag\,(artemis\,frame)} = \frac{1}{2}(2.05)\left(1.225\frac{kg}{m^3}\right)\left(1.03\frac{m}{s}\right)^2 (0.067\,m^2) = 0.089\,N$$

The mouth of ARTEMIS is 18" wide. The diameter of a standardized piece of trash (16.9 oz water bottle) is 2.5". In an attempt to theoretically calculate the drag force due to trash in the net I will treat a row of 16.9 oz water bottles spanning the entire width of our device as a flat plate which has an experimental drag coefficient of 1.28.

$$A = (18\,in)(2.5\,in) = 45\,in^2$$

$$A = (45\,in^2)\left(\frac{0.000645\,m^2}{1\,in^2}\right) = 0.029\,m^2$$

$$F_{drag\,(trash)} = \frac{1}{2}(1.28)\left(1000\frac{kg}{m^3}\right)\left(1.03\frac{m}{s}\right)^2 (0.029\,m^2) = 19.69\,N$$

Drag force from the net using an experimental drag coefficient of 0.26 and using the cross-sectional area of the mouth:

$$F_{drag\,(net)} = \frac{1}{2}(0.26)\left(1000\frac{kg}{m^3}\right)\left(1.03\frac{m}{s}\right)^2 (0.105\,m^2) = 14.48\,N$$

We can now rearrange Equation [1] to solve for the maximum amount of force from the wind ARTEMIS will be able to handle.

$$F_{thrust} - 2 * F_{drag\,(hull)} - F_{drag\,(artemis\,frame)} - F_{drag\,(trash)} - F_{drag\,(net)} = F_{wind}$$

$$F_{wind} = 39.24\,N - 3.967\,N - 0.089\,N - 19.69\,N - 14.48\,N = 1.014N$$

$$\boldsymbol{F_{wind} = 1.014\ N}$$

From the maximum wind force calculation, we can find the maximum wind velocity:

$$F_{wind} = \frac{1}{2}\rho A v^2$$

$$v_{max}{}^2 = \frac{F_{wind}}{\frac{1}{2}\rho A}$$

$$v_{max} = \sqrt{\frac{F_{wind}}{\frac{1}{2}\rho A}}$$

$$v_{max} = \sqrt{\frac{1.014\ N}{\frac{1}{2}\left(1.225\frac{kg}{m^3}\right)(0.067\ m^2)}} = 4.97\frac{m}{s}\left(\frac{1.944\ knots}{1\ m/s}\right) = 9.66\ knots$$

$$\boldsymbol{v_{max} = 9.66\ knots}$$

Based on the analysis above, ARTEMIS should be able to operate in wind conditions contained in the Beaufort Wind Scale rating 3 (7-10 knots) which is the threshold we had identified in our specifications.

Electrical Analyses

EEA.001 – Transmission frequency

The purpose of the transmission frequency analysis was to select the appropriate RF frequencies for reliable transmission of control and video. This analysis supports the functional specifications of the transfer of control and video including EE1.2, EE2.1, EE3.2, and EE4.1. It is especially important that these frequencies meet federal requirements for radio emissions and will not interfere with other vessels to ensure ARTEMIS is both legal and safe.

The analysis was performed by compiling research on Federal Communication Commission (FCC) regulations and marine radar requirements to identify the best frequencies for use in our system. This research identified 2.4GHz and 5.8GHz frequencies as ideal because they are within the unlicensed ISM band under the FCC, and do not include any marine radar frequencies. Transmitters and receivers for controls and video were selected and purchased based on the FCC radio emissions requirements as shown in Figure 2. Additionally, 2.4GHz nRF24 transceivers were specifically selected because they allow for two-way communication of control and battery signals over a single hardware interface. In conclusion, this analysis successfully identified the transmission frequencies to meet the hardware and legal requirements of the system.

Transmit Power (dBm)	Antenna Gain (dBi)	EIRP (dBm)
30	6	36
29	9	38
28	12	40
27	15	42
26	18	44
25	21	46
24	24	48
23	27	50
22	30	52

Figure 1.2. Table indicating acceptable EIRP for ISM band frequencies.

EEA.002 – Range

The purpose of the range analysis was to determine the maximum communication range for the control signals in an obstruction-free zone and specifically address the functional specification EE2.1. This is important because it defines the maximum distance the aquadrone can travel before the user loses communication and control, which will render the aquadrone useless. A significant safety net should be built in so that this will not occur.

The range of the selected control transceivers was identified through the component datasheets. The datasheet rated the transceivers for a range of 800-1100 meters. However, this rating should also be either tested or calculated to verify the provided specifications. Experimental verification could be completed by propelling the aquadrone away from the user with a rope attached until the signal is lost. At this point, a laser rangefinder can be used to identify the distance and the aquadrone can be pulled back using the rope. This would also account for any additional interference created by the waterproof containers for the electronics and the water around the aquadrone. Finally, it is also possible to calculate the theoretical range using the following equation:

$$range_m = 10^{\frac{P_{tx}+G_{tx}+27.55-20\,log(f_{MHz})-L_M+G_{rx}-P_{r_x}}{20}}$$

Where,

P_{tx} = *transmitter power (dBm)*

G_{tx} = *transmitter gain (dBi)*

f_{MHz} = *frequency of the transmitted signal (MHz)*

L_M = *link margin (dB)*

G_{rx} = *receiver gain (dBi)*

P_{rx} = *receiver power (dBm)*

However, the datasheet for the nRF24L01+PA+LNA does not include the variables needed for this equation and further research would be required to determine the inputs. Thus, this analysis has been completed to the extent possible with the provided information and experimental verification is necessary to fully address the system dynamics impacting the range.

EEA.003 – Latency

The purpose of the latency analysis was to determine the maximum delay from when signals are sent from the transmitter and received by the receiver for the video. This addresses the functional specification EE4.1 The latency is important because it impacts the usability of the device. The user will be interacting with the aquadrone in real-time, and thus a significant lag in video feedback could decrease the effectiveness of trash collection and the enjoyment of the user.

The latency of the video was identified using the product specifications and actual testing. The camera was specified to have a latency of 4ms. The actual testing was accomplished by displaying a timer on a laptop and pointing the camera at it to display the screen on the TV. Pictures were taken of the laptop and TV screen showing the time displayed on each. The difference between the two times reveals the lag as seen in Figure 3. This testing revealed an average end-to-end latency of 62.4 +/- 1.3ms. Thus, the analysis successfully confirmed the latency of the video camera is well under the 500ms threshold outlined in the specification.

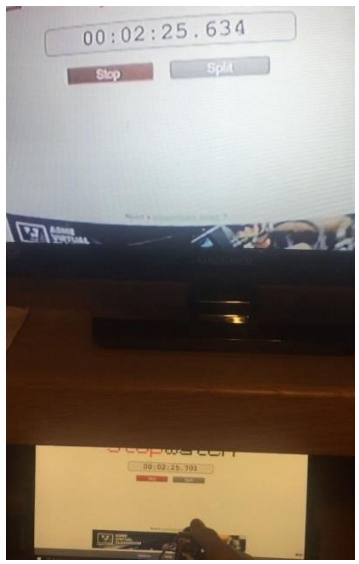


Figure 1.3. Latency testing of the camera. The real-time on the lower computer screen is 2:25:701, while the delayed time displayed on the upper TV screen by the camera is 2:25.634.

EEA.004 – Power Consumption

The purpose of the power consumption analysis was to compute the full-load current consumption of the aquadrone. This pertains to the functional specification EE1.1. The power consumption is important because it informs the battery capacity, which in turn impacts the load and structure of the aquadrone. Furthermore, it also dictates how long the aquadrone can be operated with a given battery size before the user must recharge.

This analysis was completed by determining the current draw for the various components on the aquadrone, and then calculating the total current draw of all the individual components:

$$Current_{total} = \Sigma I_{component}$$

The current draw of the speed controller and the connected propeller was determined experimentally through the thrust test. At maximum propeller speed in maximum stall condition (propeller held stationary), there was a maximum current draw of 10A. The propeller is rated for an inrush current of 40A, but this was not included in the full load current approximation as it was too short to be picked up on the current probe during testing and thus determined insignificant to the total current draw. Furthermore, the current draw of the remaining electronics was nearly doubled to allow for a conservative estimate of 1A. Based on these values, the aquadrone has a calculated maximum current draw of 11A from each battery. This is an acceptable value for the battery design and thus this analysis did not raise any significant concerns.

EEA.005 – Battery capacity

The purpose of the battery capacity analysis was to compute the minimum battery size given the approximate power consumption of the aquadrone and target operational time. This supports the functional specification EE1.1 and is critical because it informs the user how long they can operate the device before needing to bring it to shore to recharge. Similar to the range, it should have a significant safety net built-in. This analysis was completed using the following equation:

*Battery capacity (Ah) = current draw (A) * hours of operation (h)*

With a current draw of 11A per battery calculated from the power consumption analysis and a minimum operational time of 0.5 hours, the battery requires a 5.5Ah capacity. In Figure 4 it is shown that the discharge capacity at 10A, which is closest to our conservative estimate of 11A, is 2.45Ah. The discharge capacity is measured from the standard charge to the cut-off charge, so it would only drain the battery to a safe voltage level before the rapid drop-off stage. This is slightly less than the 2.5Ah nominal discharge capacity initially used for these calculations, but only causes minimal changes to the final result. Thus, a battery pack configured with two battery cells in parallel would have a capacity of 4.9Ah and would nearly meet the 0.5-hour threshold at 26.7 minutes. Furthermore, an input of 2 hours of operation can be used to calculate the ideal battery capacity. Using the same 11A per battery pack, a 22Ah capacity would be required. This can be accomplished with 9 battery cells in parallel to create a capacity of 22.05 Ah.

Furthermore, the voltage rating of the battery is determined by the maximum voltage required by the aquadrone. The propellers require around 12V, with the rest of the electronics operating at either 5V or 3.3V. Thus, a 12V battery is required. This can be accomplished by connecting three lithium-ion batteries in series. This creates a standard 11.1V battery, with a maximum of 12.6V and a minimum of 7.5V. Thus, the final battery configuration should be a 3-series, 2-parallel (3s2p) lithium-ion battery pack for proof of concept. For maximum performance, the battery should be configured as a 3-series, 9-parallel (3s9p) lithium-ion battery pack.

7.9 Discharge rate capabilities

Discharge capacity is measured with the various currents in under table and 2.5V cut-off after the standard charge.

	Discharge condition				
Current	0.50A	5A	10A	15A	20A
Relative Capacity	100%	97%	100%	97%	95%

Percentage index of the discharge at 25℃ at 10A (=2,450mAh) is 100%.

Figure 1.4. SAMSUNG INR18650-25R lithium-ion battery cells discharge capacity from the datasheet.

EEA.006 – Microcontroller

The purpose of the microcontroller analysis was to select two microcontrollers that meet the needs of the user interface and aquadrone electrical systems. This supports the functional specifications EE1.2, EE3.2, and EE6.1, which pertain to data transfer and the user interface. The aquadrone requires a microcontroller with two analog-to-digital converters (ADCs), two PWM analog outputs, one SPI interface, one UART interface, 5V or 3.3V logic, 2 Mbps or above data transfer, and 16MHz or above clock frequency. An Arduino Uno meets all of these requirements and is easy to implement with extensive community support and open-source code. It also can later add Bluetooth support which is important as a backup for the RF communication system.

The user interface requires a microcontroller with Bluetooth capability, SPI interface, 5V or 3.3V logic, up to 2 Mbps data transfer, 16MHz or above clock frequency, and ease of use for the computer science teammates. A Raspberry Pi 3 meets all of these requirements as well as operates essentially as a desktop computer which is ideal for computer science teammates. It is also well documented with extensive community support and open-source code. Thus, these two microcontrollers together meet the needs of the system while providing maximum ease of integration.

ARTEMIS Specifications

Project Definition

ARTEMIS will be a remote-controlled boat (“aquadrone”) designed to empower individuals to clean up trash from local waterways.

a. The aquadrone will effectively collect trash from the water and transport it to shore where it can be disposed of properly.
b. The aquadrone will be convenient to transport and fun to use.
c. The aquadrone will consist of two main components – the boat that is in the water, and the user interface on the shore.
d. The user will be able to control the movement of the aquadrone from the shore.
e. The user will be able to interact with the aquadrone from the shore via live video and updates on the location and battery life.

Note:

The standard item of trash will be an empty, capped, and unpunctured 16.9 oz single-use plastic water bottle.

Summary Tables

Mechanical

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method
ME1.1	IP Rating	IP54	IP67	Submerge/Spray/ Splash Test
ME2.1	Aquadrone Stability	20°	50°	Tracker App and observation
ME3.1	Speed	1 knot	2 knots	The timing between 2 points to calculate velocity
ME4.1	Wind Conditions	B.W.F - 0	B.W.F - 3	FBD Analysis
ME5.1	Visibility	100 feet	200 feet	Timing (w/ stopwatch) how long it takes an impartial viewer to identify
ME6.1	Operational Temperature	45°F - 100°F	35°F - 120°F	Thermometer/ Weather App/ COTS part specifications

*Further details on validation methods are included below

Electrical

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method
EE1.1	Battery life	30 minutes	2 hours	Timer & Analysis (in still water: 1/3 of time at min. speed & empty, 1/3 of time at med. speed & half full, 1/3 of time at max. speed & full)
EE1.2	Battery updates	5 minutes	1 minute	Timer (during battery life test)
EE2.1	Control range	100m	1km	Range finder and GPS (propel away in line-of-sight until the signal is lost)
EE3.1	GPS accuracy	Within 10m	Within 5m	Compare distance from coordinates to the actual location
EE3.2	GPS updates	9 seconds	1 second	Timer (during control range test)
EE4.1	Latency	500ms	150ms	Computer clock & timer
EE5.1	Camera resolution	Water bottle vs. driftwood from 5m	Water bottle vs. driftwood from 30m	Identification from an impartial viewer of water bottle vs. driftwood at pre-measured distances
EE6.1	User interface	3 devices	1 device	Count devices used

*Further details on validation methods are included below

General

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method
G1.1	Component Cost	$3,000	$850	Parts List, Bill of Materials
G2.1	Aquadrone Weight	50 pounds	30 pounds	Measurement with scale
G3.1	Aquadrone Transportation/Cargo Dimensions	10 cubic feet	4 cubic feet	Measurement with ruler
G4.1	Maneuverability – linear movement	Forward	Forward & reverse	Video evidence while full
G4.2	Maneuverability – turning radius clockwise & counterclockwise	180°, radius of 3 feet	180°, radius of 0 feet	Tracker App using a protractor and ruler
G5.1	Trash Intake	3 gallons	15 gallons	A pre-measured amount of trash, video evidence of collection

*Further details on validation methods are included below

Detailed Specifications

Mechanical

ME1.1 — Waterproof Rating: **The electronic enclosures of the drone shall have an IP rating of IP54 and it should have an IP rating of IP67.** Although our aquadrone will be mostly above the surface it must be protected from water and dust which will vary based on weather conditions. The IP54 rating identifies dust protection and splashing water resistance as a minimum. However, we believe our electronic housing should have a higher IP rating, IP67, which is dust-protected and waterproof when submerged up to 1m. Two qualitative tests will be used to determine the IP rating. Each test will start with a 24-hr dry-out period. The initial test will be completely submerging the sealed electronics enclosure in water for thirty minutes, where the enclosure is less than 1 meter below the surface. During the thirty minutes, the team will observe for any bubbles indicating potential leaks. After thirty minutes, remove the electronics enclosure and dry off the outside. Once the enclosure is dried, remove the seal and check for any water leakage through visual observation. If the initial test is a failure the second test will be implemented, resulting in a lower IP rating. After the dry-out period, spray the sealed electronics enclosure for five minutes with a garden hose. Then dry off the outside and check the inside for any leaks. This test will not be done with the electronics inside, ensuring that the electrical components are still functional in case of failure.

