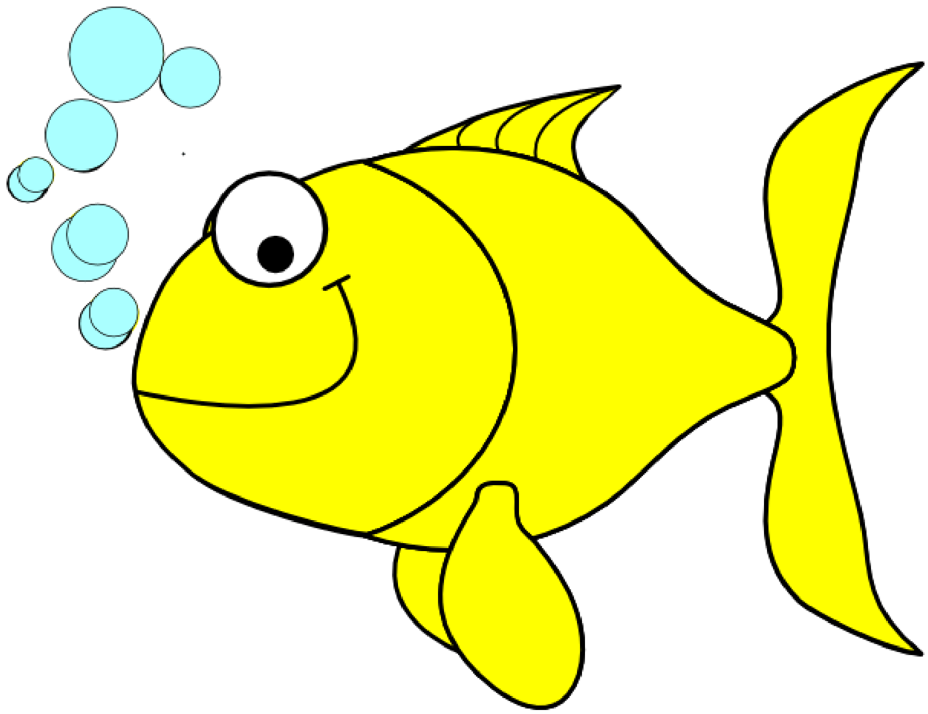
Bubbles Under The Sea



Department of Electrical Engineering and Computer Science
University of Central Florida
Dr. Lei Wei, Dr. Samuel Richie

Divide and Conquer Document - Version 2

Group 19
Jacob Lavoy, Electrical Engineer
Madison Melton, Electrical Engineer
Avery Mills, Computer Engineer
Joshua Nichols, Computer Engineering

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Motivation

Florida’s various beaches and rivers are very scenic and a big reason for tourists who come to the state. With some of our members regularly participating in community outreach programs for those with mental or physical disabilities, we had the idea of somehow helping these people to experience the same wonder and natural beauty of the ocean that they might otherwise not ever be able to fully explore. With this goal in mind we drafted an idea for some sort of underwater camera that would allow them to maneuver and see what's under the water. With that, Bubbles Under The Sea was born with a clear goal to give people who are handicapped or otherwise unable to swim the ability to explore sea and river ecosystems.

Potential customers, sponsors, and contributors

We are our own sponsors. Our most focused audience is people who are handicapped or are unable to swim who want to see underwater for research and/or fun. We wanted to make the project on the cheaper side so that it wouldn’t be something that only some people can afford, expanding our customer base, especially with our goal in mind to give as many people as possible the ability to explore underwater.

Project goals and objectives

Our primary goal is to create a retrievable, remotely operated submarine that live streams its video feed back to the user. Most underwater drones on the market cost above $1500, and ones below that price may have battery capacity for only two hours. As such, additional goals are to reduce the price below $1000, and for the sub to be easily brought back to shore by the operator. Further goals are to provide LED lights, retractable cables, and support for different types of small camera models.

Sub-goals have been identified for the controller itself:

- Ability to display live streamed camera footage.
- No more difficult to use than a standard game controller.
- Clarity of display in terms of reception and sun-glare.
- Keep less than one kilogram.

