TENNESSEE HIGH SCHOOL
Bristol, TN, USA

TECHNICAL REPORT

MAROONED MARINERS

2021 MATE ROV COMPETITION- RANGER CLASS

MEMBERS

Corbin Finch: CEO, Electrical Lead
Luke Ragan: COO, Design Lead
William Burriss: Software Lead
Amy Shi: Marketing Lead
Keona Fielitz: CFO, Marketing Advisor
Cyrus Case: Strategy Lead & Pilot
Caden Cartwright: Mechanical & Financial Advisor
Liz Chen: Marketing Advisor
Ella-marie Finch: Safety Officer

TEAM MENTORS

Lori Givney
Joseph Slone

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ABSTRACT

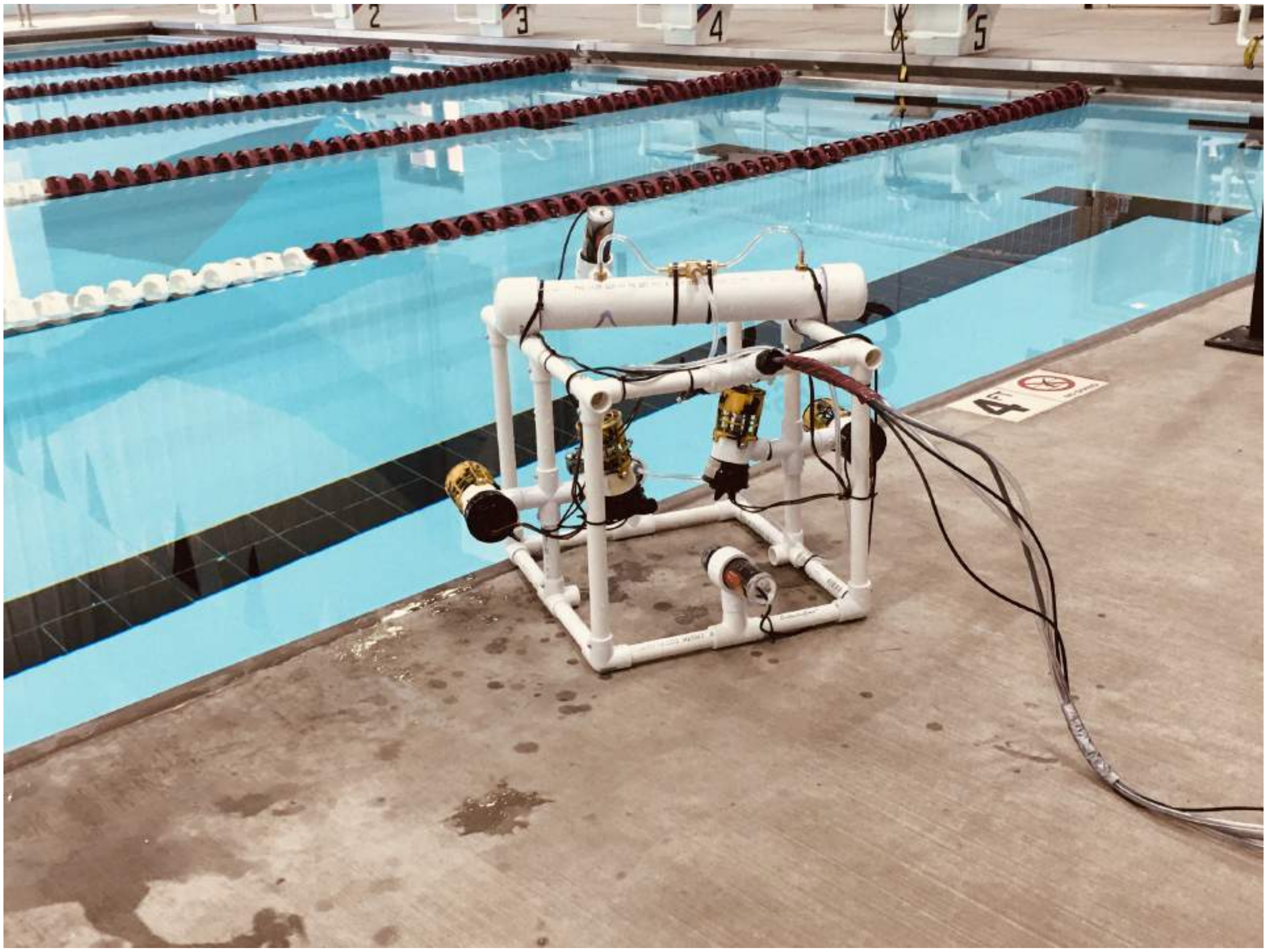


Image 1.0: Wasser Würfel sitting next to the pool side.

The Marooned Mariners is a company dedicated to improving the environmental crises that are affecting the lives of people all over the world. We realize the serious consequences of decades long pollution, deforestation, and other harmful actions, and we are moving towards reversing these adverse effects starting with our ROV, Wasser Würfel. Our team has dedicated hundreds of hours and resources to develop a prototype that is safe, efficient, and effective. It is able to remove debris from the water, disconnect power to Seabins, and perform many other tasks while ensuring that it leaves no waste behind or harms any wildlife. Despite starting the company this year, we are committed to providing our best work in regards to our ROV to combat the climate crisis. The technical report below details our design process, background information, and budgeting documentations to provide assurance on the reliability of Wasser Würfel.