ME2.1 — Aquadrone Stability: **ARTEMIS shall not flip when tipped under 20° from horizontal and should not flip when tipped under 45° from horizontal when empty.** This will be verified through physically tipping ARTEMIS to at or beyond the specified angles above a body of water. Once the desired angle is reached, ARTEMIS will be released to determine whether it flips. The angle will be verified using the Tracker App which has a protractor feature. This test will be done multiple times to ensure the accuracy of the results.

ME3.1 — Aquadrone Speed: **The aquadrone shall have a maximum speed of at least 1 knot and should have a maximum speed of at least 2 knots when full and in still water.** An average walking speed of a human is 3mph. To collect trash effectively, the aquadrone should have the right balance of moving fast to be time-effective for the user, but also not too quick as to impede the controllability of the aquadrone. This will be verified through timing ARTEMIS driving a set distance and analytically calculating the speed. Additionally, if GPS data is available from ARTEMIS, the speed will also be calculated from this data. These tests will be run multiple times to minimizes the effect of small water currents and human errors.

ME4.1 — Wind Conditions: **ARTEMIS shall be able to operate in BWF (Beaufort Wind Force) 0 wind conditions and should be able to operate in BWF 3 wind conditions when full.** ARTEMIS should be able to operate in flat water with no wind if it is to succeed at all. Ideally, ARTEMIS should be able to function in moderate weather conditions. The maximum wind speed that ARTEMIS can handle is 10 knots which is the maximum speed in BWF 3 (this is with 1.1 kg of thrust when ARTEMIS is traveling normal to the direction of the wind). We will verify this specification by driving ARTEMIS 50 feet offshore turning around and returning at or above BWF 3 wind conditions. Additionally, since there is no certainty, we will be able to physically test this, hence we will also verify this through a free body diagram analysis of the forces acting on ARTEMIS at BWF 3 wind conditions.

ME5.1 — Visibility: **ARTEMIS shall be highly visible from 100 ft away and should be highly visible from 200 ft away as observed from land during midday against a plain background.** The visibility of ARTEMIS will help ensure it will not become additional trash due to boats running into it. Additionally, if ARTEMIS is not visible the aquadrone owner will not be able to spot the location on the body of water. The verification of the visibility of ARTEMIS will consist of ARTEMIS being placed in a random location within the specified distances and measuring the time needed to locate ARTEMIS by an individual without prior knowledge of the location. Also, the team member will determine the orientation, see figure 5 below. This trial will be done multiple times.

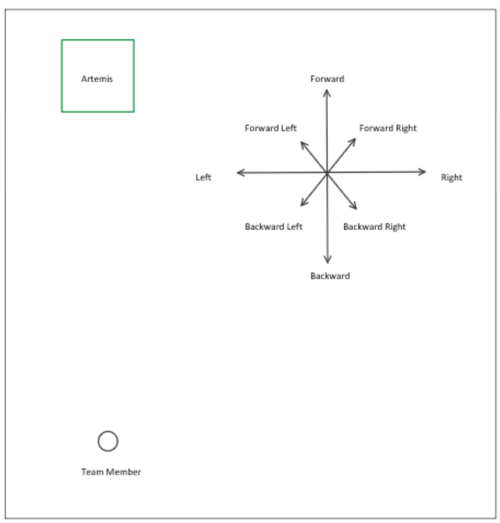


Figure 2.1. Orientation diagram for ARTEMIS to be used in the visibility testing

M6.1 — Operating Temperature: **ARTEMIS shall be able to operate in temperatures between 45°F and 100°F and should be able to operate in temperatures between 35°F and 120°F when empty and the body of water is unfrozen.** The functionality of ARTEMIS in a large range of temperatures ensures accessibility for a wide range of customers living in different locations. This will be verified by comparing the specification sheets on the various materials we buy. Additionally, if the weather permits, this will be demonstrated by operating the aquadrone in temperatures near or beyond the specified temperature range as determined by a thermometer. To demonstrate the aquadrone is functioning it will be driven forward five feet, turn approximately 90°, and collect trash two feet away.

Electrical

EE1.1 — Battery life: **ARTEMIS shall operate for 30 minutes and should operate for 2 hours in still water with 1/3 of the time at minimum speed while empty, 1/3 of the time at medium speed while half full, and 1/3 of the time at maximum speed while full.** The goal of this specification is to quantify battery life for typical aquadrone usage which includes variable speed and variable trash volume. The volume of trash will increase the longer the drone is in use. The user will also generally start at a slower speed while first searching for trash, then use the highest speed to travel directly back to shore while full to unload the trash. Finally, it would not be worth it for a user to operate ARTEMIS for less than 30 minutes, and most drone hobbyists do not use a drone for over 2 hours. This will be verified by running ARTEMIS in the water at minimum speed for 10 minutes without a load, adding half the maximum volume of trash and running at medium speed for 10 more minutes, then adding the full volume of trash and running at maximum speed for the final 10 minutes. The battery level will be monitored throughout, and if it is drained before 30 minutes have been completed, new intervals will be tested for the shorter time. If the battery level is not drained after 30 minutes, the time will be increased by 30 minutes and tested again with the corresponding new intervals. *Due to cost constraints, if the battery does not meet the 30-minute threshold, analysis identifying the number of additional lithium-ion cells required can be used to verify the specification. This will be accomplished by determining the current draw for each speed and trash category, multiplying by the amount of additional time required for each category, and then calculating the sum to determine the additional battery capacity required.*

EE1.2 — Battery updates: **The user shall receive an update on the battery voltage every 5 minutes and should receive an update on the battery voltage every 1 minute.** The user should have regular updates on the battery voltage so that they can ensure they return the aquadrone to shore before the battery dies. This will be verified by timing how often the user receives an update during the battery life test.

EE2.1 — Control range: **ARTEMIS shall have a control range of 100m and should have a control range of 1km.** Increasing the range is primarily reliant on more powerful and expensive transceivers, so 100m is a baseline threshold to prove the aquadrone can collect trash that is inaccessible from shore. The video range will be designed to be less than the control range so the user will lose their video feed and be motivated to return to the range before the controls are lost. This will be verified by using the controls to propel ARTEMIS through the water away from the tester in clear, line-of-sight conditions until the control signal is lost. At this point, the tester will use a range finder (a device that measures the distance to an object in the scope using an infrared sensor) to measure the distance. It can also be verified using GPS coordinates. A person in a boat will stay near the aquadrone at all times to ensure it can be retrieved and does not become a hazard once the signal is lost.

EE3.1 — GPS accuracy: **ARTEMIS shall be found within 10m of the given GPS location while stationary and should be found within 5m of the given GPS location while stationary.** Most cellular GPS systems are accurate within approximately 5m, so 10m accounts for the error from a phone and the error from the GPS module on the aquadrone. This will be verified by leaving the aquadrone stationery in a location, navigating to the GPS location provided by the aquadrone, and then measuring how far away the actual position of the aquadrone is.

EE3.2 — GPS updates: **The user shall receive an update on the GPS location every 9 seconds, and should receive an update on the GPS location every 1 second.** At the maximum speed of 2 knots, the aquadrone can travel approximately 10m. Thus, updates at a maximum of 9 seconds are necessary to stay within a reasonable radius for locating and retrieving the aquadrone if stuck or lost. This will be verified by timing how often the user receives a GPS update during the control range test.

EE4.1 — Latency: **The end-to-end latency of the camera to live video feed shall be less than 500ms, and should be less than 150ms.** At the maximum speed of 2 knots, the aquadrone could travel approximately 0.5m in 500ms and can travel 0.15m in 150ms. Similar to the range, more expensive equipment can reduce the latency so the goal of 500ms is to prove the concept, while less than 150ms minimizes how much the aquadrone can change position in real-time before the user sees. This will be verified by streaming live video of a computer clock with milliseconds and comparing the actual time with the displayed time. The range will impact latency but the difference will be nominal so this test should be sufficient.

EE5.1 — Camera resolution: **The camera shall allow a user to distinguish between a water bottle and a piece of driftwood of the same length in open water from a distance of 5m, and should allow a user to distinguish between a water bottle and a piece of driftwood of the same length in open water from a distance of 30m.** A user will need to distinguish trash from natural features in the environment to make decisions about what to collect. 5 meters will allow the user to identify trash immediately surrounding the aquadrone before collection, while 30m will allow the user to seek out and maneuver the aquadrone to new collections of trash. This will be verified by placing a water bottle and a piece of driftwood in the water at a measured distance of 5m from the aquadrone (within the scope of the camera). A volunteer, who has not seen the placement of the items, will be asked to look at the screen and identify the two items. This can be tested in increments of 5m, using 4 trials per increment, up until the volunteer is unable to distinguish between the two types of trash 75% of the time.

EE6.1 — User interface: **The user shall be able to interface with the aquadrone using a total of 3 devices, and should be able to interface with the aquadrone using a total of 1 device.** The user will have three main data streams: control signals to the aquadrone, live video from the aquadrone, and location & battery updates from the drone. A single device for all three data streams will be the most user-friendly. This will be verified by counting the number of devices required to interface with the aquadrone.

General

G1.1 — Component Cost: **The components required to build ARTEMIS shall cost no more than $3,000 and should cost no more than $850.** Most mid-range drones sell for around $1,000, and thus we want to keep the cost of our components within the same range to allow for a competitive price point. This will be verified from the Parts List and Bill of Materials (BOM) which together identify the total cost for all materials.

G2.1 — Aquadrone Weight: **ARTEMIS shall not weigh more than 50 pounds and should not weigh more than 30 pounds when empty.** ARTEMIS should be portable to allow users to easily transport it from home to the waterway they wish to operate it in. Thus, the weight should allow a single user to move it short distances. This will be verified by weighing the final device on a scale without any trash.

G3.1 — Aquadrone Transportation/Cargo Dimensions: **ARTEMIS shall have a maximum volume of 10 cubic feet when compacted to minimum size, and should have a maximum volume of 4 cubic feet when compacted to minimum size.** The user will need to easily compact ARTEMIS for transportation and home storage, such as within a truck bed or closet. This will be verified by measuring the length, width, and height of the device when it is fully compacted.

G4.1 — Maneuverability – linear movement: **ARTEMIS shall be able to propel forward in the water with a full load of trash, and should be able to propel both forward and backward in the water with a full load of trash.** The aquadrone needs to be able to move forwards to capture trash, and the ability to move backward would improve maneuverability and increase user-friendliness. A full load of trash will represent the worst-case situation for maneuverability. This will be verified by taking a video of ARTEMIS moving in a linear direction while in the water with a full load of trash.

G4.2 — Maneuverability – turning radius clockwise & counterclockwise: **ARTEMIS shall be able to turn clockwise or counterclockwise 180° in the water with a turning radius of 3 feet and should be able to turn clockwise or counterclockwise 180° in the water with a turning radius of 0 feet when empty.** The maneuverability of ARTEMIS is critical for it to be able to capture trash. This will be verified by taking a video of the movement of the aquadrone turning while in the water. The video can then be analyzed using the Tracker App with a protractor and ruler to measure the turning angle and the radius.

G5.1 — *Trash Intake:* **ARTEMIS shall be able to collect at least 3 gallons of the standard item of trash and should be able to collect at least 15 gallons of the standard item trash.** The consumer will want the ability to collect a certain amount of trash to make it worth their time, as well as being necessary for ARTEMIS to be effective in environmental clean-up. This will be verified by measuring the appropriate amount of trash and placing it in open water. Video will then be recorded of ARTEMIS collecting this trash from the water as qualitative evidence.

Verification of Specifications

IP Rating

Team/Project:	FIRMIV/ARTEMIS	
Test Name:	IP Rating	
Test ID Number:	TME0011	
Relevant functional specification(s) being tested:	ME1.1	
Type of test (circle)	**Black Box**	White Box
Purpose of test and test summary including number of replicates of test	This test is being done to ensure that our electronics are safe and protected from getting wet as our project relies on them working consistently. The PolyCases we have purchased that will house the electronics have an IP67 rating however we would like to validate that through some simple testing. We will do a submerge/spray/splash test as needed. We will place a dry paper towel in the PolyCase before screwing on the front plate securely. Next, we will submerge the PolyCase in water. If the paper towel is completely dry after the first test, the test is successful. If the paper towel gets wet, we will move from the submerge test to the spray test which will consist of spraying the PolyCase (dry paper towel inside) with a stream of water.	
Equipment List:	• PolyCase • Paper Towels/Towels • Bucket of water • Sink • Hose	
Necessary dummy inputs, their source, and mechanism for validation of dummy inputs:	Not applicable	
Description and/or images of the test setup	Two qualitative tests can be used to determine the IP rating. Each test will start with a dry-out period. The initial test will be completely submerging the sealed electronics enclosure in water for thirty minutes, where the enclosure is less than 1 meter below the surface. During the thirty minutes, the team will observe for any bubbles indicating potential leaks. After thirty minutes, remove the electronics enclosure and dry off the outside. Once the enclosure is dried, remove the seal and check if the paper towel has gotten wet through visual observation. If the initial test is a failure the second test will be implemented, resulting in a lower IP rating. After the dry-out period, spray the sealed electronics enclosure for five minutes with a garden hose. Then dry off the outside and check the inside for any leaks. This test will not be done with the electronics inside, ensuring that the electrical components are still functional in case of failure.	
Inputs or input ranges to be used (include number of test points and increments)	Due to the length of time for the initial test, it will only be run once. However, for the short spray testing, the test will be run twice. Nevertheless, we are confident this test will provide sound testing into the IP rating of the design.	
Anticipated results/outcomes	Based on the IP rating of the cable glands and the PolyCase we are confident that the ARTEMIS will pass this test with sufficient margin compared to our shall	

	specification of IP54. We anticipate the ARTEMIS' IP rating will be IP67, our should specification.

Specification Test Log

Date/Time of testing:	9:00pm on 4.18.21 2:00pm on 4.20.21 9:30pm on 4.25.21
Test participants:	Test Lead: Kellie Cobb Supporting Members: Jordan Barde, Andrew Josselyn
Test ID Number:	TME0011
Relevant functional specification(s) being tested:	ME1.1

Test Results

Test #1: Caulk

Date: 4/18/21 at 9:00pm

Test Result: FAIL

The container was briefly submerged underwater. Air bubbles were immediately visible, and water could be seen dripping inside from the cable gland. Thus, this method has been deemed a failure without needing to complete the 30 minutes of submersion.

Figure 3.1 Waterproofing attempt using caulking

Test #2: Hot glue

Date: 4/20/21

Test Result: FAIL

The container was completely submerged less than 1 meter underwater for 30 minutes with a dry piece of notebook paper inside. Air bubbles were not visible, but the piece of paper was visibly wet at the end of the 30 minutes. The paper was wet starting directly under the cable gland and spreading out from there. Thus, it was concluded that the PolyCase lid was waterproof (as expected given the IP67 rating), but that the sealing around the wires and cable gland was not.