Stretch Goals

Some stretch goals were identified, to be completed if time allowed. Such goals include changing from a static, interchangeable camera, to a built in camera capable of rotating 360 degrees horizontally, and 90 degrees vertically to allow for optimal aquatic life viewing. Adding VR viewing would increase the utility of having a rotating camera. Sonar rangefinding could be included to allow for the rear of the sub to detect when it is about to strike terrain, wildlife, or other objects. Two ideas exist that decouple the controller and the sub, such as an ejectable umbilical cable, or having the wire instead go to a buoy on the surface that transmits the video back via Wi-Fi. Other stretch goals include item retrieval abilities and possible graphics processing such as identifying and highlighting objects seen in the video.

Primary design challenges

There will be challenges in creating this sub such as: maintaining high video quality over the transmission line, ensuring that power is distributed evenly among components, and not creating any short circuits. Additionally, the entire system must remain waterproofed to ensure the integrity of electrical components inside of the submarine.

Features for final demonstration

In our final demonstration, we intend to show that our drone can be moved forward, backward, right, left, up, and down. We will also be able to show the video footage from the camera to see underwater. We will be able to demonstrate variable headlights, as well as the range and depth capabilities of the sub.

Market Analysis

Analysis of competitive products and projects has shown that the housing must be able to hold our equipment inside of it and withstand various pressure levels for the safety of everything inside. We should use a propulsion system that can handle the weight of our equipment and skillfully maneuver through the different environments we anticipate for it to encounter. Further analysis has shown that while existing products are certainly portable, larger models are bulkier requiring the use of both hands to deploy, and other models have significant differences in battery life for the different speeds of the vehicle. These same products focus on being easy to use and having accurate sensors, which is something we intend to continue with our solution.

Previously Discussed Design Ideas

One idea that we discussed was the idea of using a propulsion system similar to a whale's tail to steer and propel the sub. After our research, we decided that the tail would get in the way of the umbilical cord and would cause a very high risk to the cables, straining them as the tail moved up and down to propel the sub forward. Instead, we decided to go with the idea of one large rotary blade on the back and one smaller rotary blade on the bottom of the sub. This way, the large blade would be able to propel the sub forward, and the little one can guide and direct the sub.

At the beginning of our idea process, we wanted to have just one computer onshore and only the Go-Pro inside of the sub. After some research, we decided to add a Raspberry Pi onboard the sub and another one inside of the controller to transmit guidance and navigation signals and to transport the video signals coming from the Go-Pro and completely omit the computer. We also switched to having two Raspberry Pis to take advantage of their gigabit Ethernet ports which would speed up video transmission.

Engineering Requirement Specifications

Major Requirements	
Requirements	Specifications
Diving depth	At least 5 m
Cable can carry a video feed	At least 720p
Variable Headlights	Settings between 150 lumen and 1000 lumen.
Able to withstand cold and warm temperature	4 - 33° C
Umbilical cable length	15 m
Power requirements	<250 W
Production costs	Should not exceed $1000
Battery life	>3 hours when fully charged
Can accommodate cameras of different sizes	At most 13 * 11 * 9 cm
Weight	No more than 10 kg
Total Volume	No larger than 0.03 m^3

Table 1: Major Requirements

In Table 1 shown above, we have identified several major requirements and specifications. We have specified the main three demonstrable requirements at the top in bold, followed by the remaining measurable requirements.

Potential Standards

This project will be subject to a number of engineering and environmental standards in order to comply with law, and to allow our solution to interact with other products in a safe and repeatable way. Several standards have been identified for further investigation including:

- Restrictions of Hazardous Substances (RoHS)
- Ingress Protection Codes (IPX)
- Universal Serial Bus (USB)
- High-Definition Multimedia Interface (HDMI)
- Inter-Integrated Circuit (I^2C)
- Category 6 Cable (CAT6)
- User Datagram Protocol (UDP)
- Real-time Transport Protocol (RTP)

Constraints

Our solution will also be subject to several constraints throughout the design and manufacturing processes. The COVID-19 pandemic has impacted our ability to meet in-person and any parts ordered through global supply chains are still likely to be affected, possibly delaying any parts we order. Outside of the pandemic, we are also constrained in terms of time and money, as we are our own sponsors for this project.

Estimated project budget and financing

We estimate our project with all of its equipment and the resources needed to total around $1000, or around $250 per group member. Our estimated budget is shown below in Table 2, which has been modified to include our latest research into costs.

