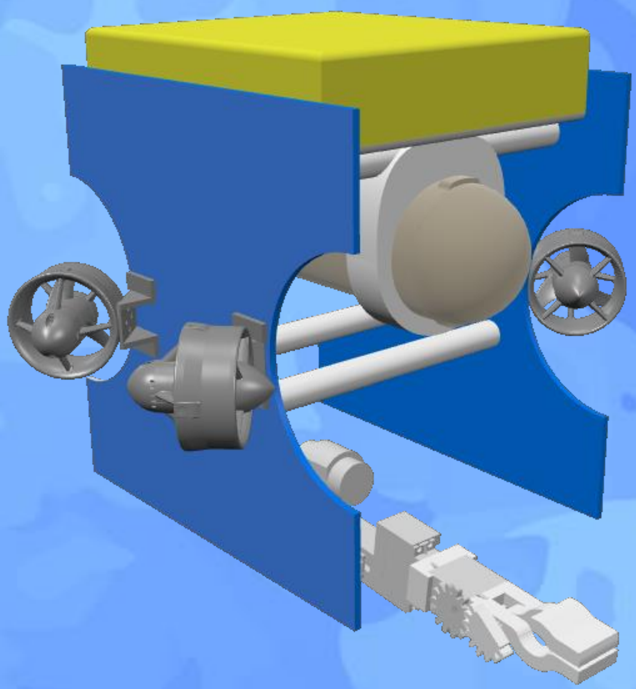
Sound School Robotics

Sound School

New Haven, CT, USA

MATE ROV 2021



Mentor: Dave Low

Team Members:

Oliver Mackinnon: CEO, Computer / Electrical Designer / 3D Designer, Returning

Rowan Hampson: CCO, 3D Designer, Tether Manager, Meeting Organizer. New

Willow Schreiner: CFO, 3D Designer, Assembly Engineer, New

Abstract

Our world struggles daily with the effects of pollution in our aquatic environments. The human effect on the natural underwater habitat ranges from littered plastic bottles to bleaching coral. Sound School Technologies tasked itself with designing a highly versatile submersible ROV capable of removing trash, providing underwater surveillance, transporting organisms, retrieving sediment samples, and maintaining underwater devices. All of these skills could be utilized to mitigate aquatic pollution and work to solve our environmental problems.

ROV Mildrid features 6 T100 thrusters manufactured by Blue Robotics providing excellent mobility, and a moveable manipulator that can rotate to pick up objects at any angle. The ROV features multiple cameras that allow the ROV to successfully navigate around its deployed area. Mildrid is connected to the surface by a 50-foot-long tether allowing for video streaming and remote control. The vehicle is controlled by an Arduino that allows for an easy driving experience with simple joystick potentiometers.

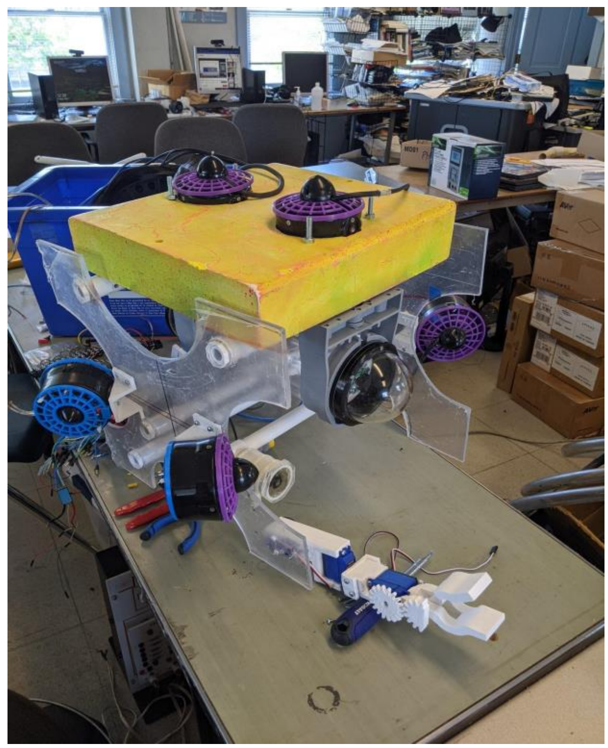


Fig. 1: Assembled ROV.