TEAMWORK

COMPANY EFFORT

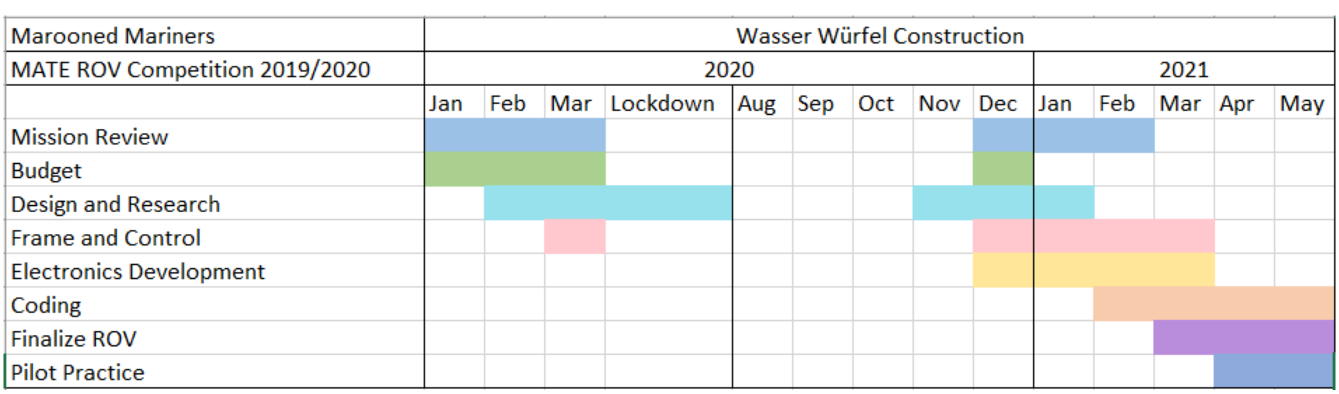
This year posed special challenges to the Marooned Mariners due to the pandemic. Throughout the project many team members were either online learners or they were quarantined due to contact tracing. In order to make sure these students were still able to contribute, our online communication was drastically increased. We used google drive and zoom to coordinate what tasks needed to be done. As a general rule, the in-person team members were responsible for physical tasks, and the online team members took responsibility for everything that could be done without the ROV itself. We also designated tasks based on training and background knowledge. For instance, William was largely responsible for coding because he had the most knowledge and experience in the field. By divvying up the taks like this, we maximized each person's contributions to the team.

PROJECT MANAGEMENT

Each member of the team has a dedicated role to ensure completion of tasks. Alongside CEO, COO, and CFO roles, many team members have roles like electrical lead, design lead, software lead, marketing lead, and strategy lead. Other team members in non-leading roles have advisory roles to assist their group's leader in their designated task. Roles are assigned based on any member's interest, experience, and involvement in that specific field. Many team members online due to COVID took on roles related to finances and planning, which allowed them to work from home while still contributing to the team.

BUILDING SCHEDULE

Our building schedule began for the previous year's competition due to the cancellation of MATE events. However, we managed to continue to plan throughout the lockdown using virtual means. We started back the following year after our VEX season with a sturdy foothold to start from. Although this was good for our ROV's development, it also meant our schedule was disjoined and required adjustments.



DESIGN RATIONALE

The process that we used in order to design our ranger was heavily influenced by the Engineering Design Process. From the beginning, we came together to look at the entire project as a whole and decide which task we wanted to concentrate on. Because this year's competition was recycled from last year's missions, we started this brainstorming process at the start of the last MATE underwater robotics season. We all brainstormed and compiled our ideas about frame design and other parts of the building process together. Finally, towards the beginning of March of 2020, we decided on specific features such as the frame and claw design, and the general layout for our electrical system. Throughout the building process and as we ran into certain obstacles, we often revisited the Engineering Design Process in order to revise our designs and overcome our obstacles.

Frame Design

The design of our underwater robot was built onto the frame design that came with the TriggerFish kit. We wanted a design that was simple so that if any changes needed to be made during the process of building, it could be done easily. Our robot is a cubic shape, thus its name, Wasser Würfel (Water Cube).

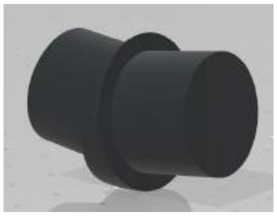
Image 1.1: Cube-shaped Frame

Choice of Materials

PVC pipes were used all throughout the frame of the ranger. We used PVC because it is lightweight and easily accessible. It is also relatively inexpensive. We used VEX materials to create our claw, which is used to collect pollution in order to complete the Pollution task. It was a repurposed claw that was used during our VEX season.

Mechanical Systems

3-D Printed Parts



Many of the parts in our system were 3-D printed. We chose to 3-D print parts so that they could be customized to fit our specific needs. Our 3-D printed parts include all of the motor attachment brackets, the shrouds, the raspberry pi enclosure, and the protoboard support piece.

Image 1.2: Angled Motor Bracket

Claw (Repurposed):

The Claw we chose to use is a modified VEX claw. This claw uses gears to open both claw arms at the same time. It was originally designed to use an electric motor to open and close the claw, but for the purposes of MATE we decided to change this. Instead of using an electric motor, we chose to use a manually operated hydraulic system to open and close the claw. There is a syringe on the claw and a syringe at poolside. For our purposes two simple 10cc syringes were the best option. When the syringe at poolside is pushed it forces the claw open, and when it is pulled, it closes the claw. We first tested this pneumatically and then moved on to the hydraulics because the power transfer works more efficiently.

Image 1.3: Hydraulic Claw

Motors (New):

For our propulsion system, we used the original motors that came with the Triggerfish kit from MATE. These motors seemed robust enough, and they attached easily to our PVC frame as they came inserted into PVC rings. We paid careful attention to the placement of these motors to allow for the best maneuverability. Two motors are oriented horizontally on the left and right for surge and yaw, and the final two motors are oriented 15 degrees from vertical in the center of the ROV, and provide heave, sway, and some small roll.

Image 1.4: Motor in PVC Ring

In order to get the inner motors to be at an angle on an entirely square frame, we 3D printed two brackets that fit inside the PVC but provide a 15 degree turn.