Budget	
Item	**Estimated Amount**
Camera	$200
Camera waterproofing case	$35
Metal shielding for cable (50 ft)	$30
Waterproof cable (50 ft)	$50
3d printer materials	$100
Pressurization materials for hull	$50
Air compressor	$0 (use Madison's)
Raspberry Pi (x2)	$150
4 inch display	$40
2 axis joystick (x3)	$25
Push button (x4)	$25
Rotary Encoder	$5
Battery	$30
Propellers	$30
Other	$230
Total	$1000

Table 2: Budget

General project milestones for both semesters

Milestone	Date/semester
Choose Propulsion method & devices	March 1st
Design PCB	March 10th
Choose Pressurization method and devices	March 15th
Design Software controls and Video	March 20th
Design Hulls for submarine	March 31st
Create submarine Hulls and Test watertightness	End of Semester
Print PCB Layout and board	End of semester
Assembly of winch system	Beginning of Senior Design 2
Assemble Drone	Beginning of Senior Design 2
Final testing and troubleshooting	Middle of Senior Design 2
Have drone fully functional	End of Senior Design 2

Table 3: Early Forecasting of Milestones

Table 3 contains our project milestones for both semesters of Senior Design. We also provide milestones of different elements of our design in Tables 4 and 5 below. Note that completion of the submarine hull itself is determined by when the pressurization measurements are complete.

Tech Milestones (Controller and Sub Body)

Tech Milestones	
Milestone	Expected Completion
Sub Controller	
Tech Investigation Completion	02/24/21
Designing the 3D model	03/04/21
Printing the 3D model	03/24/21
Start of ordering Parts	03/24/21
Fitting parts	04/07/21
Wiring the parts	04/07/21
Coding the commands	04/21/21
Debugging with software	04/28/21
Test with software	05/05/21
Attach to Drone	05/05/21
Debug with Drone	05/12/21
First test run in water	05/12/21
Refine in water	06/16/21
Demonstrate final product	07/21/21
Sub Body	
Design Investigation	02/24/21
Design 3D model	03/10/21
Printing the 3D parts, Start of ordering Parts	03/24/21
Inclusion of Raspberry Pi and Coding efforts	04/21/21
Testing	05/12/21

Table 4: Early, optimistic, milestone forecasting for the sub controller and sub body.

Tech Milestones (Pressure Control and Propulsion)

Tech Milestones	
Milestone	Expected Completion
Pressure Control	
Tech Investigation Completion	02/24/21
Design Investigation Completion	03/03/21
Pressure Tests	03/03/21
Parts Ordered	03/10/21
Pressure Control Design and Prototyping	04/07/21
Submersion Testing	05/12/21
Propulsion	
Tech Investigation Completion	02/24/21
Design Investigation Completion	03/03/21
Parts Ordered	03/05/21
Engine Control Wiring	03/17/21
Vectoring Testing	04/14/21

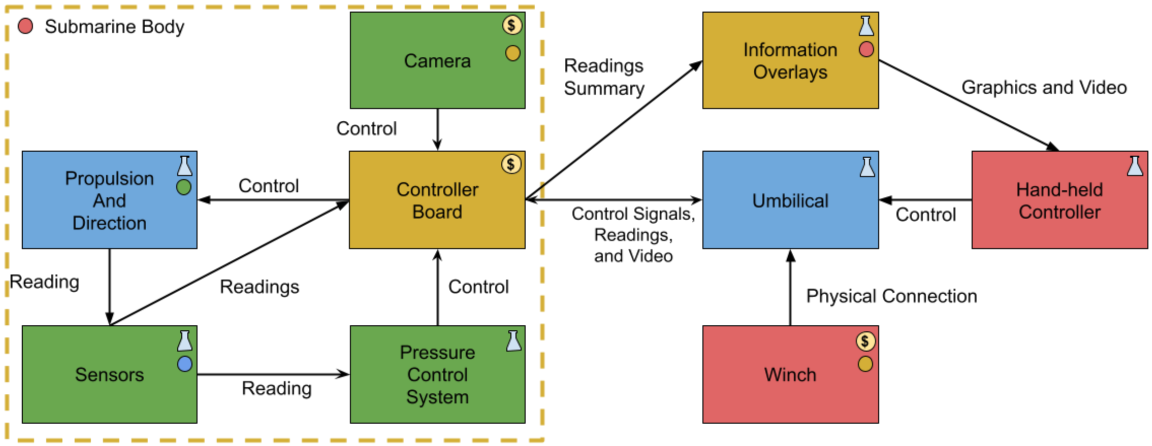
Table 5: Early, optimistic, milestone forecasting for the pressure control and propulsion systems.

