Progress Report #2

AUV Project

Phase I

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This independent study for phase 1 constitutes the design and development of a proof-of-concept autonomous underwater vehicle (AUV) capable of meeting all technical requirements to participate in the International Robosub Competition. Progress report #1, #2, and #3 document the technical development of the project.

Executive Summary

Progress report #2 of the AUV project describes completed tasks beginning February 20th till March 24th and describes completed tasks, current tasks underway, and next month's tasks. Progress report #2 has tasks that are part of milestone #2 and #3 out of the four milestones that constitute the project. Completed tasks since February 20th consist of designing the AUV's electrical block diagram, the design of several AUV CAD iterations, and the creation of the AUV budget parts list proposal. Current tasks are geared towards completing what's left of milestone #2 through conducting Ansys CFD simulations, enhancing the sophistication of AUV CAD model, and in the machining and 3D printing of custom designed components. Next month's tasks constitute completing tasks in milestone #3 which includes the physical build of the AUV model along with testing and debugging in addition to working towards the project's final report and presentation.

Tasks

Completed tasks for phase I of this AUV independent study project for the month of February and March consist of completing the AUV's electrical block diagram, the budget parts list proposal, and several iterations of the AUV CAD model. Currently, I'm on track in accordance with the AUV Gantt Chart as referenced in progress report #1. The electrical block diagram can be seen in *Figure 1*.

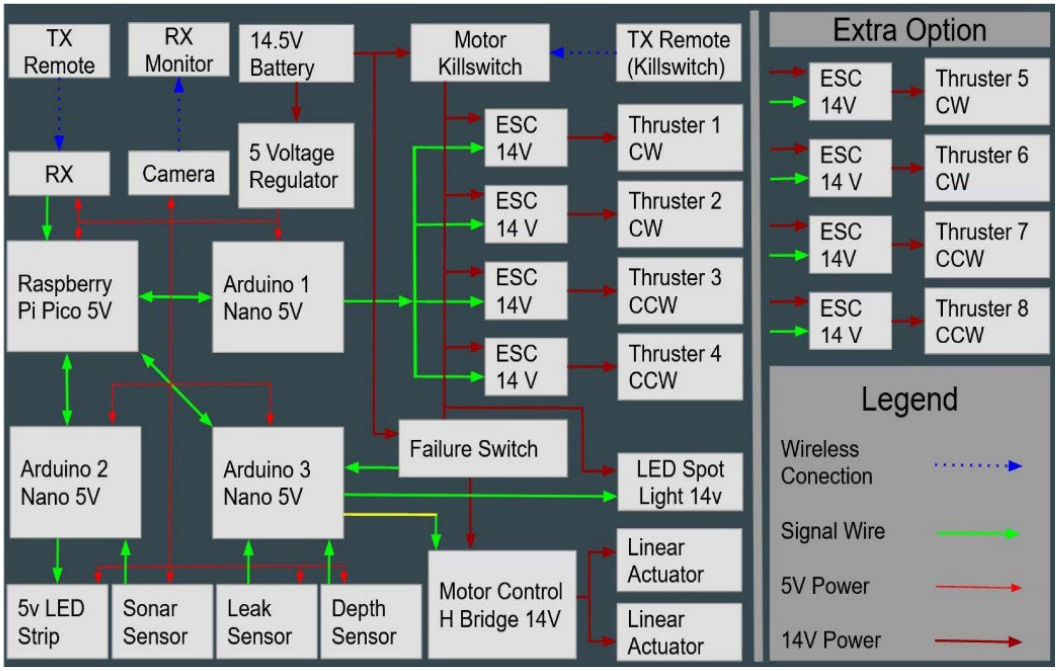


Figure 1: Electrical Block Diagram

The electrical diagram is configured based upon the AUV's computer system, buoyancy system, propulsion system, and sensory input/output system. The AUV's computer system consists of the Raspberry Pi Pico and several Arduino Nanos. The AUV's buoyancy system consists of linear actuators and an H-bridge motor controller. The AUV's propulsion system consists of 4-8 underwater thrusters and electronic speed controllers. The AUV's sensory input/output system consists of a leak detection sensor, sonar sensor, and depth sensor. The Raspberry Pi Pico serves as the main overall computer for the AUV, integrating all electronics to work together through directly communicating with all three Arduino Nanos. The Arduino Nanos control sensor input/output as well as communicates commands to the the electronic speed controllers for the underwater thrusters. The H-bridge motor controller is used for controlling the movement of the linear actuators that are used for opening and closing the syringe reservoirs that act as ballast tanks for the AUV.