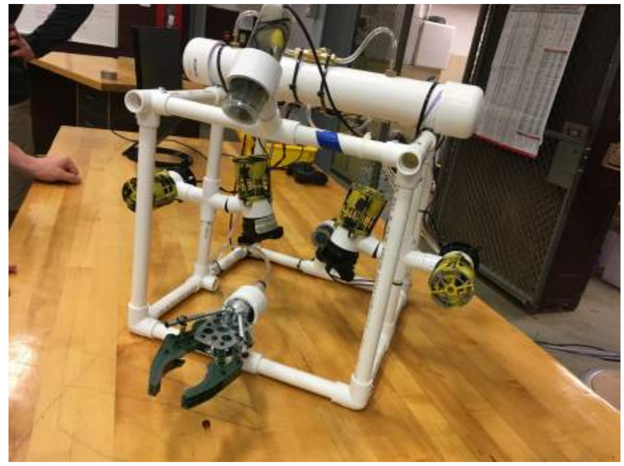


Image 1.5: The ROV and the motors

Variable Ballast Tank (New):

In order to increase buoyancy at low depths, we added a variable ballast tank. This tank is initially filled with water when the ROV departs, but has the ability to fill with air when needed. This is accomplished by a pneumatic system that links the tank with a pump on the surface. When we need to come up quickly, the team member manning the pump fills the variable ballast tank with air, and the buoyancy dramatically increases. Our testing has shown that the tank can increase buoyant force by roughly 1.5 Newtons.

Image 1.6: Variable Ballast Tank

Electrical Systems

Raspberry Pi 4 (New):

We chose the Raspberry Pi 4 for its on-board bluetooth capabilities, as well as its ability to output PWM signals to our Sabertooth Motor Controllers. We are powering our Raspberry Pi via a 5v converter that draws its power from the monitor block on the backplane.

Monitor (New):

We purchased a new monitor dedicated to the Raspberry Pi, which came in a kit with mouse, keyboard, and HDMI cable. This will be our primary display, and will let us also write and test new code directly on the Raspberry Pi.

2 Sabertooth Motor Controllers (New):

We used these Sabertooth Motor Controllers because they were what was provided with the basic triggerfish control box.

Low Pass R/C Filters (Custom):

In order to connect the Raspberry Pi to the Sabertooth Motor Controllers, we needed to pass the PWM (pulse width modulation) signals through a resistor/capacitor filter. This required we build 4 of these filters, and then solder them onto a piece of protoboard. The filter is necessary to level out the PWM into a constant voltage that the motor controllers can read.

USB Capture Card (New):

To get the RCA video signals from the backup cameras onto the Raspberry Pi, we needed to use a USB capture card to convert analog to digital. As we decided to use the monitor that came with the triggerfish kit for one camera, we only needed one capture card for the other.

Generic Bluetooth Controller (New):

Because we purchased a Raspberry Pi with bluetooth, it made sense to additionally purchase a bluetooth controller. This will allow us to communicate with the Raspberry Pi wirelessly, additionally allow us to custom code new processes on the controller itself.

Cameras (New):

Our robot has two cameras, one at the front top of the rov, and one at the back bottom. These cameras are both originally backup cameras, and provide their video feed via RCA analog signals. The one in the front, camera 1, is configured vertically at the front and points downward to accurately navigate depth. Meanwhile the camera at the back bottom, camera 2, is configured horizontally and points forward to accurately navigate the distances in front of the camera. Both cameras were waterproofed using potting epoxy and the MATE waterproofing kit.

Control Box

Our control box is neatly packed into the yellow pelican box that came in the MATE triggerfish starter kit. We modified the original control box in many ways to fit the new hardware and electronics we would be using. We first removed the joysticks and designed an enclosure that fit under the faceplate and held the Raspberry Pi secure, then designed a plate with standoff holes to hold the R/C filter protoboard. The Raspberry Pi enclosure screwed into the faceplate with the holes originally used for the joysticks, and the protoboard was hot glued to its supports, and in turn the support was velcroed to the inside of the box for easy removal and servicing. We made sure to keep cooling in mind, so the Raspberry Pi attaches beneath the right joystick hole, and allows it's fans to draw fresh air in and past the main board.

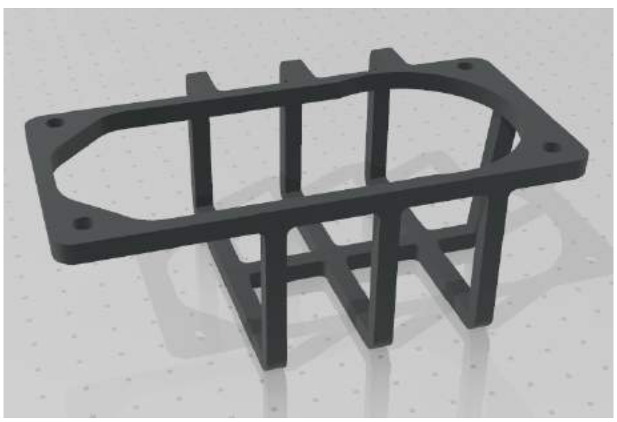


Image 1.7: The Raspberry Pi enclosure

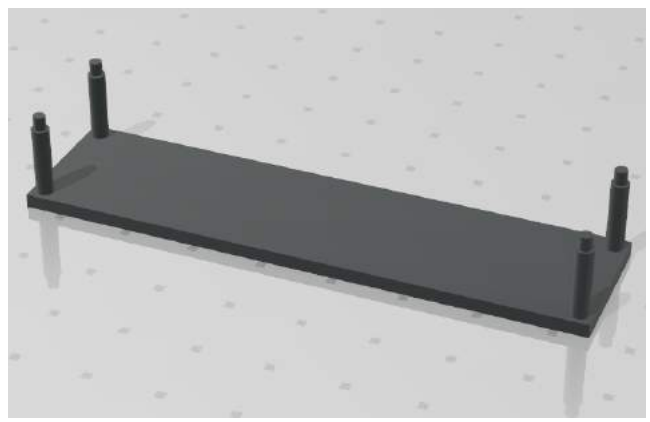


Image 1.8: The protoboard support

As we decided to power the Raspberry Pi entirely from the control box power, we needed to step down the voltage from 12 to the 5v required by the Pi. To do this, we included a 5v converted, which we velcroed to the underside of the faceplate acrylic. This 5v converter draws its power from the monitor terminal block located on the backplane of the control box. It then feeds into a USB type-C power connector that powers the Raspberry Pi. We are currently only using two of the four USB 2.0/3.0 ports on the Raspberry Pi, one is devoted to the USB capture card (located near the RCA out ports on the backplane), and the other is for a USB 3.0 hub which is housed on top of the faceplate for easy access. This USB hub is for the mouse and keyboard and fits right below the box monitor when the lid is closed. To get video feed from the Raspberry Pi onto our main monitor, we have a micro-HDMI to

HDMI cable that comes out of the left joystick hole, and when the control box is closed, it fits neatly inside.