Project Decision Matrix

Project Decision Matrix						
Idea	Cost	Sponsorship	Familiarity with Technology	Chance for learning	Motivation	Total score
Bubbles Under the Sea	2	-1	3	4	4	12
Automated -Windows	1	-1	4	3	3	10
Vacuum Tube Amplifier	4	-1	1	2	2	8
Security Peripherals	3	-1	2	1	1	6

Table 6: Project Ideas

Table 6 above contains the four highest ranking ideas proposed by members of our group for our Senior Design project. We ranked our ideas by way of cost, sponsorship, familiarity with technology, chance for learning, and motivation and chose our final project idea based off of the final score.



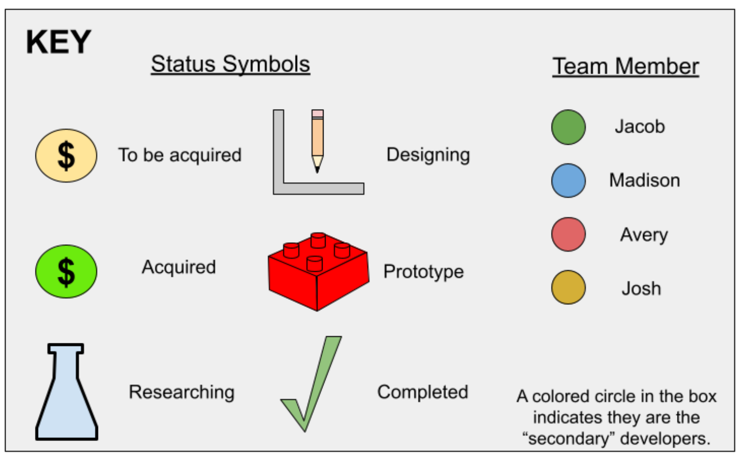
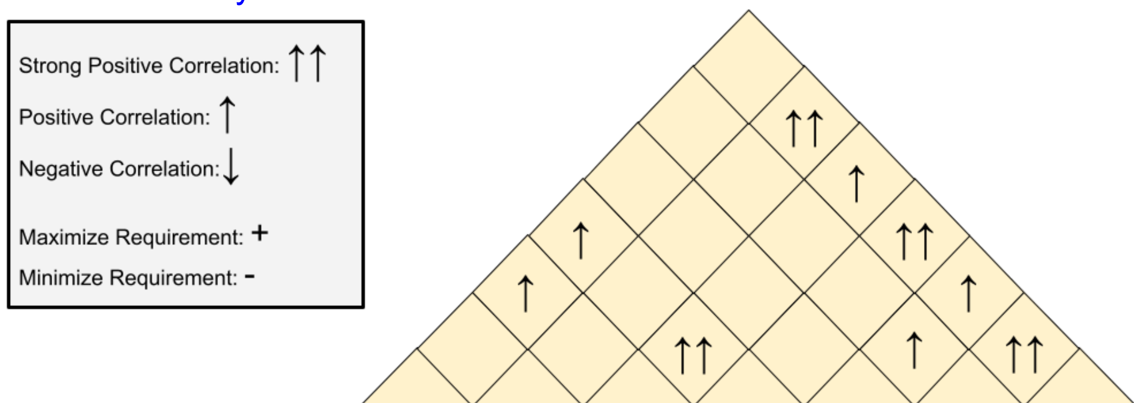


Figure 1: Role Assignments Block diagram

Figure 1 above assigns components of the project to team members based on which team members will be most efficient and to allow room for design work. Due to some shared electrical and programming experience amongst team members, components may be labeled with multiple team members.