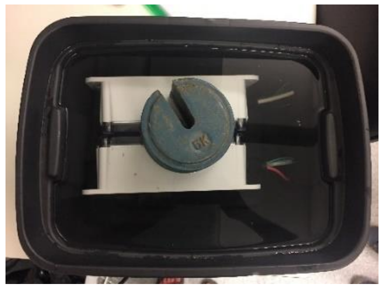


Figure 3.2 Waterproofing attempt using hot glue

Test #3: RTV silicon

Date: 4/25/21

Test Result: PASS

The container was submerged with water above the cable gland for 30 minutes with a piece of dry notebook paper inside. The container was not fully submerged because it was concluded from Test #2 that the lid was waterproof, and only the cable gland still allowed water to leak in. There also was not a bucket available at the time to fully submerge the container. Only one air bubble was visible, and the piece of paper was visibly dry at the end of the 30 minutes.

Thus, the test was a pass and the electronics enclosure complies with an IP67 rating.

Figure 3.3. Waterproofing attempt using RTV silicon

Figure 3.4. Cable gland with RTV silicon seal applied

Figure 3.5. Polycase with dry paper inside

Test Deviations

Test #3 was completed with the cable gland fully submerged, but not the entire PolyCase. This was because it was concluded from Test #2 that the lid was waterproof, and only the cable gland still allowed water to leak in. Furthermore, there was not a bucket available at the time to fully submerge the container, and the electronic containers needed to be proven to be waterproof as soon as possible.

Test Results

Pass	Fail

Test Commentary

The test was a complete pass with no further work needed to verify specification ME1.1.

Signoff

Name	Signature	Role
Kellie Cobb	Kellie Cobb	Test lead
Jordan Barde	Jordan	Supporting Test Member
Andrew Josselyn	Josselyn	Supporting Test Member
Colt Hawley	Colt Hawley	Team member

Stability

Team/Project:	FIRMIV/ARTEMIS	
Test Name:	Stability	
Test ID Number:	TME0021	
Relevant functional specification(s) being tested:	ME2.1	
Type of test (circle)	**Black Box**	White Box
Purpose of test and test summary including number of replicates of test	We are doing this test to ensure that ARTEMIS will not tip over when enduring weather conditions that cause it to lean or sway back and forth. For this test, we will be taking ARTEMIS to an easily accessible body of water. One team member will be in charge of tipping ARTEMIS to the desired testing degree while the other will be responsible for filming the test and getting a very close estimation of the angle using the protractor app on their phone. The team member responsible for filming will set up a phone in a stationary position aimed at ARTEMIS head-on. Once the phone is set up, they will hit record at which time the other team member will tip ARTEMIS up to roughly the first angle we wish to measure. The filming team member will then use the protractor app to get a very close approximation of the angle before the other team member releases ARTEMIS. Although during testing we won't have an exact angle	

	measurement, once we upload the videos into the tracker app, we can use the protractor tool in Tracker to get exact angle measurements. We will repeat this test 4 times.
Equipment List:	• ARTEMIS (fully built and integrated) • Body of water • Protractor app on cell phone • Tracker app (CPU) • 2 team members
Necessary dummy inputs, their source, and mechanism for validation of dummy inputs:	Not applicable for this test
Description and/or images of the test setup	 ARTEMIS will be tipped and measure with one hull still in contact with the water (as seen in the picture above). Once we're at the appropriate measurement we will drop the device to ensure that it stays upright and does not capsize at each of the angles indicated below.
Inputs or input ranges to be used (include number of test points and increments)	• 20° • 30° • 40° • 50°
Anticipated results/outcomes	We anticipate that ARTEMIS will not tip over from being dropped at any one of these angles. Our initial testing of a 50° angle was successful which leads us to believe once full integration is complete our final test results will be successful as well. We are confident in this belief because although our first test did not contain all integrated components, the final product will have an equal weight distribution on both sides so the results should not differ much from initial testing.

Specification Test Log

Date/Time of testing:	11:30 am on 5.13.21
Test participants:	Test Lead: Colt Hawley Supporting Members: Andrew Josselyn, Kellie Cobb
Test ID Number:	TME0021
Relevant functional specification(s) being tested:	ME2.1

Test Results

Figure 3.6. ARTEMIS being drop at about 20°

Figure 3.7. ARTEMIS being drop at about 85°

Figure 3.8. ARTEMIS stabilizing in the water

This test was an emphatic success. ARTEMIS was dropped at each of the angles specified (20, 30, 40, and 50) 4 times and had no issues with returning to a floating position and did not capsize. To push the limits, our team also tipped ARTEMIS at a nearly 90-degree angle to see if ARTEMIS would flip over or return to the floating position. Even at this extreme angle, ARTEMIS returned to the correct position. Overall, the stability testing far exceeded our expectations and we are confident in concluding that this test was successful.

Test Deviations

There were no deviations from the test plan.

Test Commentary

The test was a complete pass with no further work needed to verify specification ME2.1.

Test Results (circle)

Pass	Fail

Signoff

Name	Signature	Role
Colt Hawley	Colt Hawley	Test Lead
Andrew Josselyn	A. Josselyn	Supporting Test Member
Kellie Cobb	Kellie Cobb	Supporting Test Member
Jordan Barde	Jordan	Team Member

Speed (Statistical)

Team/Project:	FIRMIV/ARTEMIS	
Test Name:	Speed	
Test ID Number:	TME0031	
Relevant functional specification(s) being tested:	ME3.1 ME4.1 G4.1	
Type of test (circle)	**Black Box**	White Box
Purpose of test and test summary including number of replicates of test	The purpose of this test is to discover how fast ARTEMIS can go with no trash, a partial load of trash, and a full load of trash. If ARTEMIS moves too fast, then it will be difficult for the user to collect trash, therefore, losing functionality. If ARTEMIS moves too slow it may diminish some of the “fun factors” for the user and hence may not be desirable for them to continue using.	
Equipment List:	• ARTEMIS (fully built and integrated) • Body of water • Timer • Tape measure	
Necessary dummy inputs, their source, and mechanism for validation of dummy inputs:	Not applicable to this test	
Description and/or images of the test setup	This will be verified through timing ARTEMIS driving a set distance and analytically calculating the speed. The distance between the points will be measured via tape measure and will be between 10 to 15 feet across. Additionally, the body of water will be relevantly still with no major currents. These tests will be run multiple times to minimizes the effect of small water currents and human errors.	
Inputs or input ranges to be used (include number of test points and increments)	This will be our statistically sound test with 11 tests run. This number was found using the equation, $1 - C = \sum_{i=0}^{f} C_i^n * (1-R)^i * R^{n-i}$ from the Reliability Analytics ToolKit website. Where C = Confidence level, R = Reliability, and f Number of allowable failures. The values used were C = 90%, R= 0.80, and f= 0.	
Anticipated results/outcomes	We anticipate we will achieve a maximum speed of at least 1 knot.	

Full Trash					
Trial	Distance (ft)	Time (s)	Velocity (ft/s)	Velocity (knots)	Met Spec?
1	10	5	2.00	1.19	Yes
2	10	4	2.50	1.48	Yes
3	10	4.5	2.22	1.32	Yes
4	10	5	2.00	1.19	Yes
5	10	3.5	2.86	1.69	Yes
6	10	4.5	2.22	1.32	Yes
7	10	4	2.50	1.48	Yes
8	10	5	2.00	1.19	Yes
9	10	6	1.67	0.99	No
10	10	5.5	1.82	1.08	Yes
11	10	5	2.00	1.19	Yes
12	10	5	2.00	1.19	Yes
13	10	4.5	2.22	1.32	Yes
14	10	4.5	2.22	1.32	Yes
15	10	5.5	1.82	1.08	Yes

No Trash					
Trial	Distance (ft)	Time (s)	Velocity (ft/s)	Velocity (knots)	Met Spec?
1	10	5	2.00	1.19	Yes
2	10	5.5	1.82	1.08	Yes
3	10	6.5	1.54	0.91	No
4	10	4	2.50	1.48	Yes
5	10	6	1.67	0.99	No
6	10	5	2.00	1.19	Yes
7	10	5	2.00	1.19	Yes
8	10	5	2.00	1.19	Yes
9	10	5	2.00	1.19	Yes
10	10	5	2.00	1.19	Yes
11	10	5	2.00	1.19	Yes
12	10	5	2.00	1.19	Yes

The only trials on either test that did not meet the specification were due to user error (ARTEMIS was accidentally steered into the dock which slowed it down) and not due to functionality of ARTEMIS.

Test Deviations

Due to some of the mishaps from the user, we did more than the 11 trials we identified for each test to make up for those tests where we hit the dock. However, we still wanted to include the data from those trials just to have an honest and full picture of the reality of this test. Also, we only ran the test for a full load of trash and no load of trash because that would give us a best-case and worst-case scenario. We determined that this would be sufficient without testing ARTEMIS with a partial trash load. Additionally, we would like to note that the average speed of ARTEMIS throughout the full trash test was higher than that of the no trash test (Avg. speed (full trash) = 1.27 knots, Avg. speed (no trash) = 1.16 knots). This makes sense because after testing we noticed that the pipes had very slowly taken in some water which made ARTEMIS sit lower in the water, and we completed the no trash test last. The water collected by this point would create more drag and slow ARTEMIS down. Lastly, one factor we did not take into consideration was the direction we were steering ARTEMIS. Since we were at a boat launch and there were boats out on the water, one direction was in line with the wake, and the other direction was going against it. We mention this for full transparency, but the deviations are minor and accounted for by doing the 11 trials for a statistically sound test.

Test Results (circle)

Pass	Fail

Test Commentary

The test was a complete pass with no further work needed to verify specification ME3.1.

Signoff

Name	**Signature**	**Role**
Jordan Barde		Test Lead
Kellie Cobb	Kellie Cobb	Supporting Test Member
Colt Hawley	Colt Hawley	Team Member
Andrew Josselyn	AJosselyn	Team Member

Battery Life

Team/Project:	FIRMIV / ARTEMIS	
Test Name:	Battery Life	
Test ID Number:	TEE0011	
Relevant functional specification(s) being tested:	EE1.1 EE1.2	
Type of test (circle)	**Black Box**	White Box
Purpose of test and test summary	The purpose of this test is to quantify battery life for typical aquadrone usage which includes variable speed and variable trash volume. The volume of trash will increase the longer the drone is in use. The user will also generally start at a	

including number of replicates of test	slower speed while first searching for trash, then use the highest speed to travel directly back to shore while full to unload the trash. Three trials of this test will be completed.
Equipment List:	• ARTEMIS (fully integrated with remote control and batteries) • Remote controller • Maximum load of trash • Timer • Battery Charger • Digital Multimeter (DMM)
Necessary dummy inputs, their source, and mechanism for validation of dummy inputs:	None.
Description and/or images of the test setup	ARTEMIS will be placed in water with a rope attached for retrieval if necessary. ARTEMIS will be run at minimum speed for 10 minutes without a load, adding half the maximum volume of trash and running at medium speed for 10 more minutes, then adding the full volume of trash and running at maximum speed for the final 10 minutes. If the batteries are drained before the total 30 minutes have been completed, the test intervals will be reduced by 5 minutes. If the batteries are not drained after the total of 30 minutes, the test intervals will be increased by 5 minutes. The batteries will need to be fully recharged after each trial. The Electronic Speed Controller (ESC) will be used to monitor if the battery level is low, but a DMM onshore can be used to verify the battery voltage as needed.
Inputs or input ranges to be used (include number of test points and increments)	• 10-minute intervals • Low (~150 PWM), medium (~200 PWM), and maximum speed (~250 PWM) • No trash (~0 gals.), half of the maximum volume of trash (~7.5 gals.), the maximum volume of trash (~15 gals.)
Anticipated results/outcomes	The ESC has a built-in feature that will reduce power to the propellers when the battery reaches a voltage of 8.4V. If power is not reduced within 5 minutes of the desired threshold (30 minutes), the test is considered a pass.

Specification Test Log

Date/Time of testing:	3:00 pm on 5.8.21 12:30 pm on 5.13.21
Test participants:	Test Lead: Kellie Cobb Supporting Members: Andrew Josselyn, Colt Hawley
Test ID Number:	TEE0011
Relevant functional specification(s) being tested:	EE1.1 EE1.2

Test Results

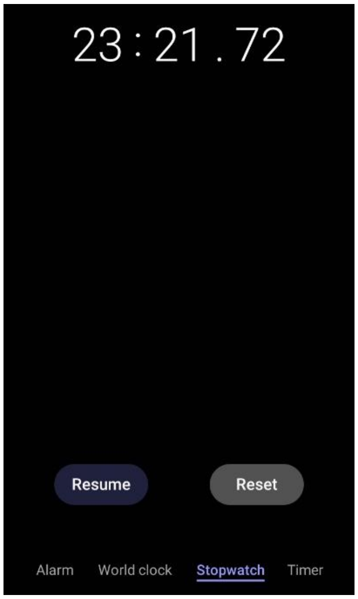


Figure 3.9. Timer showing how long the test was conducted before the

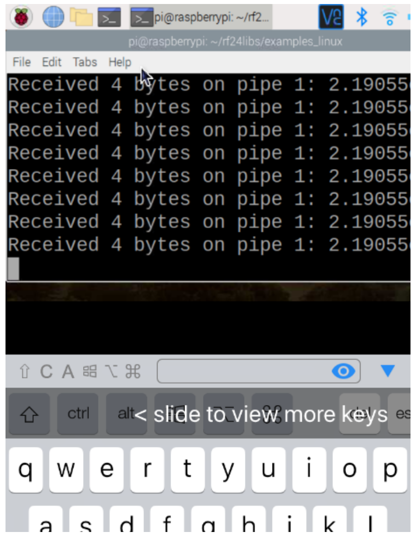


Figure 3.10. Battery life updates showing lowest voltage at end of test.

Example clip from 10 minutes at low speed with 0 gallons of trash: https://youtu.be/d0VwZFONMFo

Example clip from 10 minutes at medium speed with 3 gallons of trash: https://youtu.be/0FLHpEpacVs

Example clip from 3 minutes at high speed with 6 gallons of trash: https://youtu.be/2KFTWjIlltM

Test Deviations

In our inputs, we had initially based our volume of trash intervals on the 15-gallon maximum trash intake objective. However, our maximum trash intake ended up being only 6 gallons, so we used trash intervals of 0 gallons of trash, 3 gallons of trash, and 6 gallons of trash. In addition, the ESC user manual said that it would reduce power to the propellers if the battery voltage got low. However, the ESC did not actually do this and the propellers would just stop when the battery voltages got too low, so the outcome/result was different than anticipated. Another deviation was that the boat had to be taken out of the water for approximately 10 minutes because the propeller screws were loose and this needed to be fixed before continuing to propel the boat around. We paused the timer during this time because the current draw while stationary is significantly less than that while being operated, and it was not part of the original test plan. However, the electronics continued to draw current for 10 minutes which was not included in the total measured 23 minutes of battery life. Finally, three trials were not completed. This is because the test was time-intensive and required at least three team members to complete which was difficult to coordinate. Two tests were attempted in total. The first test identified that the battery would shut down if the net got caught and jammed the propeller. This ended the first test early because the battery shut down after the propeller got jammed. The second test was completed successfully besides the 10-minute pause to adjust the propellers.