Table of Contents

Group History

Sound School Robotics is a student run program with a mentor located at the Sound School in New Haven Connecticut. Each year, the Ocean Engineering II class competes in the MATE Competition providing a competitive ROV. This is the Sound School's eighteenth year participating in the MATE Competition.

Safety

Safety Overview

Safety is a key component to the success of a project. It is important to keep in mind that this does not just include safety during the construction phase, but also in the design for the finished product. Mildrid has many built in safety features allowing all users to remain safe during usage. First off, all thrusters are covered ensuring that no body parts get hit by propellers. Mildrid has no sharp points along the perimeter of the body and can easily be picked up by the buoyancy located on the top. Finally, Mildrid's power can easily be disconnected at any time in case of emergency. Mildrid uses no non-ROV devices, and contains no fluid power.

Safety Checklist

Workshop Safety Checklist

- Wear protective eyewear when working with anything potentially harmful to your eyes.
- Keep any loose hair tied back and change into clothing that fits well onto the body.
- No electronics that could act as distractions while working with hazardous equipment.
- Wear a respirator and turn on any ventilation equipment when dealing with anything that gives off fumes.
- Communicate what you are doing with peers to avoid potential accidents.
- Always wear closed toed shoes whenever working around equipment.
- Clear your working area to maintain a safe space while working.

Poolside Safety Checklist

- Always wear closed toed shoes.
- No running while near any surface with water.
- Keep electronics away from water unless waterproof.
- Clear the area around the pool to ensure nothing falls in, and to remove any tripping hazards.
- Keep tether neatly wound up next to the pool to remove possible tripping hazards.

Project Planning

One of the most important things contributing to the success of a project is the planning that goes into it. Sound School Robotics utilized three different programs to help with this.

We created a diagram on Diagrams.net in order to show how all the components of the competition connected to each other. Next, we created an overall schedule for the project on ClickUp in order to show when all the components needed to be designed, printed, and assembled. We saved all our designs to 3d Experience so that anyone in our group could access them. Any files that could not get saved on 3d Experience got saved to a communal Google Drive folder.