House of Quality



	Engineering Requirements	Power Usage	Sensor Accuracy	Transmission Rate	Video Quality	Weight	Bladder and Pump Sizes	Cost
Customer Requirements		-	+	+	+	-	-	-
Video Integrity	+	↑			↑			
Real Time Video	+			↑	↓			
Cost	-	↑	↑	↑	↑		↑	↑
Ease of Control	+		↑	↑	↑	↓	↓	↑
Dive Depth	+			↓		↑	↑	↑
Battery Life	+	↑				↑		↑
Engineering Requirement Targets		< 250 W	TBD	TBD	1080p	≤ 10 kg	TBD	<$1000

Figure 2: House of Quality

The house of quality shown in Figure 2 incorporates the customer and engineering requirements that we identified to be most important to a remote-controlled submarine. Trade-offs were discussed such as the one between weight and ease of control, which will have significant influence on the physical design. Different interpretations exist for how a House of Quality should be read, so we defined a positive correlation to mean that as one quantity increases, the other will also increase. These relationships are also being defined from the day by day viewpoint, rather than over the operational lifetime or in speculative scenarios, which can change the definition of a relationship. For example, during regular use the sensor accuracy should not be affected by the battery life but in the case of a low battery, the design may necessitate shutting down sensors to preserve a video feed.