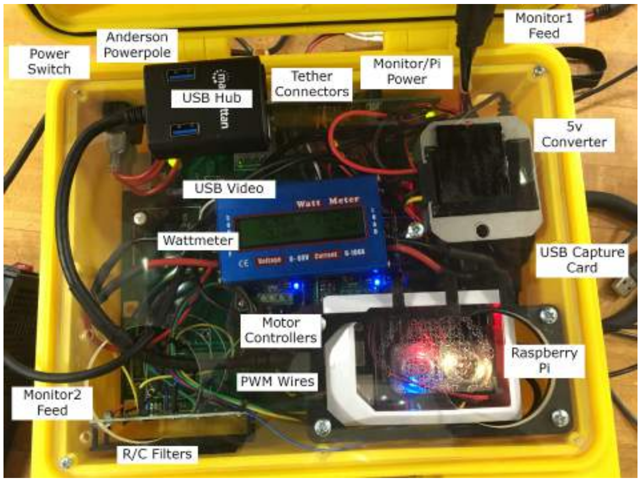


Image 1.9: Labelled interior of the Control Box

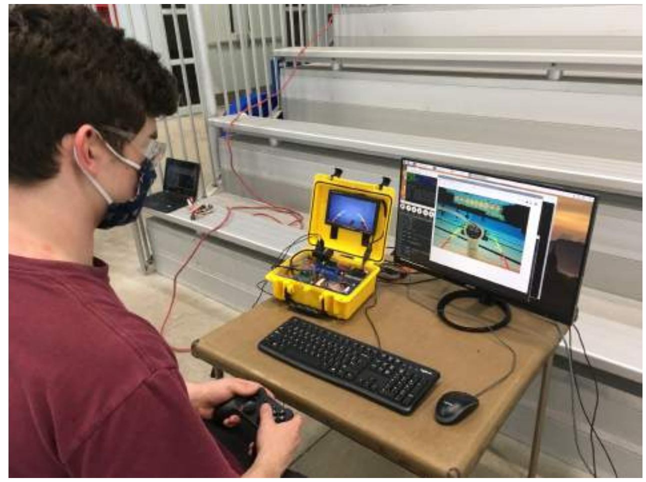


Image 2.0: Cyrus driving at the assembled control station.

In order to communicate properly with the Sabertooth Motor Controllers, we needed to output between 0 and 5 volts of power. The main difficulty we had was that the hardware-dedicated PWM (Pulse-Width Modulation) pins on the Raspberry Pi could only provide up to 3.3 volts of power. To solve this problem, we turned on the 4 times sensitivity option on the motor controllers, which allows the same 2.5 volt zero point, but now the low is 1.725 volts and the high is 3.125 volts. Each PWM line passes through a 10k resistor then leads to each assigned serial port on the motor controllers. A .1 uf capacitor is attached behind the 10k resistor and leads to ground, to level out the drops in voltage between each modulation.

Tether

In order to keep the ROV as mobile as possible, we tried to keep our tether light while still maintaining proper control of the underwater systems. We have two RCA/Power cables going to each of the onboard cameras, one sub-tether containing all of the motor power cables, one hydraulic line, and one pneumatic line. We didn't have any luck with the tether sheathing provided by the MATE triggerfish kit, so we decided to simply wrap the 5 meter length in duct-tape every half meter. We may begin to implement pool noodles every meter to reduce the weight of the tether, but we have not had enough testing to determine whether this would be beneficial or not. The tether is strain-relieved at both ends. Bottom Side, the tether passes through the basic MATE strain-relief cross. Topside, the tether is attached in various points, but the main cable is strain-relieved using the MATE control box attachment.

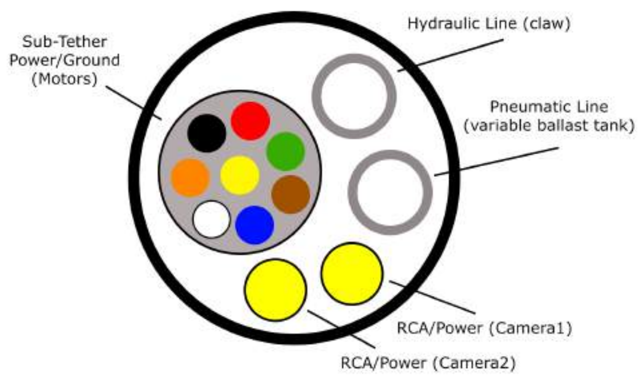


Image 2.1: Cross section of the tether

Image 2.2: The wound up tether

Software Development

Controller

The controller being utilized is a bluetooth Sunwaytek gamepad style controller. This has been linked to a raspberry pi which does all of the control calculations. The raspberry pi receives ~2.5 amps of power from the Pufferfish control box, and does not advance the amperage beyond the specified limit.

The raspberry pi processes the controller inputs, and uses those values to determine how to send outputs to the sabertooth motor controllers. The raspberry pi reduces the average output power through the use of pulse width modulation. The raspberry pi does this by calculating the intervals at which to send pulses to the sabertooth motor controller. By increasing the time between pulses, the average power output is reduced, and can be modulated based off of controller input. This system allows an external controller to communicate with the motors.

Interface

Programing interface:

- The raspberry pi utilizes the programming language python for all of the backend code. Our team chose python due to its high level of abstraction and subjective ease of use. However more importantly, python was the language that most of our team members - who knew how to code - were most comfortable with. Python, being as popular as it is, also has numerous libraries which we utilized. These include: flask, evdev, and numpy.