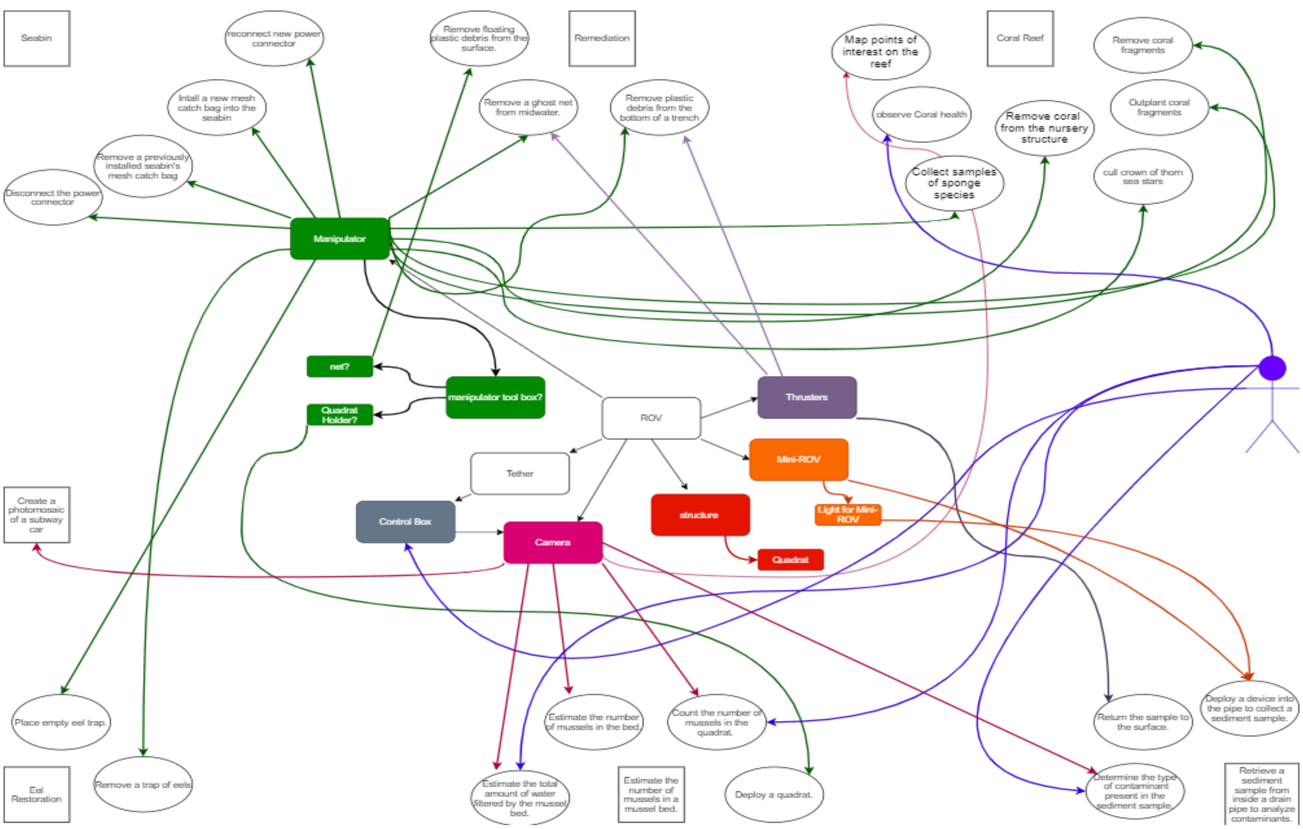


Fig. 2: Connections of challenges in relation to different parts of ROV.

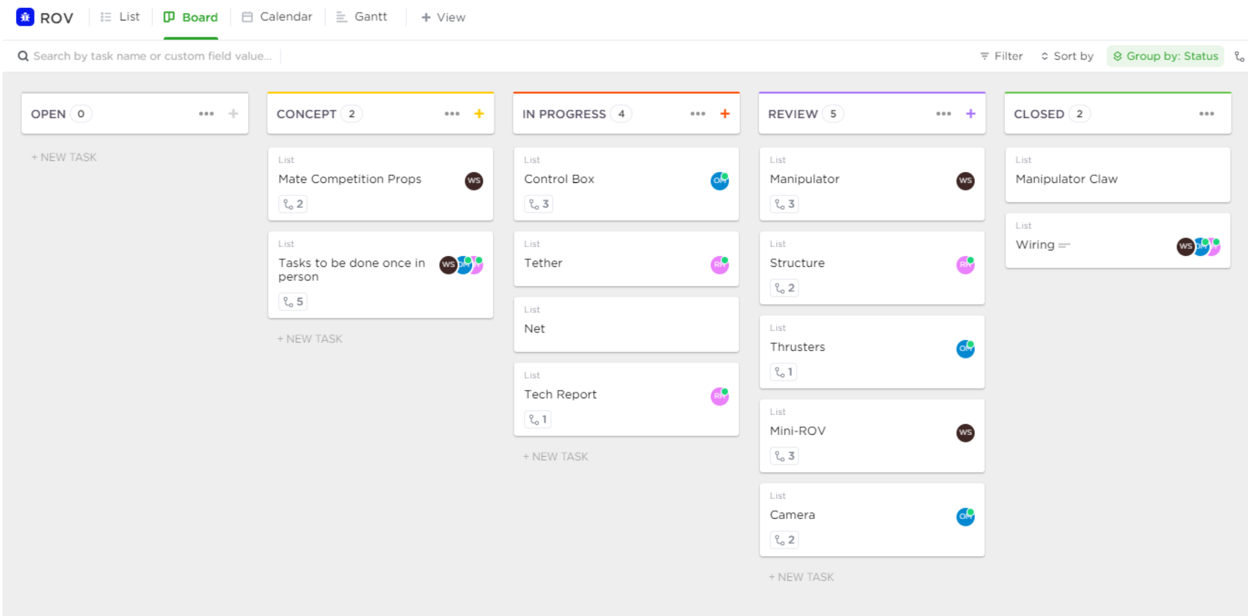


Fig. 3: Board view of ClickUp page.