The 4-8 underwater thrusters consist of both counterclockwise and clockwise thrusters. Clockwise and counterclockwise thrusters have either a forward or reverse curvature on the blades of the thruster. These thrusters come with individually attached electronic speed controllers which regulate the speed of the thruster motors. The sonar sensor functions as an echosounder through emitting an ultrasonic acoustic pulse underwater to receive responding echoes. The AUV can locate objects near to it through identifying the strongest echo produced from the different objects the ultrasonic acoustic pulse bounces off from. The sonar sensor can measure objection detection up to 164 feet underwater. The sonar sensor is important for the AUV's navigation to reach destinations underwater and in the avoidance of striking objects. The depth sensor measures pressure and depth of the AUV position underwater up to a maximum of 30 bar and a depth of 984 feet. The depth sensor also functions as a temperature sensor with an embedded temperature sensor integrated into it. The depth sensor is important as it assists in identifying the AUV's position underwater and in navigating the AUV. Knowing the depth of the AUV underwater allows the user to know how much power to provide to the thrusters to bring the AUV to the water's surface. The leak detection sensor uses cables attached to the sensor with sponges attached to the tips of the cables. When a leak is detected, the sensor turns on a bright red LED. This sensor is important as any water damage to the AUV's electronics can cause catastrophic product loss and malfunctioning to occur.

Furthermore, the electrical block diagram is configured through differentiating power wires, signal wires, and wireless communications. According to the legend given on the electronic block diagram, green arrows represent signal communication wires, bright red and maroon arrows represent power wires with differing voltages (5V, 14V) and blue dotted arrows represent wireless communication. As can be seen on the diagram, the 14V Li-Po battery powers all thrusters, electronic speed controls, the AUV spotlight, the H-bridge motor controller, the failure switch, the motor kill switch, and linear actuators. Using a 5V voltage regulator, the 14V battery is converted to 5V to power the sensors, LED strip, camera, the receiver, Raspberry Pi Pico, and the Arduino Nanos.

Moreover, *Figure 1* shows all signal communications. The Raspberry Pi Pico and Arduino Nanos communicate commands to one another. The data received by the sensors relay information to the Arduino Nano that then communicates these signals to the Raspberry Pi for processing. The Arduino Nano also sends commands to the H-Bridge motor controller, LED spotlight, and all electronic speed controllers. It can also be observed from *Figure 1* that the failure switch sends a signal to command the Arduino to turn off all power when activated. It can also be observed from *Figure 1* that the receiver directly sends commands to the Raspberry Pi.

Additionally, as observed in *Figure 1,* the transceiver sends a wireless signal to the receiver which then sends a signal to the Raspberry Pi for remote operation of the AUV. The camera also sends a wireless signal to the receiver in relaying images to a remote monitor for the user to view the camera's feed. The remote kill switch wirelessly sends a signal to activate the motor kill switch when necessary.

Regarding the computer-aided design of the AUV model, three different CAD design models were brainstormed and constructed in SolidWorks. The three different CAD models consist of an ideal model, a basic model, and a barebones model. The three different CAD models differ in total cost and their individual capabilities due to the removal or addition of optional parts. A parts list table that includes all required parts for each individual CAD model was created and can be seen in *Figure 2*. Bolded numbers represent which items were removed or added in distinguishing the three different CAD models. The parts list table was included in the AUV budget proposal which describes technical information and pictures of each individual part on the parts list table.

Item name	Ideal Qty	Basic Qty	Barebones Qty	Cost
Main Hull	1	1	1	$52
End Caps	2	2	1	$15
Dome Caps	2	1	1	$19
End Cap Adapter	1	1	1	$15
Waterproof Bulkhead	1	1	1	$13
Fitting	2	2	1	$16
Gaskets	1	1	1	$25
Sealant	3	3	1	$6
Epoxy	3	3	1	$6
Floor Plate	1	1	1	$15
Standoffs	1	1	0	$13
Brushless Motor CW	4	2	1	$64
Brushless Motor CCW	4	2	1	$64
Stabilizers pumps	1	1	0	$14
ESC Tester	1	1	0	$12
Raspberry Pi Pico	1	1	0	$28
Pico Breakout Shield	1	1	0	$16
Arduino Nano	1	1	1	$22
Nano Shield	1	1	1	$10
Arduino Mega	1	0	0	$48
Mega Shield	1	0	0	$30
12 PWM Motor Driver	1	0	0	$14
Reservoir	2	2	1	$8
Actuators	2	2	2	$32
Lipo Battery	1	1	1	$99
5 Voltage Converter	1	1	1	$15
Voltage Converter	1	1	0	$18
Failure Switch	1	1	1	$12
Lipo Charger	1	1	1	$27
Power Wattmeter	1	1	0	$16