- Flask, a web micro-framework, was used to dynamically send html files locally on the raspberry pi. This allows data to be streamed from the camera and controller directly onto the screen via the http protocol.
- Evdev is a library which allows linux input events to be detected in the python interface. This was utilized to detect controller inputs.
- Numpy is a library that allows for the manipulation of large arrays in the python programming interface. This is required for our controller program to work efficiently.

Operating system

- The raspberry pi used raspbian as an operating system. This is a distribution of linux - more specifically debian - which has been adapted to adequately suit the raspberry pi.
- Our group chose raspbian due to its popularity, ease of use, and performance on the raspberry pi.

Monitors

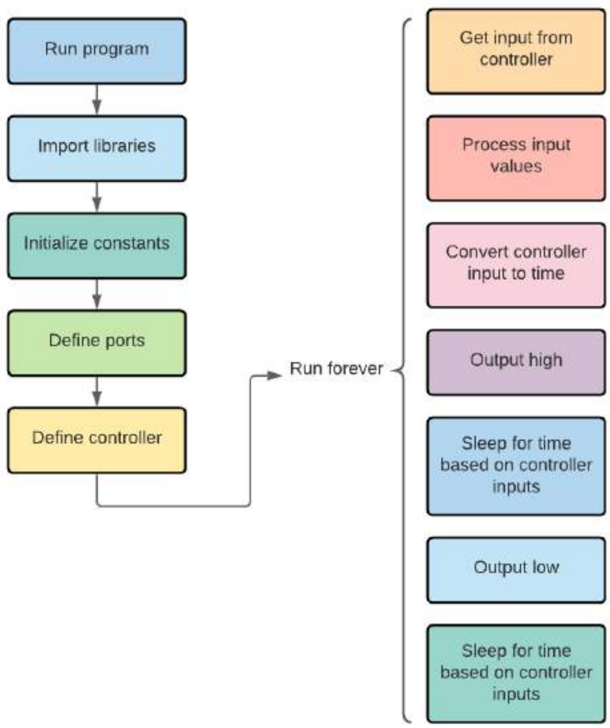
- The main monitor setup consists of a mid-size acer computer monitor which is linked to the raspberry pi. The raspberry pi receives video feed from the backup camera which has been routed through the control box and into a USB capture card. The raspberry pi then processes the video and displays it on the monitor.
- The secondary monitor is the included pufferfish backup camera monitor, this is linked directly to the control box.

Graphical User Interface

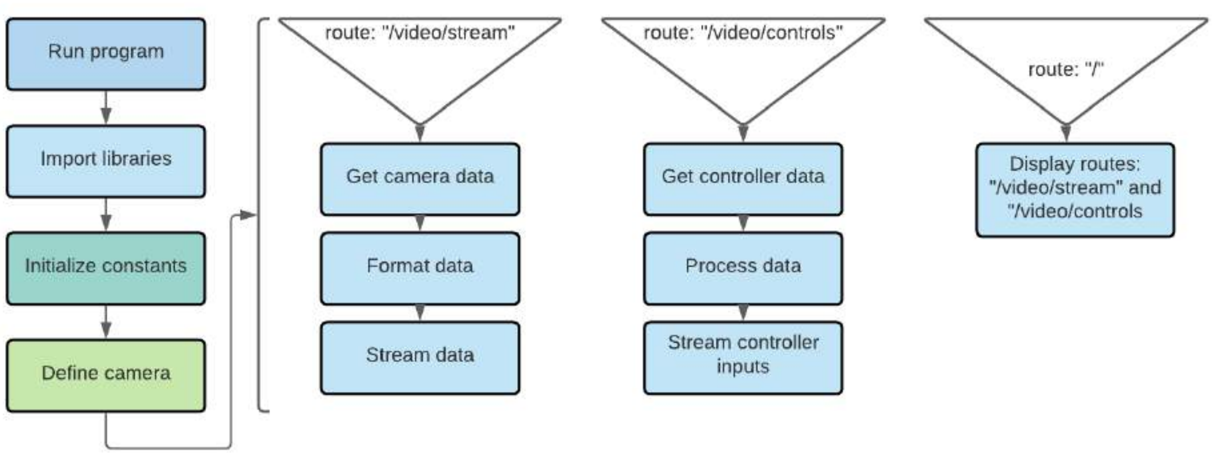
- The main camera is connected to a raspberry pi for the purpose of processing. The image values are first retrieved from the camera one frame at a time. These values are then streamed over a web server running locally on the raspberry pi. The video is then overlaid on another web server path. This path also contains data about which controls are being detected by the raspberry pi and places them on top of the video. The final result is a video feed with live controller overlays.
- The graphical user interface was programmed in JavaScript, utilizing HTML and CSS.