Design Rationale

Manipulator

We had three goals in mind for the manipulator. We wanted a maneuverable device capable of grabbing onto rope, mesh netting and capable of picking up PVC pipes with ease. The claw of the manipulator, therefore, needed to be good at holding both a thin sheet and a cylindrical object. We decided to split the claw into two parts, one to grab onto two dimensional surfaces, and one to hold onto PVC pipes. For the first part, we created a clamp and dimensioned it so that it would be able to hold a tight grip on the ghost net. For the second part, we made a hole that could encircle the pipes. We dimensioned the hole to be slightly smaller than the size of the PVC pipe diameter. The top and bottom of the claw were designed to slide through one another, so they could open and close all the way. The claw is operated by a servo, which turns a gear, which turns another gear, which turns the bottom of the claw. The top of the claw is attached to a manipulator arm, which is connected to a servo, which in turn is connected to another manipulator arm. This structure allows the claw to rotate. The manipulator is then attached to the ROV with another servo that controls the direction it is pointing, allowing it to turn and grab objects.

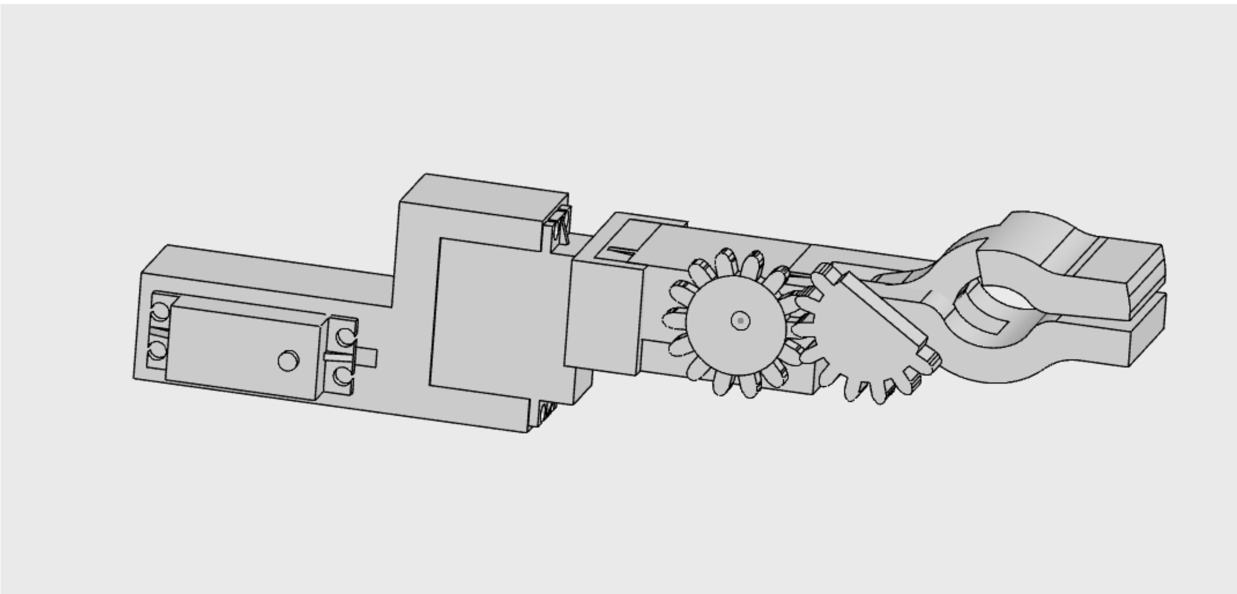


Fig. 4: CAD rendering of finished manipulator.