Test Results (circle)

Pass *(partial)*	Fail

Test Commentary

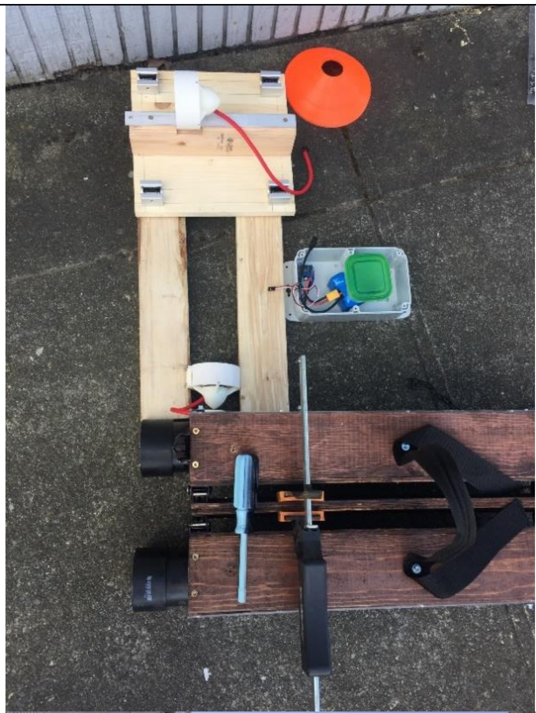
This test was a partial pass because only one trial was completed, and it was difficult to keep all systems operating reliably to represent the accurate current draw. In addition, it is important to note that the low battery “failure mode” did not occur as expected. The ESC user manual said that it would reduce power to the propellers if the battery voltage got low, however, the ESC did not do this. Instead, the propeller would just shut off once the battery dies, starting with whichever of the two batteries dies first. Thus, it is up to the user to monitor the battery life updates to determine when to bring the boat in because there are currently no failure modes built into the design.

Signoff

Name	**Signature**	**Role**
Kellie Cobb		Test Lead
Colt Hawley		Supporting Test Member
Andrew Josselyn		Team Member
Jordan Barde		Team Member

Control Range

<table>
<tr><td>Team/Project:</td><td colspan="2">FIRMIV/ARTEMIS</td></tr>
<tr><td>Test Name:</td><td colspan="2">Control Range</td></tr>
<tr><td>Test ID Number:</td><td colspan="2">TEE0021</td></tr>
<tr><td>Relevant functional specification(s) being tested:</td><td colspan="2">EE2.1</td></tr>
<tr><td>Type of test (circle)</td><td>Black Box</td><td>White Box</td></tr>
<tr><td>Purpose of test and test summary including number of replicates of test</td><td colspan="2">The purpose of this test is to discover the maximum distance ARTEMIS can be reliably controlled from the user onshore. The video range is designed to be less than the control range so the user will lose their video feed and be motivated to return to the range before the controls are lost. Both video and controls will be operated at increasing distances until communication is lost. Three trials of this test will be completed.</td></tr>
<tr><td>Equipment List:</td><td colspan="2">• Remote controller & receiver
• Electronic Speed Controller (ESC)
• Propeller
• PolyCase
• ARTEMIS (boat frame with plexiglass)
• Camera & Transmitter
• Plastic case
• Video receiver
• Measuring Tool (Google Maps on phone)
• Phone (for documentation; photos and videos)</td></tr>
<tr><td>Necessary dummy inputs, their source, and mechanism for validation of dummy inputs:</td><td colspan="2">None.</td></tr>
</table>

Description and/or images of the test setup	  The test will take place outside in an urban area to simulate the expected usage of the device. The electronics (ESC and receiver) are placed inside the PolyCase container which is placed inside the plexiglass-covered enclosure of ARTEMIS. The propeller is outside of ARTEMIS but wired to the ESC. One tester will hold the controller and walk away from ARTEMIS in a straight line. They will pull the joystick on the controller approximately every 5s to turn the propeller on and off. Another tester will remain by the propeller and alert the tester with the controller via a phone call if the propeller responds or not. The tester will

	continue walking away until the propeller does not respond. At this point, they will attempt two more times to actuate the propeller at the current distance to complete three trials. If the propeller does not respond, they will walk forward again until it does respond and test two more times at this distance. Once the propeller responds to all three trials, the tester walking will send the location to the tester by the propeller. Google Maps can be used to calculate the distance between the two points.
Inputs or input ranges to be used (include number of test points and increments)	0m -1000m distance 5s intervals between pulling the joystick on the controller
Anticipated results/outcomes	The test is considered a pass if the remote controller turns the propeller on and off at 100m for three trials. Live video is not required to verify the specification, however, the live video range will also be recorded. In addition, testing will be continued past 100m to identify a maximum range for the controller. It is expected to have a maximum range near its rating of 800m.

Specification Test Log

Date/Time of testing:	1:00 pm on 4.8.21 2:00 pm on 5.20.21
Test participants:	Test Lead: Kellie Cobb Supporting Members: Jordan Barde
Test ID Number:	TEE0021
Relevant functional specification(s) being tested:	EE2.1

Test Results

Subsystem	**Range (meters)**
Live video	100m
Controls	400m
Transceiver (battery updates)	800m

Controls:

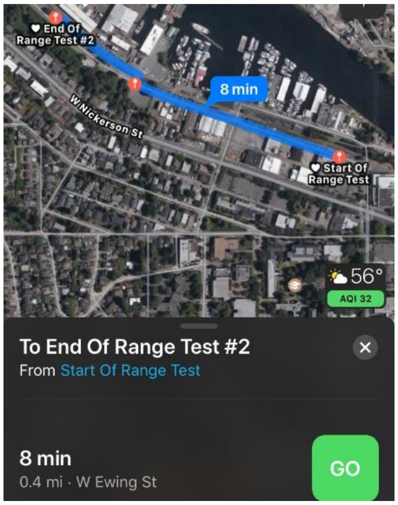


Figure 3.11. 1 trial passed

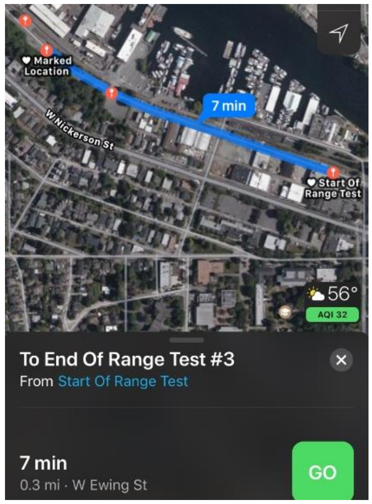


Figure 3.12. 2 trials passed

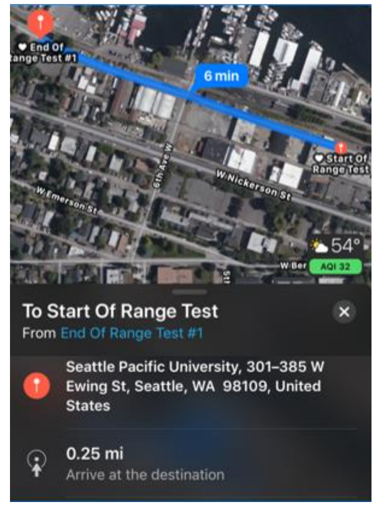


Figure 3.13. 3+ trials passed

The propeller first stopped responding at 0.4 miles (644 meters), shown in Figure 16. The propeller would not respond to any additional trials at this distance but responded again at 0.3 miles (483 meters), shown in Figure 17. The propeller responded to one additional trial at 0.3 miles but did not respond to the three total trials to pass at this distance. The propeller finally responded reliably (passing over three total trials) at 0.25 miles (402 meters) in Figure 18. This is considered the final range for controls and passes specification EE2.1. Live video and the transceiver battery updates were also tested to determine the range, although not required in the specification. The video stopped transmitting reliably at 0.06 miles (100 meters), while the battery updates transmitted reliably up to 0.5 miles (805 meters) as shown in the image below.

Transceiver:

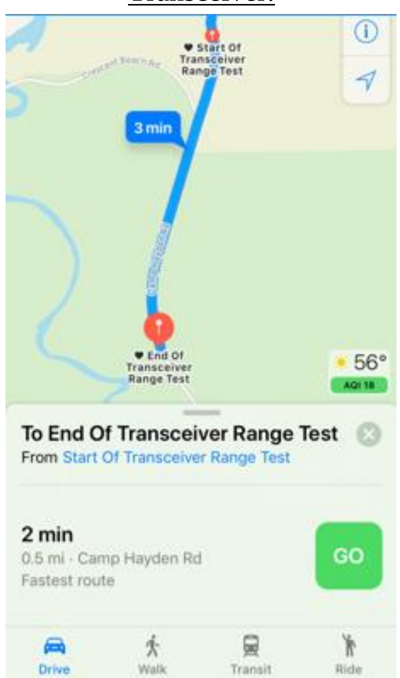


Figure 3.14. Transceiver range distance calculated through a map on a phone.

Test Deviations

There are no deviations from the written test plan. However, the written test plan did deviate from the verification method suggested in the specification write-up. This is because it was determined too risky and difficult to propel ARTEMIS out on the water until the control signal was lost. Few ropes are long enough to pull ARTEMIS back after losing communication, and it would be difficult to use a range finder at 600 meters with just a small boat on the water to focus the infrared sensor on. In addition, the specification write-up suggested that the range test should be completed in clear, line-of-sight conditions. However, we could not find a place with clear line-of-sight conditions for the distances needed. Instead, the road curved and there were trees, buildings, and fences obstructing the line of sight. Thus, the range provided in this test is a worst-case scenario.

Test Results

Pass	Fail

Test Commentary

The test was a complete pass with no further work needed to verify specification EE2.1. In addition, the range of the live video feed and transceivers for battery updates were also tested to provide comprehensive data for all three data streams (controls, video, battery updates) on ARTEMIS. The video range was purposely designed to be less than the range of the controls to encourage the user to move ARTEMIS closer to shore before the controls cut out. The transceiver range for battery updates was purposely designed to be greater than the range of the controls to allow the user to determine if the battery is dead or if the controls are out of range in the situation where the propellers are no longer responding.

Signoff

Name	Signature	Role
Kellie Cobb	Kellie Cobb	Team Lead
Jordan Barde		Supporting Test Member
Andrew Josselyn		Team Member
Colt Hawley	Colt Hawley	Team Member

Maneuverability (Linear)

Team/Project:	FIRMIV/ARTEMIS	
Test Name:	Maneuverability (linear)	
Test ID Number:	TG0041	
Relevant functional specification(s) being tested:	G4.1	
Type of test (circle)	**Black Box**	White Box
Purpose of test and test summary including number of replicates of test	The purpose of this test is to ensure that ARTEMIS can propel forward through the water. This will be conFIRMed by remotely controlling the boat to travel between two buoys or other marked locations in water and recording video evidence. Three trials of this test will be completed.	
Equipment List:	• ARTEMIS (fully integrated) • Maximum load of trash (dependent on Trash Intake Test) • Body of water • 2 buoys or landmarks in a body of water • Tape measure	
Necessary dummy inputs, their source, and mechanism for validation of dummy inputs:	None.	
Description and/or images of the test setup	Two buoys or other landmarks in a body of water will be measured to be at least 10ft apart using a tape measure. ARTEMIS will be placed in water with a full load of trash and a rope attached for retrieval if necessary. Starting at the first buoy, a tester will use the remote controller to propel ARTEMIS towards the second buoy. If it reaches the second buoy, they will either propel or pull it back to the first buoy to repeat the test. Video will be recorded as evidence of ARTEMIS propelling forward.	
Inputs or input ranges to be used (include number of test points and increments)	A full load of trash (~15 gals.) Buoys 10ft apart tested 3 time	
Anticipated results/outcomes	The test is considered a pass if ARTEMIS can propel forward between two buoys spaced a minimum of 10ft apart for three trials.	

Specification Test Log

Date/Time of testing:	1:30 pm on 5.11.21
Test participants:	Test Lead: Jordan Barde Support: Kellie Cobb
Test ID Number:	TG0041
Relevant functional specification(s) being tested:	G4.1

Test Results

Kellie and Jordan completed this test at the same time that we conducted the speed test. The proof for this test is simply visual observation (as seen in the video below). It did take some experience in using the remote controller to get ARTEMIS to move in a straight line consistently. However, functionally speaking ARTEMIS was able to move linearly with ease.

Please view the video evidence on the link below:

Linear Maneuverability Test Video

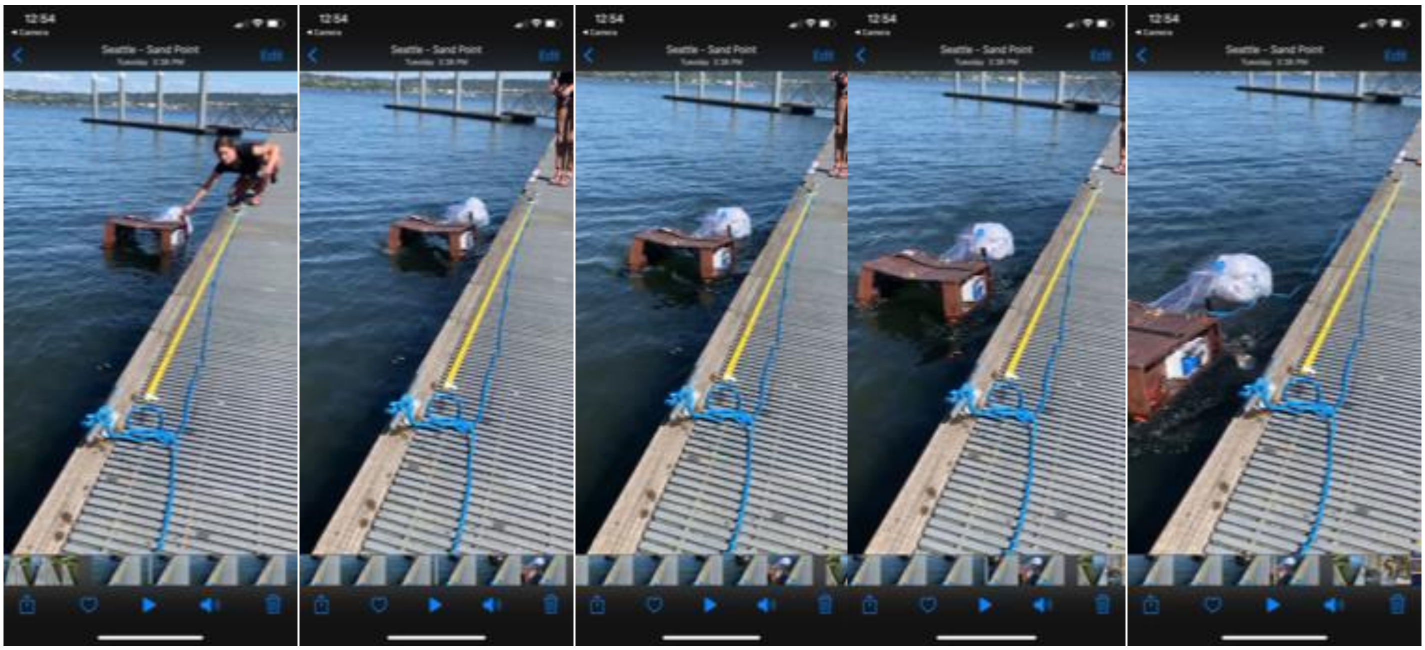


Figure 3.15. Images of maneuverability test for ARTEMIS

Test Deviations

We did not end up using buoys to conduct this test like we first indicated. We simply used the tape measure on the dock from the speed test to identify our start and endpoints and then visually observed if ARTEMIS was moving in a straight line. Also, in our inputs, we had initially said we would test the linear maneuverability with 15 gallons of trash. However, our maximum trash intake ended up being only 6 gallons, so this is the amount of trash we used in this test.

Test Results

Pass	Fail

Test Commentary

The test was a complete pass with no further work needed to verify specification G4.1.