Software Flow Diagrams

Motor Control

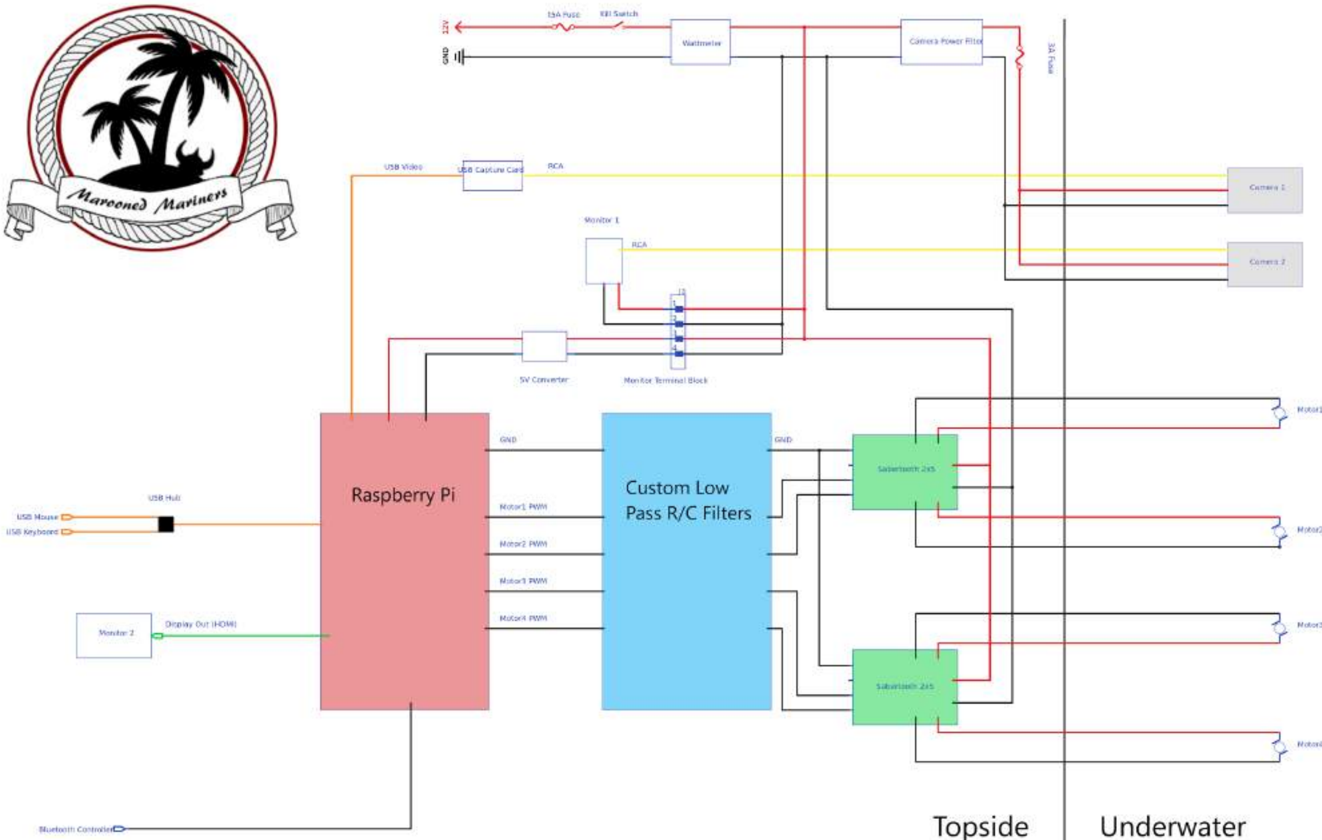


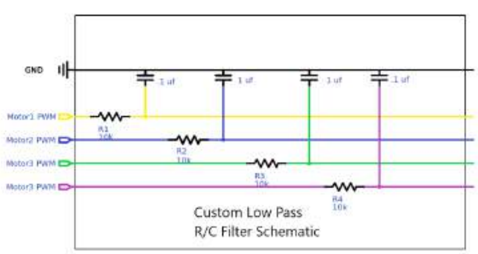
Camera interface



SYSTEM INTEGRATION DIAGRAM (SID)

Electrical SID:



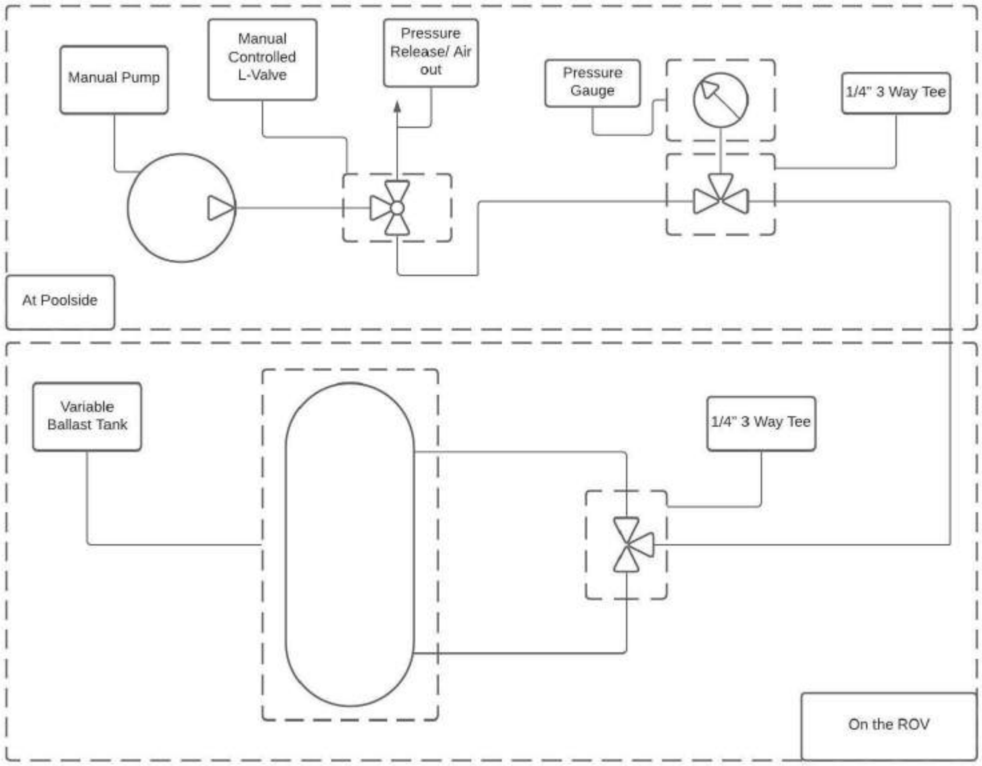


Fuse Calculations:

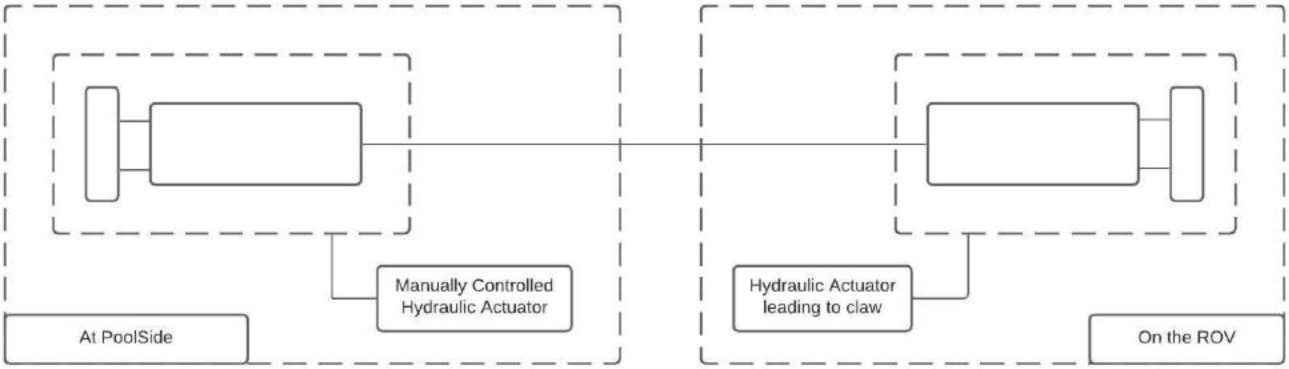
Thrusters: 2.5 A each x4 = 10 A
Raspberry Pi (including USB peripherals): 3 A
Cameras: 150 mA each x2 = 300 mA
Monitor1: 200 mA

150% x 13.5 = 20.25 A total < 25 A

Pneumatic SID:



Hydraulic SID:



SAFETY

Company Safety Philosophy

The safety of the team members and all those in the near vicinity is of great importance to the Marooned Mariners. All members were instructed in safety precautions and basic rules to keep everyone safe. As well as having members uphold the principles of caution, a responsible adult was present at all meetings.

Safety Standards

In order for someone to work with any type of tool, they first needed to receive training and guidance for that specific device. While working with or being around any moving parts, all team members were required to wear safety goggles and proper clothing/footwear. Some other activities required additional protection, such as gloves, to minimize teammates exposure to dangerous substances/hot objects. To minimize tripping over stray objects, wires were kept in neat coils or marked for greater visibility.

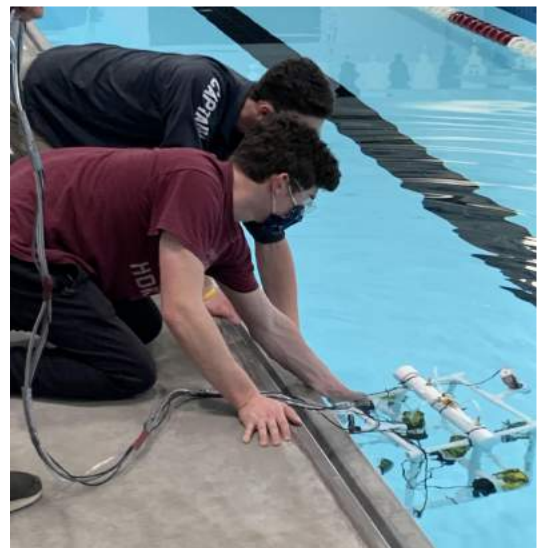


Image 2.3: Teammates observing safety protocols while launching.

Safety Features

To ensure that safety requirements are met, we have put several safety elements on the ROV. The control box has a 25 amp fuse, meaning a short will immediately shut down the control box and ROV. Additionally, the ROV will not be plugged into the control box until the Raspberry Pi has safely booted up and began its operation features. All motors are entirely enclosed. This includes the propellers, whose shrouds are also painted bright yellow. The ROV also contains two cameras that are constantly monitored while the ROV is being operated. All edges are rounded to keep those handling it safe. Also, every cord or wire that exits the ROV is strain-relieved to reduce the chance of breaks in wires or hydraulic/pneumatic lines. This means the entire ROV can be lifted via the tether, if necessary because of immobilization.

Safety Checklist

Phase	Requisite
Building the ROV	Tether, control box and ROV are arranged in a stable position before being worked on
	Thrusters are off above water
	Team members are appropriately dressed with closed-toed shoes, hair tied back, safety goggles, etc.
	Members warn those around them before using any hazardous devices or materials
	Members are correctly instructed on tool usage before handling
	Everyone is fully informed about emergency procedures and locations of first-aid kits
	There is at least one adult supervising each meeting
Launch/ Retrieval	All ROV components are secure
	There are no sharp edges
	Wires are not exposed, but kept neat
	Control box systems are initialized before attaching tether
	Thrusters are covered by securely attached shrouds
	Any electronics are completely waterproofed
	Tether is in a safe place, untangled and with all strain relief functional
	Member carrying ROV is holding marked handles and following lifting procedures as to not harm their back
	The environment is safe for operations
	One adult is present at any testing
	All members are fully informed about all emergency procedures regarding the ROV

CRITICAL ANALYSIS

TESTING AND TROUBLESHOOTING

During the testing process there have been many observations made whether that be the structural integrity of the ROV or even how well the camera quality is underwater.

Electrical:

- We were having trouble with the control box not sending power to the whole box and getting video feed from the cameras. It turns out the backplane had messed up and it would in the end be easier to make a new one so that's what we ended up doing.
- For what we were trying to do we needed to make our own circuit board so we used jumper wires and protoboard to make that board.
- We tested the camera feed multiple times and could never get the second camera to show any feed, but we ended up having to unplug a wire from the previously mentioned protoboard and it ended up working.
- There were a few times our motor controllers would overheat just from the very compact stuffy layout of our control box. There was no real way around this but it didn't happen so often for it to be a problem so we would just replace them.
- We ended up installing a watt meter for monitoring the control box.
- For the power connector on the tether cable we had to solder a new one for the motors.
- We would frequently check all soldering to ensure proper connections between parts.