Tether

The tether consists of a power wire, a ground wire, a CAT5 cable, and three RCA video cables. We initially planned to use a signal amplifier but found it to be unnecessary after testing. This would allow for future productions of the ROV to be more cost efficient. After putting these six wires together, we realized some sort of tether management system was needed. We decided to wrap the wires in a mesh wrap that could be undone easily in the future if we needed to make changes. We then attached the tether to a garden hose reel. With this setup, the tether could easily be reeled in or out, and would stay as one wire.

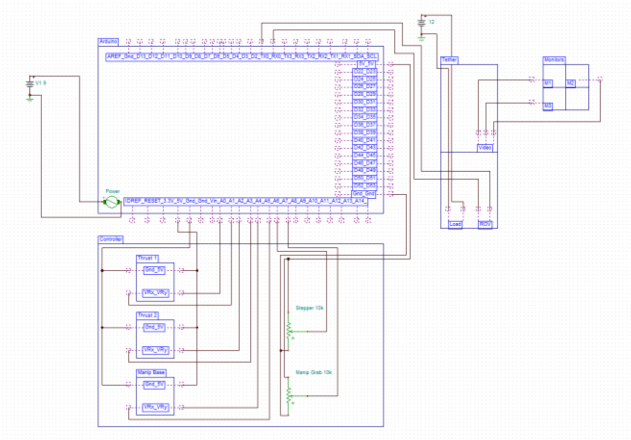
Thrusters

We knew the thrusters needed to be powerful while still managing to maintain maneuverability. We wanted an ROV that was able to surge, sway, and heave, while still being capable of yawing.

We satisfied these constraints by using six Blue Robotics T100 thrusters vectored at 45 degrees. These thrusters were chosen because of their variable high force output as well as their reliability. They take DC power and are controlled by an ESCs attached to an Arduino. The motors run on 12V DC, and draw 6.7A. We decided on placing the motors at a 45 degree angle because it would allow for the best mobility. The ROV could strafe at any angle while still being able to yaw tactfully. The last two thrusters were placed vertically. One was attached on the front with the other attached to the back. The six thrusters were controlled by two joystick potentiometers. This allowed for the joysticks to send the Arduino a magnitude and a direction, and the Arduino to send the ECS a value which would send a separate magnitude corresponding to each thruster. We reused thrusters from previous years because they fit the need as well as saved money for the budget.

Control Box

The ROV is remotely controlled on the surface by the designated pilot. The Control Box uses an Arduino to receive input from the pilot. The control box features three joystick potentiometers, and two normal potentiometers. Two of the joystick potentiometers are used to control the movement of the ROV, while the remaining one is used to control the vertical and rotational



movement of the manipulator. The two potentiometers are both used to control servos. One is meant to control the opening and closing movement of the manipulator, while the other is meant to control the angle of the net located on the top of the ROV. The topside Arduino receives these signals and decides what it should do with them. The topside Arduino then turns them into bytes and sends it through the three serial connections available on the Arduino. The bottom side Arduino receives these signals, decodes them, and then supplies the different motors with the desired signal.

Fig. 5: Top Schematic in TINA.

Camera

When determining the location of the cameras, we knew we needed one camera in the power bottle on the ROV, and one on the top to see the balls that needed to be picked up. Apart from those two, we decided it would be beneficial to add a second camera onto the structure within view of the manipulator, as the claw was not easily seen from the top camera. The cameras take 12V DC power allowing them to be attached to the same circuit the thrusters are attached to. Because we wanted two of the cameras to be outside of the ROV, we needed to waterproof them. The cameras were placed in a clear jar and filled with epoxy. The epoxy could be drilled into or sanded down as needed allowing for an easy solution for mounting.

Buoyancy

Fig. 6: waterproofed camera.