Signoff

Name	Signature	Role
Jordan Barde	[illegible]	Test Lead
Kellie Cobb	Kellie Cobb	Supporting Test Member
Colt Hawley	Colt Hawley	Team Member
Andrew Josselyn	[illegible]	Team Member

Trash Intake

Team/Project:	FIRMIV/ARTEMIS	
Test Name:	Trash Intake	
Test ID Number:	TG0051	
Relevant functional specification(s) being tested:	G5.1 ME3.1	
Type of test (circle)	**Black Box**	White Box
Purpose of test and test summary including number of replicates of test	The purpose of this test is to ensure that ARTEMIS can intake the 3-15 gallons of trash that we indicated in our specifications. Previously (with previous prototypes) we have met this specification with ease and have high confidence that we will again.	
Equipment List:	• Empty water bottles • Grocery bag • Trash bag • ARTEMIS (frame; do not need a full integration for this test) • Phone (for documentation)	
Necessary dummy inputs, their source, and mechanism for validation of dummy inputs:	Not applicable for this test	
Description and/or images of the test setup	Once the trash intake system is installed, we can place 3 gallons of trash (standard plastic grocery bag full of empty water bottles) and 15 gallons of trash (standard trash bag full of empty water bottles) in the water and see if ARTEMIS can passively "eat" this amount of trash.	
Inputs or input ranges to be used (include number of test points and increments)	Our standardized piece of trash is a 16.9oz unpunctured plastic water bottle.	
Anticipated results/outcomes	If the mouth of ARTEMIS can passively take in at least a 3-gallon bag full of trash then our specification will have been met and the test will have been successful.	

Specification Test Log

Date/Time of testing:	2:00 pm on 5.11.21
Test participants:	Test Lead: Andrew Josselyn Support: Kellie Cobb, Jordan Barde
Test ID Number:	TG0051
Relevant functional specification(s) being tested:	G5.1 ME3.1

Test Results

The results of this test proved that ARTEMIS can intake and collect at least 3 gallons. Therefore, the test was successfully passed. The proof for this test is visual observation seen in the photos and videos below. Furthermore, the amount of trash was verified based on the size of the trash bag they were passed in.

Please view the video evidence on the link below:

ARTEMIS Trash Intake Test Video

Test Deviations

We were unable to collect over 3 gallons of 16.9 oz empty water bottles for the test. Therefore, we substituted for the water bottles with similar size and shape plastic bottles. Additionally, we were unable to test the full capacity of the trash intake system, because we were unable to collect a total of 15 gallons of plastic bottles of similar size. Nevertheless, since ARTEMIS was able to intake and store over 3 gallons, it met the specification and passed the test.

Test Results

Pass	Fail

Test Commentary

The test was a complete pass with no further work needed to verify specifications G5.1 and ME3.1.

Signoff

Name	**Signature**	**Role**
Andrew Josselyn	Josselyn	Test Lead
Jordan Barde	Jordan Barde	Supporting Test Member
Kellie Cobb	Kellie Cobb	Supporting Test Member
Colt Hawley	Colt Hawley	Team Member

Verification for Specifications Without a Test Plan

ME4.1 Wind Conditions

We conducted a wind analysis to discover the maximum wind conditions that ARTEMIS would be able to handle while still being able to get back to the user onshore. This is extremely significant because if the user took ARTEMIS out with wind speeds that were too high then ARTEMIS would become a piece of floating trash. Due to the unpredictability of wind, we decided that this may be a tough specification to physically test. Therefore, we chose to do a Free Body Diagram (FBD) analysis for the forces acting on ARTEMIS as shown in Figure 1 to come up with a theoretical value for a maximum wind speed.

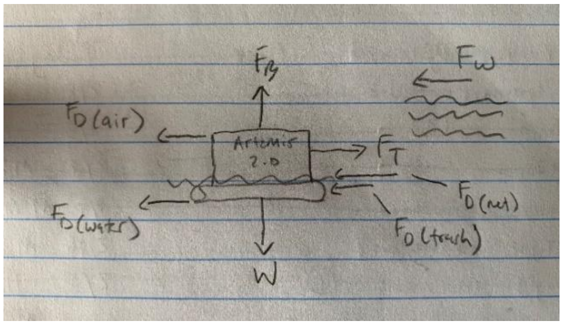


Figure 3.16. Free body diagram of the forces acting on ARTEMIS.

$$\sum F_x = 0$$

$$F_{thrust} - 2 * F_{drag\ (hull)} - F_{drag\ (artemis\ frame)} - F_{drag\ (trash)} - F_{drag\ (net)} - F_{wind} = 0 \ [1]$$

If the equation above is true, then ARTEMIS will not be able to provide enough thrust to overcome the opposing forces acting on it and therefore will not be able to move. If this were to happen then ARTEMIS would not be able to get back to the user onshore and would become floating trash.

To calculate thrust I will be using the average velocity value (w/ full load of trash) from our speed tests which were $1.27\ knots = 0.653\ \frac{m}{s}$.

Thrust Calculation:

$$F_{thrust} = \frac{[(mv)_2 - (mv)_1]}{(t_2 - t_1)} = \frac{(mv)_2}{(t_2 - t_1)} = \frac{(13.6\ kg)(0.653\ \frac{m}{s})}{(5\ s - 0\ s)} = 1.777\ N \text{ (per propeller)}$$

Since there are 2 identical propellers:

$$F_{thrust} = 2 * 1.777\ N = 3.554\ N$$

Drag force on the hull using an experimental drag coefficient on a long cylinder of 0.82:

$$F_{drag\ (hull)} = \frac{1}{2}(0.82)\left(1000\frac{kg}{m^3}\right)\left(0.653\frac{m}{s}\right)^2 (0.00456\ m^2) = 0.798\ N$$

$$2\left(F_{drag\ (hull)}\right) = 2(0.798\ N) = 1.594\ N$$

Drag force on the frame using an experimental drag coefficient on a rectangular prism of 2.05:

$$F_{drag\ (artemis\ frame)} = \frac{1}{2}(2.05)\left(1.225\frac{kg}{m^3}\right)\left(0.653\frac{m}{s}\right)^2 (0.067\ m^2) = 0.036\ N$$

The mouth of ARTEMIS is 18" wide. The diameter of a standardized piece of trash (16.9 oz water bottle) is 2.5". In an attempt to theoretically calculate the drag force due to trash in the net I will treat a row of 16.9 oz water bottles spanning the entire width of our device as a long cylinder (perpendicular flow) which has an experimental drag coefficient of 1.

$$A = (18\ in)(2.5\ \text{in}\ ) = \ 45\ in^2$$

$$A = (45\ in^2)\left(\frac{0.000645\ m^2}{1\ in^2}\right) = 0.029\ m^2$$

$$F_{drag\ (trash)} = \frac{1}{2}(1)\left(1.225\frac{kg}{m^3}\right)\left(0.653\frac{m}{s}\right)^2(0.029\ m^2) = 0.008\ N$$

Drag force from the net using an experimental drag coefficient of 0.26 and using the cross-sectional area of the mouth:

$$F_{drag\ (net)} = \frac{1}{2}(0.26)\left(1000\frac{kg}{m^3}\right)\left(0.653\frac{m}{s}\right)^2(0.00145\ m^2) = 0.080\ N$$

We can now rearrange Equation [1] to solve for the maximum amount of force from the wind ARTEMIS will be able to handle.

$$F_{thrust} - \ 2 * F_{drag\ (hull)} - \ F_{drag\ (artemis\ frame)} - \ F_{drag\ (trash)} - F_{drag\ (net)} \ = \ F_{wind}$$

$$F_{wind} = 3.554\ N - 1.594\ N - 0.036\ N - 0.008\ N - 0.080\ N = 1.836\ N$$

$$\boldsymbol{F_{wind} = \ 1.836\ N}$$

From the maximum wind force calculation, we can find the maximum wind velocity:

$$F_{wind} = \frac{1}{2}\rho A v^2$$

$$v_{max}{}^2 = \frac{F_{wind}}{\frac{1}{2}\rho A}$$

$$v_{max} = \sqrt{\frac{F_{wind}}{\frac{1}{2}\rho A}}$$

$$v_{max} = \sqrt{\frac{1.836\ N}{\frac{1}{2}\left(1.225\frac{kg}{m^3}\right)(0.067\ m^2)}} = 6.69\frac{m}{s}\left(\frac{1.944\ knots}{1\ \frac{m}{s}}\right) = 13\ knots$$

$$\boldsymbol{v_{max} = \ 13\ knots}$$

Based on the analysis above, ARTEMIS should be able to operate in wind conditions contained in the Beaufort Wind Scale rating 4 (11-16 knots) which is slightly beyond the threshold we had identified in our specifications.

Test Results

Pass	Fail

Test Commentary:

This analysis was a complete pass with no further work needed to verify specification ME4.1.

ME5.1 Visibility

Description:

ARTEMIS shall be highly visible from 100 ft away and should be highly visible from 200 ft away as observed from land during midday against a plain background.

Testing:

On Tuesday, February 23rd, Andrew and Colt conducted the visibility test on Wallace's field.

We did several timing tests. We timed how long it would take Andrew to locate the drone after being turned around with no prior information on the drone's location or orientation. After turning around, Andrew would need to call out the location and orientation of the drone as quickly as possible.

Here are the timing results:

55 Yards (165 ft Mid-Field)
1.5 seconds
1.71 seconds
1.27 seconds
110 Yards (330 ft Full-Length)
1.3 seconds
This is a picture during our timing tests showing the placement of the drone on Wallace's field.

The images we took do not do the in-person observations justice. We can see that the drone is visible at the mid-field line and the flag helped Andrew quickly determine the location and orientation of the drone

Figure 3.17. Image from the visibility test on Wallace Field

Conclusions

1. The Specifications have a should of 200 ft and a shall of 100 ft. We were able to successfully be highly visible beyond the 200 ft. We met our visibility specification for Winter Quarter! ☺
2. There was no outstanding difference in the times. Also, the times were very quick. Therefore, we felt that no further testing was needed because it was obvious the drone was easy to spot on the field at any spot. This reassures us that the drone will be quite visible to the user from the shore in full operation.
3. The pictures don't do the visibility justice- it was quite visible at the halfway person point, and even at the full-field distance the flag and white paper inside the frame helped significantly.

Test Results

Pass	Fail

ME6.1 Operational Temperature

Description:

ARTEMIS shall be able to operate in temperatures between 45°F and 100°F and should be able to operate in temperatures between 35°F and 120°F when empty and the body of water is unfrozen.

Testing:

For this specification, Colt researched all the different Commercial Off The Shelf (COTS) components that make up ARTEMIS and compiled the operational data into the following table.

Part Description	Operational Temperature	Source
(3) ¾" x 4in. X 8ft Cedar Hardwood	Anything below 669.2°F	Cedar Burning Temperature
(2) 20in x 32in x 0.093in Clear Acrylic Sheet	-40°C to 80°C (-40°F to 176°F)	Acrylic Operating Temperatures
(4) 3in. L Bracket	Up to 750°F	Steel Operating Temperature, Page 4
#8 x 1-5/8 in. Phillips Bugle-Head Construction Screw (1 lb./Pack)	Up to 750°F	Steel Operating Temperature, Page 4
Varathane Gel Wood Stain- Red Mahogany	N/A, 55-90°F for Initial Staining	Stain Temp
Varathane Spar Urethane, Oil-Based (Not Used Yet but purchased for future application)	N/A, 55-90°F for Initial Staining	Stain Temp
PolyCases	0°F to 176°F	Polycase.com
Batteries	-20°C to 75°C (-4°F to 167°F)	SAMSUNG
Electronic Speed Controller	Up to 212ºF	RCElectricParts
Transceivers	-40ºC - 85ºC (-40ºF - 185ºF)	Nordic Semi
Arduino Uno	-25ºC - 70ºC (-13ºF - 158ºF)	Arduino Help Center
Camera & Transmitter	-10ºC – 50ºC (14ºF - 122ºF)	FOXEER

Test Results

Pass	Fail

EE2.1 Battery Updates

Specification:

The user shall receive an update on the battery voltage every 5 minutes and should receive an update on the battery voltage every 1 minute. The user should have regular updates on the battery voltage so that they can ensure they return the aquadrone to shore before the battery dies. This will be verified by timing how often the user receives an update during the battery life test.

Test Results:

Battery updates were first verified by measuring the actual voltage of the batteries and the transmitted voltage. The transmitted voltage should be the lower voltage of the two batteries and is lower than the actual voltage due to several voltage drops on the PCB. However, this is beneficial because it warns the user of a low battery before the battery reaches a critical level. The display from the Raspberry Pi shows that a battery update is received every minute, and displays a voltage accurate to the measured battery voltage within 0.6V.

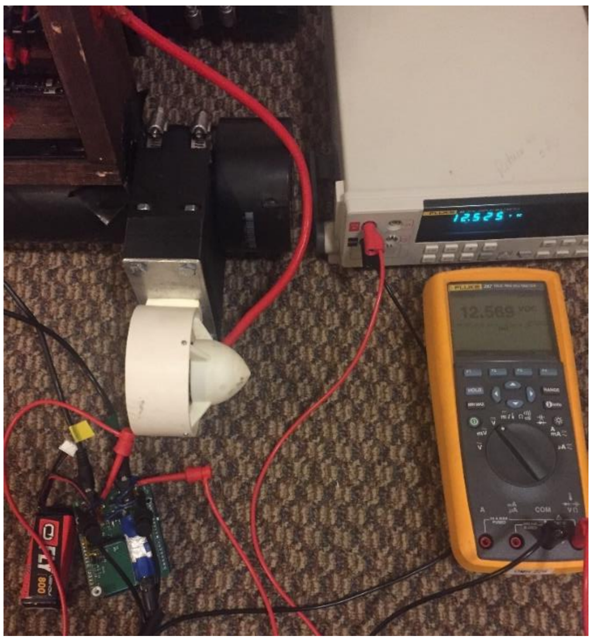


Figure 3.18. Battery life updates test set up

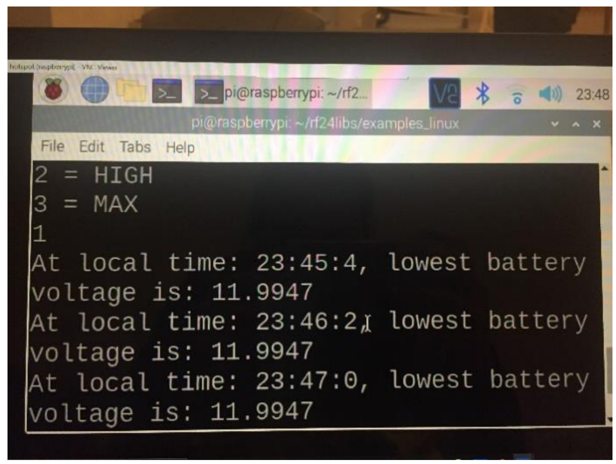


Figure 3.19. Battery life updates

Next, the battery updates were tested with the propellers running at the same time. This was successful, so finally the battery updates were used during the battery life test to monitor the battery voltages during the test.

Test Results

Pass	Fail

Test Commentary:

The test was a complete pass with no further work needed to verify specification EE2.1.