Structural:

- We have a PVC frame that we had just dry fit together until we had decided to screw it together using self tapping screws.
- For a quick way to come to the surface it has a variable ballast tank hooked up to a bike pump that we fill with air and manually fill it back up with water when we need it to go back underwater.
- We 3D printed shrouds to go around the propeller blades so as to not get hurt by them as well as keep anything from getting tangled in them.
- We had air leaking out of the air tank so we used epoxy where the brass fitting went into the PVC, and PVC cement on the end caps.

CHALLENGES

One of the most challenging obstacles to overcome was the wiring in the control box. As we added the Raspberry pi, the space inside of the control box drastically decreased. The raspberry pi brought a power converter, a USB cord, and another circuit board with it. This made fitting all of our wiring into the control box difficult to say the least. This was largely solved with the 3-D printing of the Raspberry pi enclosure and shortening many of the wires that are in the control box. This was very time consuming, but it produced a final product that was able to fit within the control box and be easily transported. Another major problem faced was the transfer of information for documentation. Many of our team members were not able to work on the ROV in-person. These members, enthusiastic to help, largely volunteered to work on the documentation of the ROV. We experienced a problem, however, in the transfer of information between the online and in-person team members. To solve this problem we experimented with many different forms of communication. Finally, we found that Zoom and Google Drive provided the transfer of information that we needed. There were also numerous small challenges faced in the ROV itself. Things as small as motor angles, tether management, and assembling pneumatics were time consuming obstacles.

LESSONS LEARNED

As the Marooned Mariners continued throughout the season many lessons were learned along the way. We learned that the 5V port on the sabertooth motor controllers was actually a power output. This knowledge came as a shock when the Raspberry pi was being powered from the motor controller. We also learned that when calculating buoyancy it is best to make the ROV positively buoyant. It is much easier to add more weight than it is to add more flotation. We also learned the value of a wide view of the area through our experimentation with camera angle and position. Perhaps the biggest lesson we learned, though, is just how important communication is amongst team members. This problem is addressed multiple times throughout this document because of how drastically efficiency improved after we were able to effectively communicate.

BUDGETING

Budgeting is very important to our team. We made sure to keep track of all our receipts and purchases throughout the season. Most of our materials were purchased and not re-used since this was our first year doing MATE. The table includes the price of each item, all the items totaled, and the grants we received. Good accounting is crucial to running a smooth and efficient business. Organized budgeting contributed to an organized design process.

	Project Expense and Budget		
	Item/Expense	Type	Amount
Components	1 SeaMate TriggerFish (Rev4), Video System Kit, SKU 3 ACC-6046-AA-01	New	180.00
	1 SeaMate TriggerFish ROV Kit (Rev4), SKU 3-TRG-3051-AD-01	New	725.00
	12V Converter 24V to 5V Step Down	New	12.99
	Vlts to Digital Converter USB	New	19.98
	Total		937.97
Materials	2- 1in. SCH40 CAP	New	1.69
	8- 1/2in. SCH40 SIDE OUT ELB	New	13.52
	2- 1/2in. X 10ft. 315-PSI PR	New	3.86
	5- 2-1in. PVC DWV	New	10.80
	BH PPH SELF DRL 8x1/2 100	New	5.69
	1/4in. X 1/4in. FIP coupl	New	4.21
	3/8in. X 1/4in. FIP coupl	New	5.02
	3/16in. BARB x 1/4in. MIP	New	3.31
	16 Gauge Red Primary Wire 25	New	5.42
	16 Gauge Black Primary Wire	New	5.42
	NIGO Industrial 3 Way (L Port) Ball Valve	New	24.79
	DBI Side PC13 Board Prototype	New	12.99
	Jump Wires M to F 12in.	New	17.98
	Kobalt 1/4in. Bottom mount	New	12.34
	5- 1/8in. Barb x 1/4in. MIP	New	20.50
	PTFE Tape 1/2in x 43ft.	New	1.89
	2- 1/4in. FIP TEE	New	9.89
	2- 1/2in. MIP x 1/4in. FIP B	New	9.89
	1/4in. HEX Nipple	New	2.85
	Total		176.96
Tools	WOODS 6in. Long Nose Plier	New	8.54
	SW wire Stripper U-Notch	New	5.69
	CO 10in. Straight Jaw Lock	New	13.29
	SW USA Wire Stripper Basi	New	10.44
	Bicycle Pump	Owned	19.96
	Total		18.00
	Travel		90.00
	1,095 Hours of Labor		
Donations	American Society of Engineers		150.00
	Less TV Robotics Grant Discount		800.00
	Strongwell		300.00
	Total Donations		1250.00
	Total Amount Spent		1202.93
	Total Amount Remaining		27.07

ACKNOWLEDGEMENTS

We want to extend a special thanks to the American Society of Engineers and Strongwell Corporation for their generous donations toward our team and our robot. Another special thanks goes to Bristol Tennessee Essential Services and the Bristol Chamber of Commerce for their continuous support of our team. We also wanted to thank our wonderful mentors, Lori Givney and Joseph Slone, for lending their guidance, time, tools, patience, and encouragement as we went through this process. We want to thank Tennessee High School for allowing us to use their facility. Lastly, we would like to thank our entire team for showing up and dedicating so much time and effort into this project.

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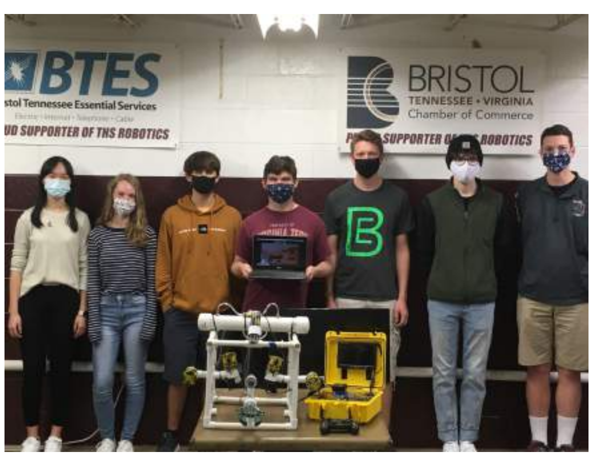

Image 2.6: Team Members