We attached Syntactic Foam to the top of the ROV to provide buoyancy. The foam had a density of 250 kg/m^3. The top was chosen as the ideal location as it will stabilize the ROV to remain upright while moving. The dimensions of the foam was cut to 30x40x1.4cm, thus giving it an area of 1,700cm^3. The foam has 6 holes cut through it. Four of the holes are cut just wide enough to have bolts put through them to secure the foam to the top of the structure. The foam also has two holes cut in the top in order to mount the two vertical T100 thrusters. The foam is painted yellow in order to provide visibility to keep people and animals a safe distance away from the ROV. The ROV has a total volume of 3648 cubic centimeters. On the sides of the ROV are 4 places to hold weights. The weights are easily adjustable to account for differences in water density.

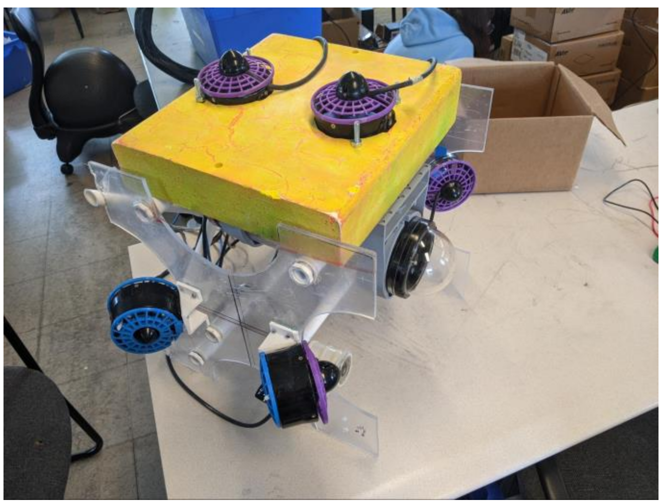


Fig. 7: Mildrid with flotation attached.

Power Systems

The power system in our ROV was designed to allow all components to receive power from a main power supply above water.

The power starts at a 12V source with a 25 Ampere fuse before entering the tether. This ensures that the power given to the power bottle is never over 25 Amps. Our plan required three different voltages for our ROV; 12V, 9V, and 5V. Originally, we discussed sending down multiple lines to provide these different voltages, but it was ultimately decided against because of voltage drop through smaller wires. Instead, we decided to use a 12V to 9V step down converter, and a 12V to 5V step down converter.

The 12V of power was divided evenly between the two converters, the 6 T100 thrusters, the stepper motor, and the three cameras. The 9V converter's main purpose was to power the Arduino. No other objects are attached to the 9V converter. The 5V converter is tasked with powering 4 servo motors. All of these objects are connected in parallel and should not take more power than the converter will give.

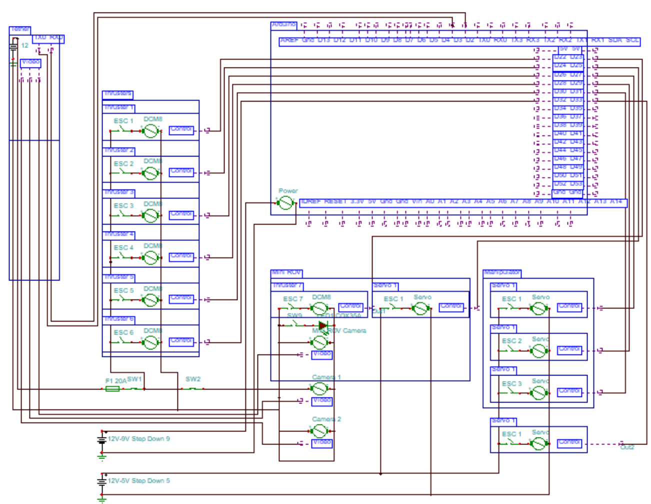


Fig. 8: TINA bottom Schematic

The ROV uses a power supply of 12V to emulate the power supply used in the MATE competition.

Structure

Fig. 9: Original CAD model of structure

The structure of the ROV is made with plexiglass and ½in PVC pipes. Plexiglass was used as the material for the sides. Bars that connect the two plexiglass sides were made with PVC pipes in order to support the inner workings of the ROV.