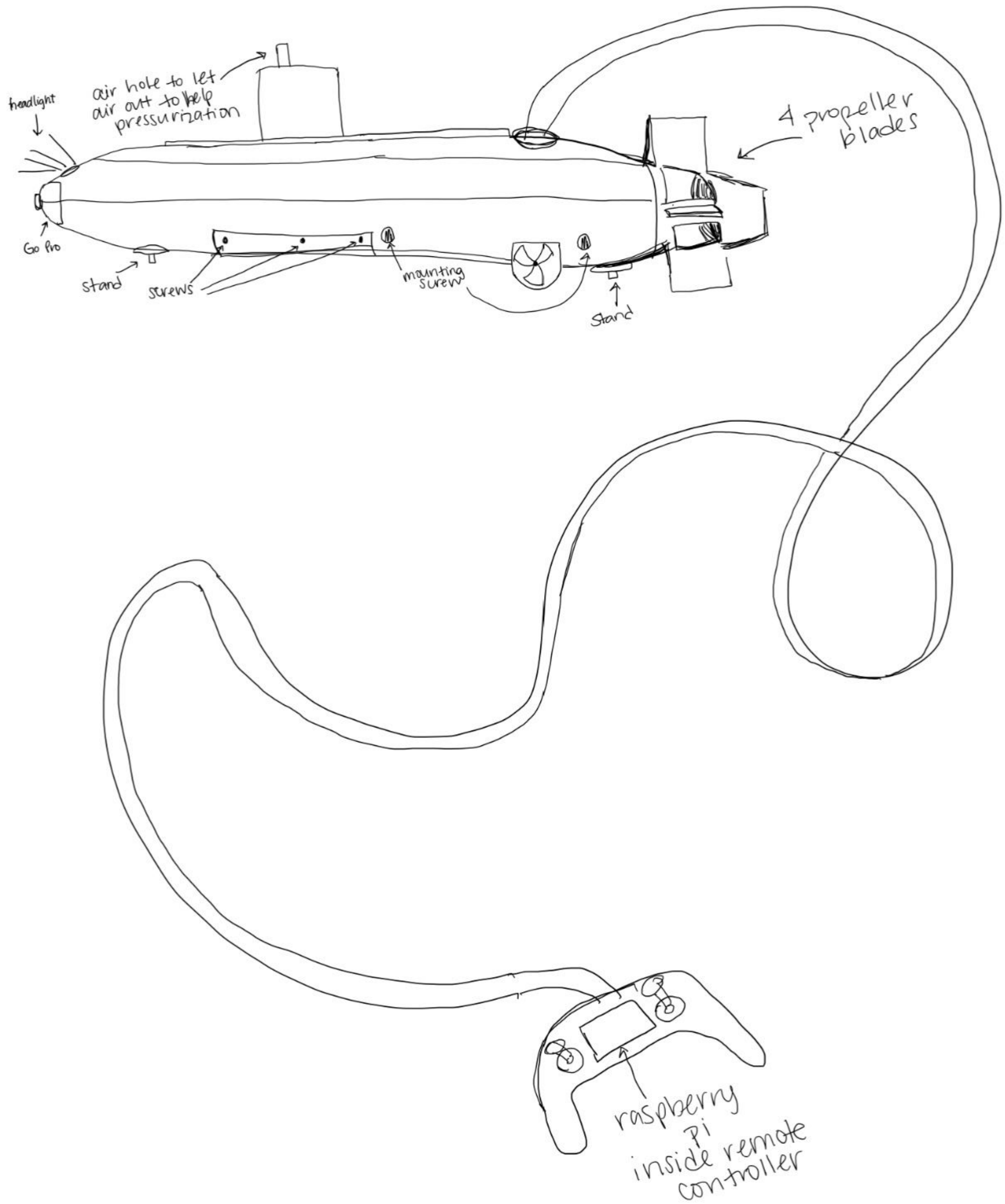


Figure 3: Design Idea

Figure 3 shows our basic idea of how we should connect the controller to the winch and the winch to the drone. We would have some flex-seal on the outside of the camera's case to attach to the housing. There will be a hole in the housing at some placement with a grommet that would allow for the cabling to attach to the camera and the propulsion system. The camera would stream live video data to the computer through the cable. We will have metal shielding around the cable to make sure that it would not deteriorate when rubbed against rocks/coral or if bitten by a fish with teeth. The spool of wire would have an emergency crank in case it runs out of power and we need to retrieve the drone from the water. The camera would be at the front of the drone to get the best footage of the ecosystems seen. The micro-USB cable would be attached to the camera at one end and the Raspberry Pi at the other end.

The controller would contain a Raspberry Pi with a screen where we will see video footage as well as readings from the pressure sensors inside the hull and the status of the motors.

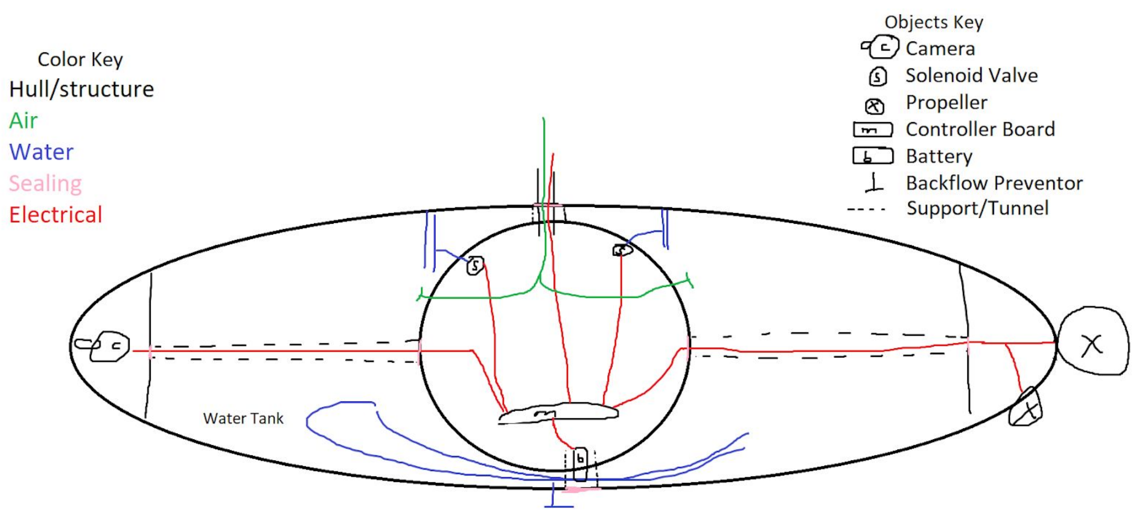


Figure 4: Structural Plans for the Submersible.

Figure 4 was made to show what pieces will be essential to giving the submarine the ability to navigate water. We have decided to go with a pressurized double hull so that we can control its buoyancy and depth in the water using the space between outer and inner hulls as a fillable water tank. We would also have three airtight interior hulls for storing the electronic pieces needed, located at the front, center, and back. The center hull would be holding the controller and most electronics, being supported by struts that act as tunnels to carry wiring to the other two air chambers. Around the center interior hull would be an external hull that would allow the submarine to fill up with water so that it would be able to dive easier. This tank would be filled with water by two solenoid valves on either end of the center hull, and filled with air by a pump that would come in through the umbilical cord with multiple backflow preventers to allow proper drainage.