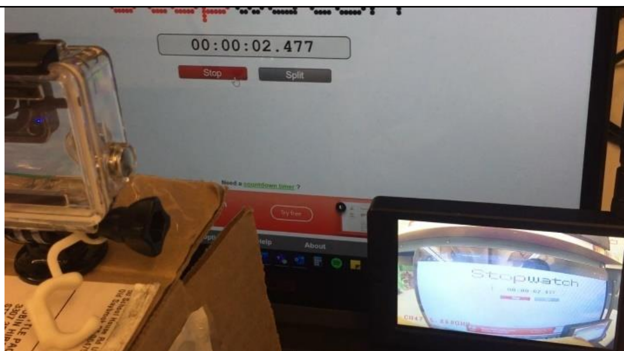
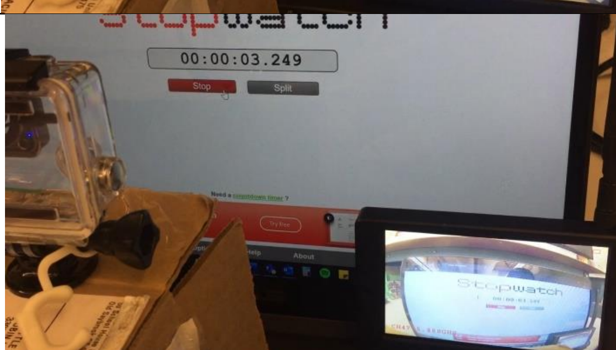
EE4.1 Latency

Specification:

The end-to-end latency of the camera to live video feed shall be less than 500ms and should be less than 150ms. At the maximum speed of 2 knots, the aquadrone could travel approximately 0.5m in 500ms and can travel 0.15m in 150ms. Similar to the range, more expensive equipment can reduce the latency so the goal of 500ms is to prove the concept, while less than 150ms minimizes how much the aquadrone can change position in real-time before the user sees. This will be verified by streaming live video of a computer clock with milliseconds and comparing the actual time with the displayed time. The range will impact latency but the difference will be nominal so this test should be sufficient.

Test Results:

There was no difference between the displayed time and actual time throughout the 5 trials as indicated below. This displayed time is difficult to see in the images but a zoomed-in clip is provided to attempt to display the matching time. There may be a slight increase in latency with a larger range, but as mentioned before it will be nominal, and should not go above the 500ms threshold required to pass this specification.

<table>
<tr>
<td>
</td>
<td>
</td>
<td>Screen Reads: 2.477 Seconds
Camera Reads: 2.477 Seconds</td>
</tr>
<tr>
<td>
</td>
<td>
</td>
<td>Screen Reads: 3.249 Seconds
Camera Reads: 3.249 Seconds</td>
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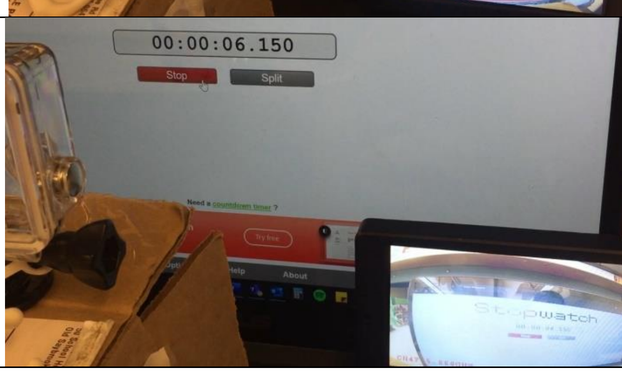
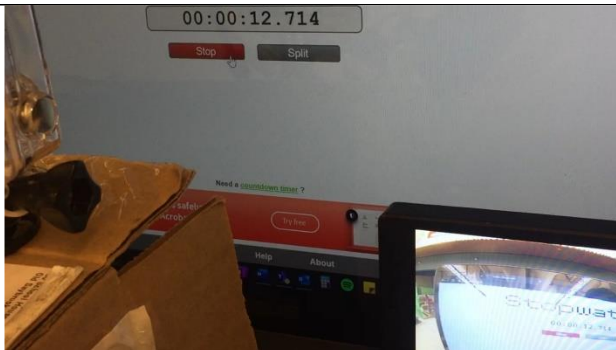
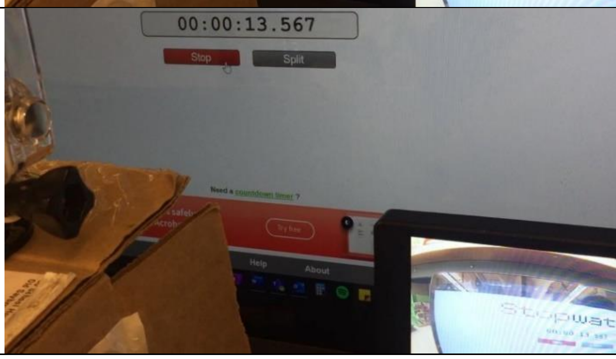
<tr>
<td>
</td>
<td>
</td>
<td>Screen Reads: 6.150 Seconds
Camera Reads: 6.150 Seconds</td>
</tr>
</table>

	 Screen Reads: 12.714 Seconds Camera Reads: 12.714 Seconds
	 Screen Reads: 13.567 Seconds Camera Reads: 13.567 Seconds

Test Results

Pass	Fail

Test Commentary:

The test was a complete pass with no further work needed to verify specification EE4.1.

EE5.1 Camera Resolution

Specification:

The camera shall allow a user to distinguish between a water bottle and a piece of driftwood of the same length in open water from a distance of 5m, and should allow a user to distinguish between a water bottle and a piece of driftwood of the same length in open water from a distance of 30m. A user will need to distinguish trash from natural features in the environment to make decisions about what to collect. 5 meters will allow the user to identify trash immediately surrounding the aquadrone before collection, while 30m will allow the user to seek out and maneuver the aquadrone to new collections of trash. This will be verified by placing a water bottle and a piece of driftwood in the water at a measured distance of 5m from the aquadrone (within the scope of the camera). A volunteer, who has not seen the placement of the items, will be asked to look at the screen and identify the two items. This can be tested in increments of 5m, using 4 trials per increment, up until the volunteer is unable to distinguish between the two types of trash 75% of the time.

Test Results:

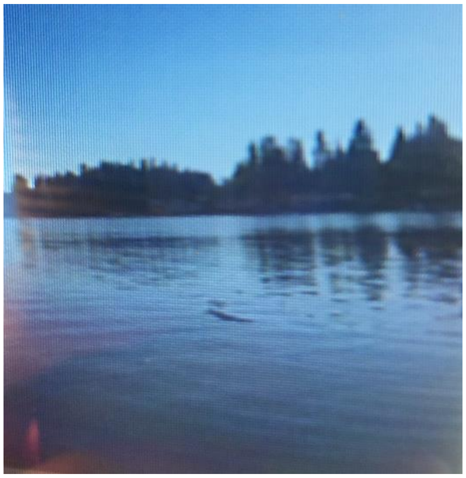


Figure 3.20. Driftwood and water bottle 5 meters away.

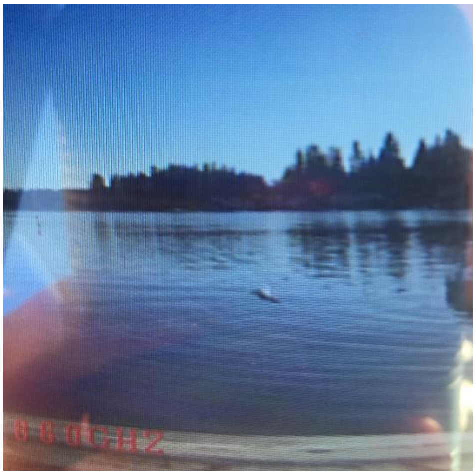


Figure 3.21. Driftwood and water bottle 10 meters away.

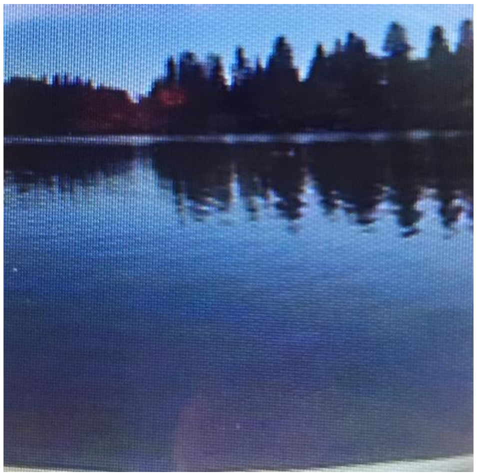


Figure 3.22. Driftwood and water bottle 30 meters away.

The photos are lower quality because it is a picture of the screen. Using a volunteer not associated with the project, the water bottle was distinguished from the driftwood 100% of the time from a distance of 5m away, 75% from a distance of 10m away, and under 75% over a distance of 10m (15m to 30m). Thus, the specification met the threshold of distinguishable from a distance of 5m.

Test Results

Pass	Fail

Test Commentary:

The test was a complete pass with no further work needed to verify specification EE5.1.

EE6.1 User Interface

Specification:

The user shall be able to interface with the aquadrone using a total of 3 devices and should be able to interface with the aquadrone using a total of 1 device. The user will have three main data streams: control signals to the aquadrone, live video from the aquadrone, and location & battery updates from the drone. A single device for all three data streams will be the most user-friendly. This will be verified by counting the number of devices required to interface with the aquadrone.

Test Results:

Figure 3.23. UI Device #1: Controller (joystick and transceiver)

Figure 3.24. UI Device #2: Video receiver and display

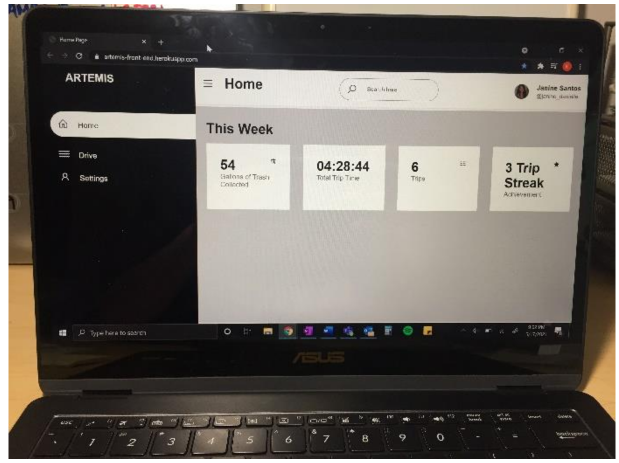


Figure 3.25. UI Device #3: Computer or phone for accessing website

Test Results

Pass	Fail

Test Commentary:

The test was a complete pass with no further work needed to verify specification EE6.1.

G1.1 Component Cost

Description:

The components required to build ARTEMIS shall cost no more than $3,000 and should cost no more than $850.

Test Results:

For the duration of the project, our team kept a tabulated collection of all the component costs of the project. This aided in assisting Robin Hirano with tracking our purchases and team budget, but it also serves as a way to verify that we have met this specification.

For this spec, we are using <u>only materials needed to produce our final project</u>. Further details on the team's whole project costs will be provided at the end of this document.

Electrical Parts	Cost
(1x) Foxeer Razer Mini Camera	$24.99
(1x) RunCam 5.8GHz Video Transmitter	$22.01
(2x) 40A Brushless Electronic Speed Controller	$47.32
(12x) Samsung 25R INR 18650 2500mAh 3.7V Lithium-Ion Battery Cell	$48.00
(1x) Vruzend Battery Kit V2.1 & (2x) DC 5.5x2.1mm Female Charging Connector	$61.78
(2x) Battery Monitoring PCB & (2x) Connector from Battery to ESC	$20.90
(1x) Shrink Wrap for battery	$12.00
(1x) Camera 5.8GHz Receiver & Display	$48.00
(1x) Waterproof GoPro Case for Camera	$50.00
Misc. Parts for Wiring Harness (wires, glue, etc.)	$5.00
(1x) PCB & Components	$99.21
(2x) Transceiver	$11.00
(2x) Underwater Thruster	$63.85
(1x) Adafruit GPS Module & Cable Adapter	$52.53
(1x) GPS Antenna	$12.39
(2x) DC Power Jack 5.5x2.1mm Male to Male Extension Cable (1.64’ & 6’)	$8.50
(1x) J-B Weld 31314 High Temperature RTV Silicone Gasket Maker and Sealant	$6.90
(1x) Arduino Uno	$25.00
(1x) 4 Channel Radio Controller and Receiver	$31.99
(1x) 3S 11.1V Li-Po Battery (for transceiver)	$21.71
(1x) Raspberry Pi 0 with headers and SD card	$15.00
(1x) 10Ah 5V Power Bank (for Raspberry Pi)	$18.49
Misc. Components – 3.3V regulator, capacitors, connectors	$10.00
(1x) 3S Lithium-Ion Battery Charger	$14.30
Cable Glands and Stand-Offs for PolyCase	$4.37

Mechanical Parts	Cost
Bulk ME build parts	$95.52
(RETURNED 2' PIPES)	$17.40
Repurchasing 10' abs pipe	$16.89
Linear rails	$36.32
Paracord	$5.48
D ring hangers/ carabiners	$10.07
Mesh Dunk/chum bag	$12.00
Folding shelf brackets	$30.80
Handy panel- 3/4 2/4 Sande Plywood	$25.65
Clear Acrylic Sheet .093"x20"x32" x 2	$120.07
1" Hex Neo Washer Screw 1lb	
Black 3" Corner Brace x 2	
Flex Seal 14oz	
3/4 x 4 x 8ft Cedar Board x2	
1" Hex Neo Washer Screw 1lb	$57.79

Black 3" Corner Brace x 2	
Varathane Red Mahogony Stain	
Exterior Clear Waterbase	
3 Foam Brushes 2"	
3 Foam Brushes 3"	
(RETURNED EXTERIOR CLEAR WATERBASED)	$20.18
Varathane Oil-Based Spar Urethane	$36.00
1-5/8" Construction Screws 1lb	
3/4 x 4 x 8ft Cedar Board	
Polycase	$92.00
cast fishing net (Amazon)	$26.41
Hex Bolts and Nuts	$1.66
2 Straps	$6.00
2 Screw Eye	$13.17
2 pack S Biners	
Chain	
Magnolia Hardware-Bolts, Nuts, and Flex Tape	$23.80
Flex Tape	$14.14
Handles	
Pipe and Caps	
Keith Lunch in exchange for 3D Printing Service	$14.30
Nuts and Bolts	$7.85
Kiddie Pool	$22.04
Drop Seat Table Support	
Trycooling 2 pack Heavy Duty Zinc Alloy Table Locks	$18.72
LED Lights x2	$25.48
$1,457.55	

Test Results

Pass	Fail

G2.1 Aquadrone Weight

Description:

ARTEMIS shall not weigh more than 50 pounds and should not weigh more than 30 pounds when empty.

Test:

For this test, we measured Colt without Artemis to get a base reading of Colt's weight. Then, we had Colt stand on the same scale with ARTEMIS and took the difference to find the weight of ARTEMIS.

Figure 3.26. Colt w/o ARTEMIS
177.4 lbs

Figure 3.27. Colt with ARTEMIS
207.4 lbs

Test Results

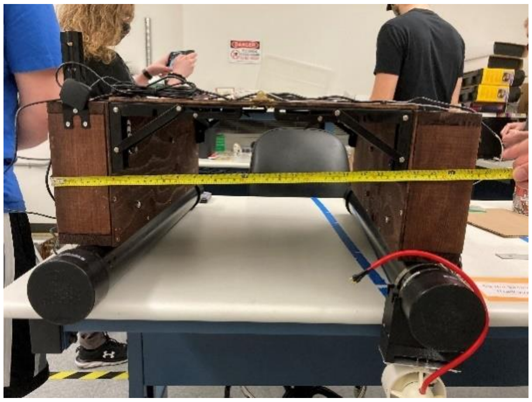
Pass	Fail

G3.1 Aquadrone Transportation/Cargo Dimensions

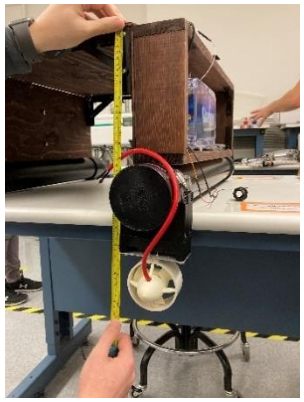
Description:

ARTEMIS shall have a maximum volume of 10 cubic feet when compacted to minimum size and should have a maximum volume of 4 cubic feet when compacted to minimum size.