Plexiglass was used for the sides because it is sturdy and easy to shape. It could also be cut in order to not inhibit the water flow of the thrusters. Originally, we believed that squares cut into the sides of the ROV would be better. We believed we could cut out excess space and improve water flow through the ROV. We instead decided to cut four circles along the outside of our ROV. This would give us more mounting room for objects and increase waterflow even more than the square cuts.

The main use of the PVC bars was support for the sides, but also worked as a place to put stuff on. The use of ½in PVC pipes allowed for a sleek interior as well as a sturdy frame for the structure.

In order to use electrical components underwater, we needed dry housing. We decided to use the 4” Watertight Enclosure made by Blue Robotics.

Software

When it came to software, we focused on three main aspects for the development: reliability, straightforwardness of use, and cost. We decided that two Arduinos connected with an ethernet cable running a modified version of C++ would fulfill these aspects.

The Arduino connected to the control box worked as a sending module. All the inputs would be read by the Arduino, and values would be sent to the receiving Arduino through the tether. The receiving Arduino would read the signal and communicate to the ESCs and servos what needs to be done. The Arduino is able to complete this process multiple times per second leading to very responsive controls.

Testing and Troubleshooting

General Testing

In order for Mildrid to be successful, we knew that we would have to undergo rigorous testing of every component. We worked on one component at a time to isolate our focus to just that. When a problem arose, we all had expertise on the component, and one of us usually knew how to fix it. One problem that we had issues with was the structure not being particularly sturdy. When we first created it, it would tip from side to side. None of us predicted it would happen. We investigated the issue and came up with a few possible solutions. We contemplated wedging objects in between the foam and the plexiglass to attempt to make the area smaller. Although this may have worked, we instead decided to reinforce the backside of the structure by creating a truss with PVC Pipe. This solved the issue that we once had, allowing us to move onto other things.

Coding Testing

Because all of the members of our group were relatively inexperienced with coding, we decided that before creating one singular code to load onto the Arduinos, we would test each individual component. Once we resolved any issues we had, we isolated the code onto one Arduino to ensure it worked. We then brought in the aspect of the Serial connection between the two Arduinos. Because of Mildrid's easy to access design, troubleshooting thrusters/servos not working properly was not a hassle.

Electrical Testing

One of our main concerns for Mildrid was getting and supplying power to all of the parts. We gathered all the necessary electrical components and laid them out on the floor. During this process we used many terminal blocks to avoid soldering just in case things needed to be changed later. We connected everything and tested it. We had two issues on our first test, but they were quickly solved with the use of a Multimeter. After all issues with power were resolved we finished by soldering everything together.

Logistics

Finances

To make sure that our team had the resources needed to afford the materials for the ROV and props, the city of New Haven supported us by providing funding for the needed materials. Whenever possible our team reused parts to save money, we reused PVC and PVC connectors that were in the classroom and wires from previous tethers. Even though we did our best to reuse parts, there were still some parts we needed to purchase.

Thing Bought	Amount	Budget	Total Cost	Reused/Bought	Total Bought 2021
T100 Thrusters	6	800	720	Reused	
Arduino Mega	2	100	74	Reused	
CAT5 Cable	100ft	20	11.2	Reused	
1/2in PVC	20ft	20	5.6	Bought	5.6
Plexiglass	30x36in	20	35.9	Bought	35.9
Traxxas Servos	5	80	85	2 Reused 3 Bought	34.8
Cameras	3	20	16	1 Reused 2 Bought	8
1in PVC	5ft	10	4	Bought	4
Envirotex Lite	1	20	17	Reused	
4" Enclosure	1	80	90	Reused	
Flange	2	60	58	Reused	
Dome Cap	1	40	39	Reused	
14 Hole Cap	1	40	28	Reused	
Penetrators	14	100	126	Reused	
Video Cable	3	50	33	Reused	
18 AWG Wire	200ft	40	44	Reused	
1in Click Clamps	2	5	3.5	Reused	
4in Click Clamps	2	20	25	Reused	
Zip Ties	1	5	3	Bought	3
Tether Wrap	50ft	50	45	Reused	
Joystick Potentior	3	20	30	Reused	
Potentiometer	2	3	2	Bought	2
Syntactic Foam	1	100	84	Reused	
Ender Printer	2	300	350	1 Reused 1 Bought	175
Printer PLA	3	100	60	2 Reused 1 Bought	20
	Total	2103	1989.2		288.3

Company Organization

Fig. 10 Budget Data including reused parts.