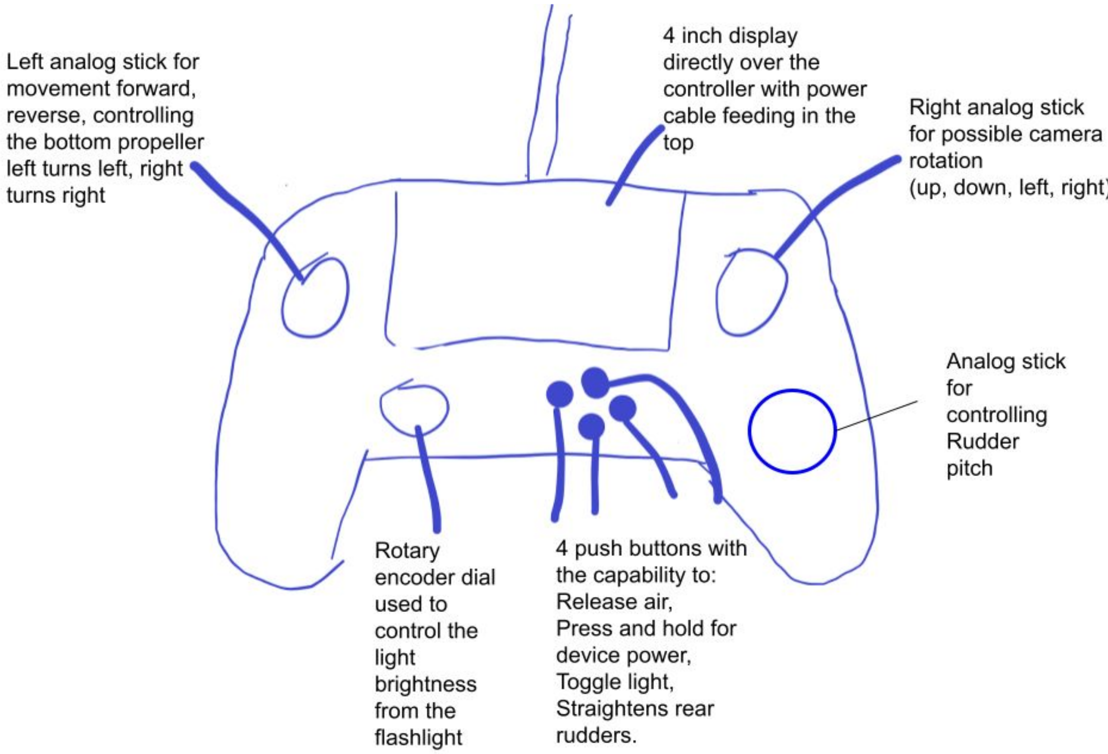


Figure 5: Initial Controller Design

With underwater navigation comes a variety of challenges when dealing with movement. Due to the submarine being in a constant fight between sinking and floating back up to the surface, the design in Figure 5 incorporates a control for the rear rudders allowing us to redirect the submarine in a new direction to adjust. The controller will also have bladder controls, allowing either air or water to be added to the sub. The rear rudders and forward movement can be locked to allow changing of the pitch, either descending further or to escape the current water depth.

There will be three analog sticks allowing control over the sub. One stick adjusts the camera's view so that should we need to pan the camera to catch something moving across the submarine we easily can. The second analog stick would be for movement, so the submarine can move forward and backward using the main rear propeller. It will also have the capability to steer left and right using a smaller propeller that rests on the bottom of the sub. The third analog stick controls the rudder pitch. The rotary dial on the bottom right of the controller is what allows the headlight to be a variable intensity should it ever need to be dimmed or raised. The four push buttons on the controller will control the air/water release, toggling device power, toggling the headlights on and off, and to reset the rudderes to a position that allows the sub to move in a straight line. The main area of the controller contains a four inch display screen that rests on a Raspberry Pi that is embedded into the controller. This display will allow us to directly see what the sub sees and show warning messages from the sonar rangefinders on the sub. The Pi would be used to receive the digital signals from the boat and send signals to the boat for controls.