Test Results:



Width
25.5in



Height
20in

Length
32.5in

Folded Width
10.5in

$$Volume = W\ x\ H\ x\ L$$

Unfolded Volume

$$Volume = (25.5in)(20in)(32.5in) = 16{,}575\ in^3 = 9.59\ ft^3$$

Folded Volume

$$Volume = (10.5in)(20in)(32.5in) = 6{,}825\ in^3 = 3.95\ ft^3$$

Test Results

Pass	Fail

G4.2 Maneuverability- Turning Radius

Description:

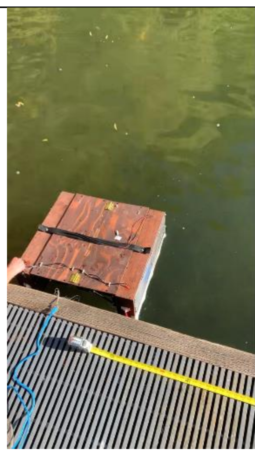
ARTEMIS shall be able to turn clockwise or counterclockwise 180° in the water with a turning radius of 3 feet and should be able to turn clockwise or counterclockwise 180° in the water with a turning radius of 0 feet when empty.

Test Results:

The results of this test proved ARTEMIS can turn clockwise or counterclockwise 180° in the water with a turning radius of 2.875 feet. The pictures are deceiving because the starting point is on the inside panel while the ending point is showing the outside panel at 5 ft. To get the turning radius, we simply subtracted the width of 25.5" from the 5' shown in the picture giving us a 2.875-foot turning radius.

Please view the video evidence on the link below:

[Turning Radius Video]

	
Starting Point	Ending Point- 2.875 ft Radius

Test Results

Pass	Fail

Specifications Status Table

Mechanical Specifications

Spec ID	Requirement	Status	DR 3.1 Justification
ME1.1	*Waterproof Rating:* The electronic enclosures of the drone shall have an IP rating of IP54 and it should have an IP rating of IP67	PASS	• Marine Waterproof Case (Polycase) rated for IP67 • Cable glands rated for IP68 • RTV silicone for sealing around wires • Passed waterproof test
ME2.1	*Aquadrone Stability:* ARTEMIS shall not flip when tipped under 20° from horizontal and should not flip when tipped under 50° from horizontal when empty.	PASS	Andrew and Colt tested the stability of ARTEMIS by tipping it at 4 different angles to see if it would flip.
ME3.1	*Aquadrone Speed:* The aquadrone shall have a maximum speed of at least 1 knot and should have a maximum speed of at least 2 knots when full and in still water	PASS	Jordan and Kellie conducted the speed test by measuring 10’ on a dock and then driving ARTEMIS back and forth timing how long it took to go 10’ for a minimum of 11 trials.
ME4.1	Wind Conditions: ARTEMIS shall be able to operate in BWF (Beaufort Wind Force) 0 wind conditions and should be able to operate in BWF 3 wind conditions when full.	PASS	A full free body diagram analysis has been done accounting for all forces acting on ARTEMIS.

Spec ID	Requirement	Status	DR 3.1 Justification
ME5.1	Visibility: ARTEMIS shall be highly visible from 100 ft away and should be highly visible from 200 ft away as observed from land during midday against a plain background.	PASS	Andrew and Colt tested the visibility of the aquadrone on Wallace Field, placing it at increasing distances and timing reaction times. We found that there will be no issue seeing the boat in the water, especially with our visibility flag.
ME6.1	Operating Temperature: ARTEMIS shall be able to operate in temperatures between 45°F and 100°F and should be able to operate in temperatures between 35°F and 120°F when empty and the body of water is unfrozen.	PASS	Colt completed an in-depth analysis of the major components that make up ARTEMIS, both mechanical and electrical. All components have passed the operating temperature spec ranges.

Electrical Specifications

Spec ID	Requirement	Status	DR 3.1 Justification
EE1.1	*Battery Life*: ARTEMIS shall operate for 30 minutes and should operate for 2 hours in still water with 1/3 of the time at minimum speed while empty, 1/3 of the time at medium speed while half full, and 1/3 of the time at maximum speed while full.	PARTIAL PASS	Tested for the worst-case scenario (infinite load) in the thrust experiment. Battery life calculated to be 27min, with calculations identifying 9 more sets in parallel required for 2-hour battery life.
EE1.2	*Battery Updates:* The user shall receive an update on the battery voltage every 5 minutes and should receive an update on the battery voltage every 1 minute.	PASS	Battery updates are received and displayed by Pi every 3 seconds.
EE2.1	*Control Range:* ARTEMIS shall have a control range of 100m and should have a control range of 1km.	PASS	OTS controller range tested in PolyCases in the boat – reliable up to around 800m.
EE3.1	*GPS Accuracy:* ARTEMIS shall be found within 10m of the given GPS location while stationary and should be found within 5m of the given GPS location while stationary.	VARIANCE	GPS will be implemented next quarter which should be feasible using open-source drivers. Uses well-documented GPS breakout board.
EE3.2	*GPS Updates:* The user shall receive an update on the GPS location every 9 seconds, and should receive an update on the GPS location every 1 second.	VARIANCE	GPS components were purchased and will be integrated next quarter. The transceiver program can send GPS updates, but the code needs to be written.

pec ID	Requirement	Status	DR 3.1 Justification
EE4.1	*Latency:* The end-to-end latency of the camera to live video feed shall be less than 500ms and should be less than 150ms.	PASS	Completed during fall quarter. The video streaming system is the same, but with a new, portable monitor.
EE5.1	*Camera Resolution:* The camera shall allow a user to distinguish between a water bottle and a piece of driftwood of the same length in open water from a distance of 5m, and should allow a user to distinguish between a water bottle and a piece of driftwood of the same length in open water from a distance of 30m.	PASS	Camera and display tested to distinguish between driftwood and a water bottle. 100% success at a distance of 5m, 75% success at a distance of 10m, below 75% success threshold after 10m.
EE6.1	*User Interface:* The user shall be able to interface with the aquadrone using a total of 3 devices, and should be able to interface with the aquadrone using a total of 1 device.	PASS	1) Video monitor 2) Computer or phone for website 3) Control module (console and transceiver)

General Specifications

Spec ID	Requirement	Status	DR 3.1 Justification
G1.1	*Component Cost:* The components required to build ARTEMIS shall cost no more than $3,000 and should cost no more than $850.	PASS	The total for the project costs is about $1500, with the true cost of ARTEMIS being equal to or less than this amount due to changing materials as needed.
G2.1	*Aquadrone Weight:* ARTEMIS shall not weigh more than 50 pounds and should not weigh more than 30 pounds when empty.	PASS	ARTEMIS weighs slightly more than 30 pounds.
G3.1	*Aquadrone Transportation/Cargo Dimensions:* ARTEMIS shall have a maximum volume of 10 cubic feet when compacted to minimum size and should have a maximum volume of 4 cubic feet when compacted to minimum size.	PASS	ARTEMIS can fold up to less than 4 cubic feet.
G4.1	*Maneuverability – linear movement: ARTEMIS shall be able to propel forward in the water with a full load of trash, and should be able to propel both forward and backward in the water with a full load of trash.*	PASS	ARTEMIS has been verified during our tests to move in a linear path with trash on board.
G4.2	*Maneuverability – turning radius clockwise & counterclockwise: ARTEMIS shall be able to turn clockwise or counterclockwise 180° in the water with a turning radius of 3 feet and should be able to turn clockwise or counterclockwise 180° in the water with a turning radius of 0 feet when empty.*	PASS	ARTEMIS can make a nearly 3ft turn in the water.
G5.1	*Trash Intake: ARTEMIS shall be able to collect at least 3 gallons of the standard item of trash and should be able to collect at least 15 gallons of the standard item trash.*	PASS	ARTEMIS could successfully hold 15 gallons of trash.

Interface Specs

Technical Information	
Voltage	12.6V per battery pack
Maximum Current	23A per battery pack
Battery Capacity	5Ah per battery pack
Average Operating Time	23 minutes
Radio Frequency	2.4GHz, 5.8GHz
Latency	0ms
Control Range	400m
Size	$4ft^3$ folded, $10ft^3$ unfolded
Device Weight	30 pounds
Maximum Tipping Angle	80°
Device Average Maximum Speed	1.2 knots
Wind Conditions	15 mph
Visibility Distance	330ft
Maximum Trash Intake Volume	3 gallons
Operating Temperature	35°F-120°F
Turning Radius	3ft

Standards Compliance		Source
FCC	*This device complies with part 15 and part 18 of the FCC Rules.*	DA-18-581A1.pdf (fcc.gov) https://www.ecfr.govl
EU	*2014/53/EU Radio Equipment Directive (RED)*	https://ec.europa.eu/growth/sectors/electrical-engineering/red-directive_en
IEC	*IEC 61140:2016*	https://standards.iteh.ai/catalog/standards/iec/4a8d46c1-eafd-48ff-8727-18c1faef3aec/iec-61140-2016
GDPR	*GPDR compliant.* Data format: Remote access of the Raspberry Pi is protected end-to-end using RSA 2048-bit keys and AES 128-bit or 256-bit encryption through VNC Viewer.	https://static.realvnc.com/media/documents/vncconnect-gdpr.pdf

Standards Compliance		Source
UN	*Law of the Sea*	UNCLOS+ANNEXES+RES.+AGREEMENT
UL	*Drone Standard UL 3030* *UL 1426 Compliant*	Drone Standard UL 3030 Takes Flight | UL UL Standard | UL 1426
CE	*CE Mark Compliant*	CE MARK FOR DRONES | Drones - RPAS | Alter Technology Group (wpo-altertechnology.com)
CARB	*N/A*	N/A
OSHA	*OSHA Regional UAS Program Compliant*	OSHA's use of Unmanned Aircraft Systems in Inspections - 11/10/2016 | Occupational Safety and Health Administration
IP	*IEC IP68 Compliant*	IP ratings | IEC
FAA	*UAV Hobbyist Laws Compliant*	Drone Laws in the U.S.A. | UAV Coach (2021) Drone Laws in Washington (2021) - UAV Coach
Department of Defense: US Coast Guard	*Vessel Navigation Rules*	US Coast Guard Navigation Rules: International - Inland Note: Although these rules do not directly apply to drones, it is the current assumed robotic unmanned marine vehicle users should abide by them.
Legal Status of Unmanned Maritime Vehicles	*Generally Compliant with the Legal Status of Unmanned Maritime Vehicles*	The Legal Status and Operation of Unmanned Maritime Vehicles: Ocean Development & International Law: Vol 50, No 1 (tandfonline.com)
BoatUS Foundation	*Navigation Light Compliant*	Navigation Lights: BoatUS Foundation
For more information, check with your local, state, and federal laws and regulations to see what rules apply.		
For more information, refer to the Law of the Sea by the United Nations Convention (UNCLOS) ***If applicable, as some countries are not official parties of the UNCLOS*** 		

Note: The RF 2.4GHz and 5.8GHz link for data and video is a proprietary protocol and does not comply with a standard (Bluetooth or WLAN). Thus, Bluetooth or IEEE 802.11 compliance is not listed. Instead, FCC parts 15 and 18 regulates all use of intentional radiators on the ISM band. An example of the data format for the 2.4GHz data link is to read the Rx-payload, send the command byte x61 followed by a variable to store the payload.

Risk Analysis

Risk Brainstorming

Risk Category	Failure Mode
Financial	The price of raw materials increases dramatically
Financial	COTS manufacturers increase prices
Resource	Specific vehicle required to transport parts
Resource	Accessibility to OMH for building
Resource	Stealing ARTEMIS
Resource	Accessibility to local water for testing/operation of ARTEMIS
Programmatic	Interdependent parts
Programmatic	Shipping delays (especially during a pandemic)
Technical	Trash floats out of ARTEMIS/net
Technical	Electronics electrify surrounding water
Technical	Visibility of ARTEMIS fails and it is hit by a passing boat/jet ski
Technical	Capsizes
Technical	Pontoons flood with water
Technical	Wiring gets loose
Technical	One battery dies before the other and only one propeller works
Technical	A child gets caught in the net and drowns
Technical	Net gets jammed in propellers
Technical	Controls get taken over by someone else
Technical	RF interference causes erratic behavior
Technical	Lithium-ion batteries overheat and explode
Technical	Whale lands on ARTEMIS
Technical	Waterproofing fails and electronics box takes on water

Major Risks

Risk Category	Failure Mode	Severity	Likelihood	RAC
Financial	The price of raw materials increases dramatically	2	3	6
Resource	Accessibility to local water for testing/operation of ARTEMIS	3	2	6
Programmatic	Shipping delays (especially during a pandemic)	2	4	8
Technical	Controls get taken over by someone else	4	2	8
Technical	Pontoons flood with water	3	5	15
Technical	Net gets jammed in propellers	3	3	9

Severity Key		
Rating	**General Description**	**ARTEMIS Specific**
1	Non-Severe	Slight cosmetic differences or flaws that do not impact operation. No increased cost.
2	Slightly Severe	Issues in operation that an untrained individual can repair in 30 minutes. Minor increased cost.
3	Moderately Severe	Cannot operate without being sent back for significant repairs by trained personnel. Moderate increased cost.
4	Highly Severe	Cannot operate and will harm people or property without being sent back for significant repairs by trained personnel. Significantly increased cost.
5	Catastrophic	The device will cause death to a person or damage property and the environment without being replaced by a new device. Significantly increased cost.

Frequency Key	
Rating	**General Description**
1	Extremely Unlikely (virtually impossible or no known occurrences on similar products or processes, with many running hours)
2	Remote (relatively few failures)
3	Occasionally (occasional failures)
4	Reasonably Possible (repeated failures)
5	Frequent (failure is almost inevitable)

RAC threshold:	5

Risk Mitigation Details

Controls Get Taken Over by Someone Else

Risk: Someone other than the intended user interferes with the RF controls and gains the ability to operate ARTEMIS.

Frequency: 2 (requires someone with malicious intent with the right technology at the right time/place as someone is operating ARTEMIS – rare but possible)

Severity: 4 (people or property could be harmed, a recall would create significantly increased cost)

Implications: The original operator loses control entirely and the unintended user can use ARTEMIS however they like. If the unintended operator has malicious intent, they could use the aquadrone to hit other people or property, or potentially entangle a child in the net.

Mitigation:

> *Redesign:* Program ARTEMIS to include an identification code when the controller pairs with the receiver at the beginning of the operation. If the identification code changes (aka someone else has taken control), the propellers will shut down and ARTEMIS will be dead on the water until the original controller pairs again.

The logic for current strategy: ARTEMIS is currently designed to not exceed 2 knots. This speed limits how much damage could be accomplished by hitting people or property with the aquadrone. The RF controls also use a proprietary communication standard (designed by the COTS company rather than a standard like BLE), which makes it more difficult to “hack” and gain control. Furthermore, redesign is costly at this time and the frequency is estimated as low.

Net Gets Jammed by Propellers

Risk: The propellors get jammed by the net being able to freely float into them.