Item name	Ideal Qty	Basic Qty	Barebones Qty	Cost
H-Bridge	1	1	1	$9
KillSwitch Remote	1	1	1	$37
TxRx Debugging	1	1	0	$50
TxRx Operations	1	1	1	$17
Antenna Jack	1	1	0	$6
Antenna Cable	1	1	0	$13
Hookup signal wire	1	1	0	$14
Hookup power wire	1	1	1	$17
Wire connectors	1	1	0	$10
Terminal Block	1	1	0	$12
Depth/Pressure/ Temperature sensor	1	1	0	$85
Leak detection sensor	1	1	1	$32
Leak sensor tips	2	2	2	$8
Sonar Detector	1	1	1	$360
USB to TTL Serial adapter	1	1	0	$45
I2C Bus Splitter	1	1	0	$45
I2C Logic Converter	1	1	0	$7
Proximity sensors	1	1	0	$9
Accelerometer	1	1	0	$33
Camera	1	1	0	$90
Video Amplifier	1	1	0	$110
Submerge Sensor	1	1	0	$16
LED Navigation light	1	1	0	$21
LED Status strip	1	1	0	$35
Total Number of Items	**71**	**63**	**29**	
Total	**$2,307**	**$1,940**	**$1,069**	
Current amount secured	**$1,000**	**$1,000**	**$1,000**	
Requested amount	**$1,307**	**$940**	**$69**	

Figure 2: Parts List Table

The ideal model can be seen in *Figure 3*. The ideal AUV design model has 66 total parts with a total cost of $2,307. The ideal AUV design has a large diversity of sensors for data input plus a camera, eight thrusters, and stabilization pumps. The ideal AUV is nimble and has advanced speed. The main components of the ideal AUV consists of the Raspberry Pi Pico, Arduino Nanos, the Arduino Mega, a camera, the 12 PWM motor driver as well as an LED spotlight and LED status strip. The ideal AUV has sonar, pressure, leak detection, proximity, submerge, and accelerometer sensors. The LED status strip indicates important health signals of the AUV for the user to identify remotely.

Option 1: Ideal AUV Model

Extremely agile and versatile

8 propeller thrusters

Fastest of the 3 models

Camera/Monitor FPV 5.8Ghz

Debugging Remote

Onboard 9-Axis Accelerometer

Health Status LED Strip

Item total: 66

Total cost: $2,307

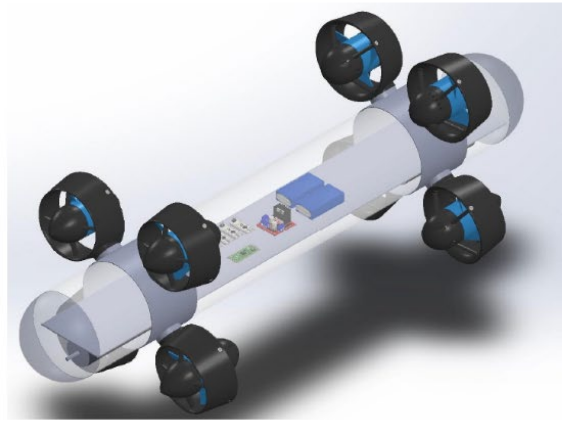
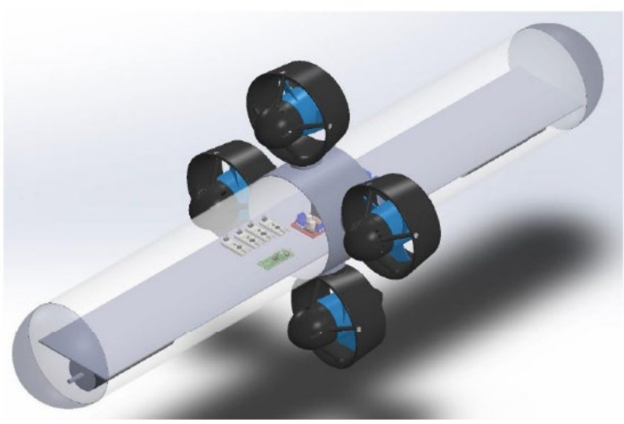