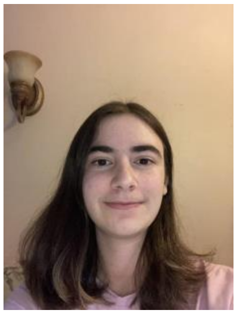
Sound School Technologies includes only three members. In each meeting we held we would alternate between who would lead the meeting and who would take notes, so as to share the responsibilities. We followed Robert's Rules for Order as a means of making decisions fairly.

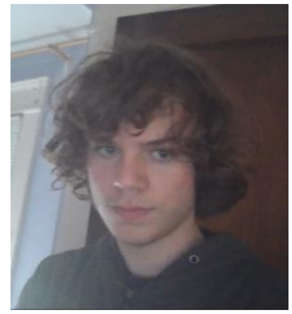
This meant we would hold a vote on all decisions proposed, to make sure everything was properly discussed, and everyone got a say.

Challenges Faced

As the coronavirus meant we would be holding class online, we needed to work on the project over a long distance. There were delays in the building as parts such as servos and cameras needed to be dropped off at our houses. We needed to find and learn how to use an online program that could design pieces and share them with each other. We needed to coordinate in class who would print and assemble what at home. We each needed a 3d printer to be set up in our homes, and we had to deliver printed pieces to one another. Another major problem we faced was finding time and an area to test our ROV in a pool. In previous years, the Sound School has had free access to pools of neighboring high schools, but as a result of covid it was much more difficult to plan.

About Us-Team Members





Team members (from left to right.)

Willow Schreiner - I am a new member. I go to the sound school with the rest of my teammates. I mostly help with brainstorming, writing, and prop building.

Oliver Mackinnon - I'm a returning member who has competed in three competitions before this. I am the main programmer on my team, but also help out with 3D design, part assembly, and electrical engineering.

Rowan Hampson- This is my first year attending the MATE Competition. I helped with designing, organizing meetings, and constructing.

What We Learned, and What We Could Improve In The Future

Something we could have improved on was planning. Keeping on top of deadlines is important. If they get missed, they must be completed as soon as possible. Planning ahead provides the team with direction to move forward in. We often had times where we were at a loss of what to do even though the project was not close to being completed. Better planning could have helped resolve this issue.

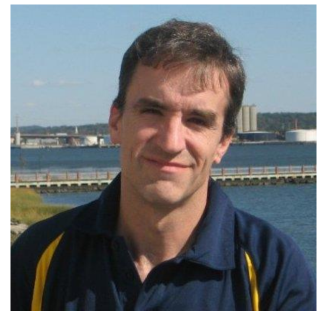
Another key component to success is knowledge. One of the most important things we missed was getting prior knowledge before starting a project. We would work on a specific aspect for a week, and then encounter a problem where if we had better prior knowledge before starting the problem could have been avoided. In the future, members of our company will read and gain knowledge on a subject prior to designing.

One of the biggest obstacles we faced was Covid-19, but we learned how to work around that by communicating through google meet and discord. We got hands on work done by meeting at a designated member’s house to carefully work on the ROV. In the future hopefully Covid-19 won’t be as big a concern so it’s easier in future years to complete group projects.

Acknowledgments

We would like to thank MATE for hosting a competition to expand our knowledge, and giving us the opportunity to compete.

Thank you to Dave Low for devoting a significant amount of time towards improving our team work, and giving useful feedback to us when we needed it.



Thank you to the people on arduino.cc, Programming Electronics, and CodeHS for their help while programming the ROV.

Thank you to the people at OnShape for allowing us to use their program for 3D design

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