Frequency: 3 (during testing the net would get caught in the propellors occasionally)

Severity: 3 (cannot operate without being sent back for the battery to be reset and the propellers untangled. This causes a moderate increased cost)

Implications: The propellors can get broken, the net can get torn. When the net gets jammed in the propellers it kills the battery.

Mitigation:

> *Redesign:* Create a mesh covering that would go around the propellors to prevent the net from being able to get caught while still not impeding the flow of water for operational use.

The logic for current strategy: During our first round of testing, this occurred, but it was a fairly easy fix for a trained person (Kellie). Thankfully, nothing got damaged or need replacement. We learned from this and on all future tests had a designated person ensure the net would not get caught during testing. This problem was something we did not anticipate in our design process and going forward it would be a relatively easy fix. At this point, we do not plan on fixing this issue because we have already exceeded our budget and are at the end of the quarter. The redesign would be completed if ARTEMIS were to be sold commercially.

Pontoons Flood with Water

Risk: The pontoons take on water, causing ARTEMIS to sink.

Frequency: 5 (currently the pontoons were slowly taking in water, increasingly with each trial)

Severity: 3 (The leak was so slow that we were able to see and address it before anything catastrophic happened, but it would require trained personnel to repair)

Implications: As ARTEMIS takes on the water it increases the weight causing it to sit lower in the water and increasing the drag on the water. This reduces the speed and effectiveness of ARTEMIS. If the pontoons take on too much water the entire device can sink and become unretrievable to the user.

Mitigation:

> *Redesign:* We could redesign the pontoons so that no holes would be drilled into them which is what caused the leakage. Another strategy would be to design in an IP68 rated part to ensure no water can penetrate holes in the pontoons.

The logic for current strategy: During the first round of testing this did occur requiring us to replace the pontoons. At the time we used RTB to seal the areas where the pontoons meet the wood frame and the bolts. However, this failed to properly seal at least one of the pontoons. At this point, we do not plan on fixing this issue as we have already completed the testing and exceeded our budget. The redesign would be completed if ARTEMIS were to be sold commercially.

Post-Mitigation Table

Risk Category	Failure Mode		Post-Mitigation Severity	Post-Mitigation Likelihood	Post-Mitigation RAC
Technical	Controls get taken over by someone else	Program in an identification code at initial control connection.	4	1	4
Technical	Pontoons flood with water	Redesign the pontoon attachment to not need any holes.	3	1	3
Technical	Net gets jammed in propellers	Create a mesh covering to prevent the net from being able to get caught in propellers	3	1	3

As we can see from the post-mitigation table, all of our mitigation strategies are aimed at decreasing the likelihood of the risks we identified through a re-design of ARTEMIS. All of the post-mitigation scores are now below the threshold of 5 that we identified, meaning that the mitigation strategies would be considered a success.

Project Impact

To fully understand the impact that full-scale production of ARTEMIS would have you have to understand the urgency of the issue. Studies have shown that about 8 million metric tons of trash enter the ocean each year.[1] This trash has a multifaceted impact on all life on Earth. No matter the size of the marine life marine debris, especially plastic, is harmful. Furthermore, this trash harms and sometimes kills marine life in a multitude of different ways. To summarize, large pieces of trash can entangle and trap marine mammals, turtles, and large fish. Depending on the size and placement of the trash this could ultimately kill the animal. Nevertheless, smaller pieces of trash are just as deadly if not even more deadly. Small pieces of trash are ingested by animals and get trapped inside their stomachs. This can lead to starvation or the concentration of harmful chemicals inside the animal.[2] Additionally, trash in the ocean blocks out light reducing the number of plankton, a fundamental piece of the marine food chain. Moreover, this ultimately affects humans. We use the ocean for everything from the beauty industry to the health care industry. The development of some of the COVID-19 vaccines relied on the ocean for key ingredients.

The initial impact of ARTEMIS is the reduction of the trash in the ocean. FIRMIV understands that due to the scope of the issue and Senior Design, we would not be able to design a product to successfully remove the trash from the entire ocean. However, ARTEMIS would reduce the amount of trash entering the ocean each year allowing for other organizations to better address the issue of the trash in the open ocean. With 8 million metric tons of trash entering the ocean each year, the reduction of this number is vital to the reduction of the amount of trash in the ocean. Furthermore, ARTEMIS would enable people to clean their local waterways around the globe, slowly improving the habitats of marine animals. Now collecting trash is not intended to be a solution to the trash in the ocean, instead, it is a mitigation of the issue. The true impact of ARTEMIS is not the amount of trash collected, but in engaging the general public. By making ARTEMIS affordable and customer-based, we engage a larger population to clean the ocean. ARTEMIS is designed to engage people to educate themselves on the harm of trash in the ocean and the wastefulness of humans. Collecting trash is a patch but reducing the amount of trash produced through changing the culture is the solution.

Even though the positive environmental impact of ARTEMIS is a primary function of the drone, its negative impact is on the environment. When in use ARTEMIS is a foreign object in the environment and as such is disruptive of nature. Although a single drone does not largely disturb the environment, full-scale production of the drone could. A large number of drones in a single area would disturb the environment creating unnatural noises and lights for the surrounding wildlife. Furthermore, the impact created by ARTEMIS is even greater if the product fails. Despite the testing and analyzes that were completed, full-scale production and sale of ARTEMIS would potentially result in the loss of some of the products. Thus, we would unintentionally be adding to the marine debris, the very objects we are intending to reduce.

The removal of the trash in the Ocean may seem to mainly have an environmental impact, however, we live in an interconnected and complex world. On the face removing the trash will have an important beneficial environmental impact, but this impact will not stop there. Below the surface, the full-scale production of ARTEMIS would have a long-lasting global impact economically and socially. First economically, people rely on the Ocean for both the livelihood and their substance. The trash in the ocean is hurting the fish and other marine life populations. As these populations lower, it becomes more and more difficult for the small-scale fishers to catch fish and make money or even enough fish to eat. Thus, this will lead to people running into debt or even starving to death. Although this may only directly affect the economies of areas around groups of substance and small-scale fisher, it will affect the global community. Globally fish will become rarer leading to higher prices until only the rich will be able to afford fish. The consequence of trash in the ocean disproportionally affects low-income areas. Therefore the benefit of ARTEMIS cleaning the environment will significantly impact this group.

The social impact of ARTEMIS is the conclusion of the other impacts and the underlining impact that connects to all aspects of the multifaceted impact of ARTEMIS. The effects of trash in the ocean disproportional affect the minorities and people of color. The purpose of designing a consumer-based device is to engage a wide range of people. Through the fun activity of collecting trash using ARTEMIS, we hope to spark people’s interest to learn more about the harm caused by trash in the ocean. Therefore, as people learn more they begin to wrestle with the disparities we uphold in the global society. Environmental justice and environmental work cannot be fully done without engaging in racial reconciliation. The most beneficial engagement in the fight to protect the environment requires the recognition that the rich exploit the environment and pass the most negative consequences to the suppressed. Racial reconciliation and environmental justice is interwoven together and inseparable.

The social, economic, and environmental impact of ARTEMIS is entwined together. The initial impact of ARTEMIS is environmental, however, this ultimately impacts global economics. Additionally, by learning about the environment people will begin to engage in racial reconciliation. ARTEMIS is designed both as a fun drone and a way to spark people’s passion for social, economic, and environmental issues. ARTEMIS is not the ultimate solution but instead an introduction. This will have lasting impacts on local communities and the entire globe.

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Appendix

Honors Panel Speech

And with that, “A Consumer-based Aquatic Trash Collecting Drone: A Engineering Design Case Study”. To start, the Engineering Capstone courses offer a different experience than some of the other senior capstone courses. Instead of focusing on research, the engineering capstone engages interdisciplinary teams to design and build a product selected by each team. I am a part of FIRMIV which consistence of three mechanical engineers, one electrical engineer, and two computer science students. The product we designed is ARTEMIS which stands for the aquatic removal of trash for ending messes in seas.

A study from 2015 in the magazine Science, estimated that between 4.8 and 12.7 million metric tons of trash enter the ocean in 2010. This trash has a multifaceted impact on all life on Earth. The large trash can entangle and trap marine mammals, turtles, and fish. Whereas smaller pieces get both eaten by animals and also block out sunlight in the ocean. Ultimately this affects us, humans who use the ocean for anything from the beauty industry to the health care industry. I will talk more about the importance of this work later.

To move to our solution. All similar trash-collecting drones that are available are expensive and intended for governments and nonprofit organizations. Instead, we wanted to design a customer-based affordable, and accessible product. In making ARTEMIS we sought to engage the larger public in taking the initiative to clean up their local waterways. Therefore, this required us to create a fun and interactive low-cost experience for the customer.

The device has two sections. First, the web interface allowing potential users to connect and receive updates regarding their device such as battery life. In the future, this may also include GPS location updates as the necessary hardware is already built into ARTEMIS. However, due to the scope of the project and limited time as a senior capstone we were unable to create the required software to receive the GPS data from ARTEMIS and transmit it to a website. The other part of ARTEMIS is the physical device, pictured on the right. The essential functions of ARTEMIS are flotation, collecting trash, maneuverability, and communication.

In regards to flotation, the basic structure of ARTEMIS mirrors a catamaran boat consisting of dual parallel hulls. These hulls attach to two pontoons made from sealed 32 inches long three-inch ABS piping. Based on Archimedes Principle, the mass of a floating object is equal to the mass of the fluid displaced, the pontoons provide a combined buoyance force of approximately 88 pound-force when fully submerged. This force can float approximately 40 kilograms of weight. This is significantly larger than the ARTEMIS which currently weighs approximately 14 kilograms. This additional buoyance force prevents catastrophic failures by ensuring ARTEMIS can function with a single pontoon.

Furthermore, between the two hulls is a passive intake trash-collecting net created using a cast fishing net and 18 inch long quarter-inch diameter aluminum bars. This net can hold at least 15 gallons of trash. However, the full trash capacity has not been determined, because we did not have enough plastic bottles. Due to the various sizes and shapes of trash items we selected empty plastic 16 oz water bottles as the standard trash item.

Additionally, another vital function of ARTEMIS is motion. To achieve this we selected differential thrust propellers. ARTEMIS has a minimum speed of at least 1 knot when fully loaded and a turning radius maximum of 5 feet. We selected differential thrust propellors instead of a propellor and rudder because this will enable us to have a smaller turning radius and greater control of the device. This is an important specification for ARTEMIS since a large amount of trash along the coast is trapped in harbors. ARTEMIS needs to be able to maneuver safely within the confined space of the harbor without damaging itself or the boats around it.

The last essential function is two-way communication between the control and ARTEMIS. Without the ability to communicate the device would become unusable and failed, this could result in the unintentional creation of additional marine trash, the very thing we are attempting to clean up. We chose to communicate through radio waves because they will enable a longer communication range than similar communication methods such as Bluetooth. The radio frequencies were selected in consideration of the Federal Communication Commission and Coast Guard Requirements regarding marine communication and all other standards and laws regulating marine communication. This is to ensure that ARTEMIS does not interfere with any distress signals. 2.4 gigahertz radiofrequency was selected for the camera with a range of 100 meters. 5.8 gigahertz radiofrequency was selected for the propellor controls and battery updates with a minimum range of 800 meters. The smaller range for the camera encourages users to keep ARTEMIS within this range so that ARTEMIS does not lose control.

Now that I have discussed the essential functions of ARTEMIS, I will discuss our team's design process and highlight the key features of our design.

First, we always kept in mind that collecting trash is the main objective of our project. When thinking about the user experience, we wanted the device to be effective in the trash collecting process- collection and storage. We used standard sizes of grocery store bags and household garbage bags to determine the quantity of trash our device should hold. Our solution was a passive intake design coupled with a cast fishing net that would effectively hold 15 gallons.

Our second concern was the scope of the project. Our objective in addressing the public to partake in trash collection greatly implies that our design needs to be user-friendly in size, weight, portability, accessibility, etc. Our device can collapse to 4 cubic feet in volume, nicely fitting into any car's trunk. It can then expand for operational use. The device weighs approximately 30lbs in total.

One of our engineering challenges was the need to mount propellors in a way that was non-invasive as waterproofing is of great concern to both the pipes and the electronics housings. We utilized Solidworks 3D software to develop and design a custom 3D printed part that allows our propellors to be securely attached to the boat without drilling any holes into the device. With the waterproofing concerns, we specifically chose a C.O.T.S product to help ensure we meet IP ratings of 68 to ensure our electronics will not be damaged in the event the boat is submerged.

Our engineering project proved difficult in the mechanical realm due to conflicting principles based on our values- we wanted foldability capabilities and a rigid frame when folded out for use. We wanted rigidity with low profiles so we would not obstruct trash flow. The list goes on. Engineering has taught us that although there are certainly trade-offs, with clever designing you can minimize these trade-offs. We are very pleased with the inclusion of Commerical of the shelf parts that help us meet this need. We included folding shelving brackets, rotating locking mechanisms, and folding D-clips for the net. All these elements have a small profile but were chosen as they maximize their effectiveness for the whole project. This has proven very effective.

Lastly, we needed to address the safety concerns of our project. If consumers would be using this in bodies of water across Puget Sound, then we needed to incorporate appropriate marine features. We cleverly included waterproof battery-run LED lights following standard boat codes. We also included a high visibility flag with a mount for extra visibility while on the water's surface.

Now that I've talked a bit about this, I will also show some videos of the device being used. In this video, you can see that ARTEMIS is being used and has good moveability. And the second video you'll see us testing out the turning radius showing that it has a close turning radius so it can be used within confined spaces such as harbors.

I will now talk about the impact of ARTEMIS. The goal of ARTEMIS is both to collect trash but also to engage the larger public and taking the initiative to clean up their local waterways. As people take the initiative to clean up their waterways, we hope to encourage people to educate themselves about the issues facing our world, such as the plastic that is currently in the ocean, and other issues regarding climate change. Now, as people engage in educating themselves about plastic and oceans people can begin to realize that low-income people and countries are disproportionally affected by climate change. Richer countries often exploit that environment around them, while passing off the negative consequences of their actions to lower-income people. This in effect dehumanizes lower-income areas as they get passed off the negative consequences that are unwanted by the richer countries without any concern for their humanity.

However, we live in a global society and these consequences are affecting everyone in the world today and so we shouldn't just pass off these consequences. We need to all engage in the process of reconciling together and reconciling with the environment around us.

Too often in engineering, the process of design only mainly focuses on how the product is going to be used in its initial life and not about how it will either be recycled or repurposed at the end of its life. For too long in engineering, the question of how is this going to decay into the environment was not asked in design meetings. Some of the plastics today will live longer than anyone alive, as well as last longer than potentially all of humanity. This can be a scary fact, however, if we take the initiative to start cleaning the ocean now we can work at providing a better future for everyone include the potential use of ocean plastic as a fuel source for gasification power plants.

Also in understanding how plastics get into the ocean especially the throw-away culture in the US, we hope that people will look at how objectivity in science and engineering especially is not something that should be upheld fully. Although there are certain things that objectivity may be a good goal. Although we cannot achieve that goal, we should understand that when we believe that the world is objective and that humans can achieve objectively we discredit and dehumanize others who have a different perspective than us. We in effect, are attempting to uphold our biased viewpoints as the objective viewpoint held by all humans. Thus, not adhering to our viewpoint is unhuman. We as a society need to investigate and look at how the products we design or the actions we take affect the world, even after the operational life or the action is done. Until then we will continue to take actions that have a negative impact on the world around us after they are done.

And with that, I will let this back to Cheney so that she can introduce Hannah for a second presentation and afterward mean Hannah will continue to discuss these topics and come in, bring it all to a conclusion.