Figure 3: Ideal AUV CAD Model

The basic model can be seen in *Figure 4.* The basic AUV model has 58 total parts with a total cost of $1,940. The basic AUV design has a variety of sensors for data input plus a camera, stabilization pumps, and has four thrusters allowing for agility and a moderate fast pace. The main components of the basic AUV model consists of the Raspberry Pi Pico, Arduino Nanos, a camera, an LED spotlight, sonar, pressure, and leak detection sensors. The basic AUV model lacks the 12 PWM motor driver, the LED status strip, Arduino Mega, as well as the submerge and proximity sensors.



Option 2: Basic AUV

Agile

4 propeller thrusters

Basic sensors

Camera/Monitor FPV 5.8Ghz

Item total: 58

Total cost: $1,940

Figure 4: Basic AUV CAD Model

Option 3: Barebones AUV

Hard to maneuver

2 propeller thrusters, Slow

Item total: 27

Total cost: $1,069

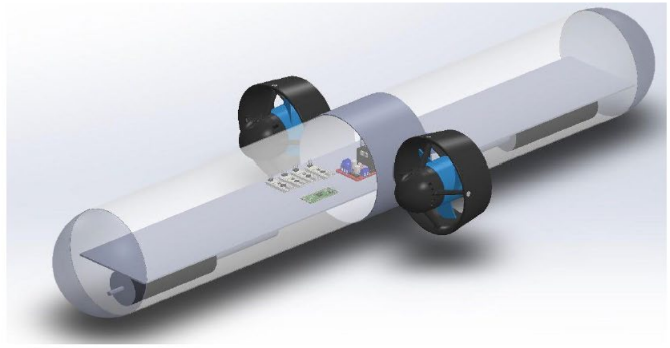


Figure 5: Barebones AUV CAD Model

The barebones model can be seen in *Figure 5.* The barebones AUV design model has 27 total parts with a total cost of $1,069. The barebones AUV lacks a variety of sensors for data input and has two thrusters causing a lack of agility and sluggishness. Main parts that the barebones AUV is lacking consist of additional thrusters, stabilizer pumps, the Raspberry Pi Pico, Arduino Mega, the camera, as well as a pressure, proximity, submerge, and accelerometer sensors. The barebones AUV has the Arduino Nano and sonar as well as leak detection.

Current tasks underway consist of learning and using the computational fluid dynamics software, Ansys, in running engineering simulations for the AUV. The data gathered from these simulations would assist in refining the AUV CAD model as needed before the actual fabrication of the submarine begins. I will be performing buoyancy simulations based on the size, weight and custom buoyancy system of the AUV. The custom buoyancy system of the AUV functions through two syringe reservoirs that take in and expel water as needed for the AUV to achieve its desired buoyancy level. Consideration of the AUV's volume and surface area would also be simulated to determine what is required to achieve neutral buoyancy. Additionally, I will be conducting propulsion simulations in determining thruster control, necessary thruster power, and in identifying the difference of using four thrusters versus eight thrusters.

Additional current tasks include creating more AUV CAD model iterations to advance the amount of detail and sophistication of the CAD model. I am currently working on importing more electronic CAD parts, creating the exterior valves on the hull for the syringes to take in and expel water, a secondary enclosure to protect the electronics on the electronic bay, as well as the screws, nuts, washers, and holes to add to the dome end caps and thruster mounts. Furthermore, I am working on custom designed CAD parts such as thruster mounts and the mount to hold the electronic bay inside the hull which will be designed and either machined or 3D printed. I will also be consulting with machinists and 3D printer experts to determine if my custom designed parts need modifications to machine or 3D print properly.

Future tasks consist of the physical build and assembly of the AUV when the parts have come and in programming the AUV to autonomously perform basic tasks such as moving up, down, reverse, left and right. Another task would be having all the electronics in the AUV programmed to communicate effectively. Lastly, conducting multiple tests of the AUV after programming will be required to determine its operability and what aspects need to be modified to achieve desired functionality.