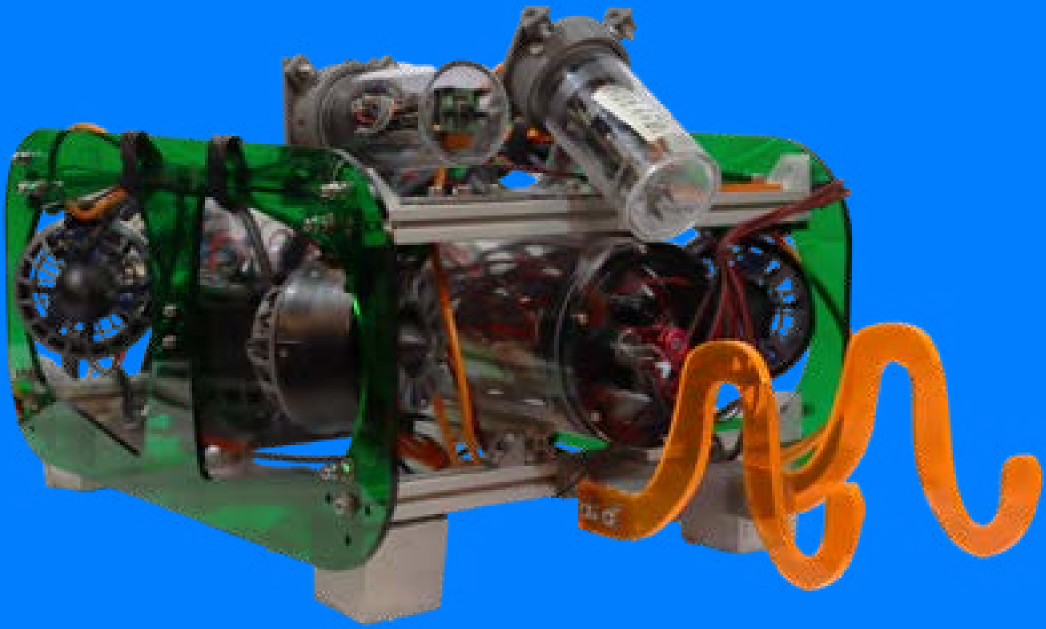
JUNE 2023 ISSUE 02 MATE ROV 21

Sunk Robotics

TECHNICAL REPORT 2023



CEO - Matthew Harris

CFO - Noah Gibson

Government Affairs - Zachary Bertocchi

Electrical Project Lead - Scott Campbell

CAD Project Lead - Aaron BenDaniel

Research and Development - Benjamin Wirz

Prop Design and Testing Lead - William Tseng

Mentor - Samuel Christy

Mentor - Noah Lewkowitz

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Abstract

The 2023 MATE ROV Competition is Sunk Robotics's second year of competing. This year, rather than completely overhauling our design, we focused on making incremental improvements to develop a high-quality and reliable ROV. Our ROV is designed to help do maintenance on various aquatic renewable energy sources without endangering human lives. We also worked on making a buoyancy engine that can very power efficiently do vertical profiles.

In this technical document we will go over; how we organized our team, managed our project, approached problem solving, the various structures in our ROV, our philosophy towards whether we will build, buy, or reuse components, our safety procedures, owur troubleshooting procedures, and last but not least our accounting

Potential Clients

The STEVE Model from Sunk Robotics is designed to aid in the sustainability of the world and the oceans through its ability to conduct ecological operations as well as repair technology that combats climate change, such as offshore wind turbines.

The skillset of the robot would allow for our potential clients to include government agencies attempting to handle ecological crises and companies operating offshore windmills.

Project Management

The Sunk Robotics team has employed the skills of members from the Programming and Web Development vocational shop and the Robotics and Engineering vocational shop. We have divided our Sunk Robotics team into individual subteams working on different subsystems of the robot.

In order to keep all of the small teams at the maximum productivity and ensure that there was no duplication of efforts, we had bi-weekly meetings. During these meetings, we made sure that everyone had something to do and that no one was in need of assistance, as well as caught everyone up on how every part of the ROV was working in case someone would not be able to come to later sessions. We utilized Discord as a way to organize communication while keeping all team members informed.

We used Google Calendar to schedule what would be getting done at each of our meetings. We made sure to have clear measurable goals that we would reach over the course of the meeting for each team member.

Before using any resources we did a cost-benefit analysis and searched for cheaper alternative materials. If it was possible we would laser cut a prototype to insure that it was the right size and integrated well with the rest of the ROV. If possible we would design parts to be made on the laser cutter because of its very fast turnaround time. All of the parts in our ROV were designed specifically to complete the mission tasks, so we preferred making very efficient specialized parts rather than expensive and difficult to use general purpose parts.

The Team

Our team is made up of the following individuals:

- ***Matthew Harris*** - Programming and Web Development Shop - Junior
- ***Noah Gibson*** - Programming and Web Development Shop - Junior
- ***Zachary Bertocchi*** - Robotics and Engineering Shop - Junior
- ***Scott Campbell*** - Robotics and Engineering Shop - Sophomore
- ***Aaron BenDaniel*** - Robotics and Engineering Shop - Sophomore
- ***Benjamin Wirz*** - Robotics and Engineering Shop - Sophomore
- ***William Tseng*** - Robotics and Engineering Shop - Sophomore

Our team was supervised by:

- ***Samuel Christy*** - Robotics and Engineering - MVTHS Instructor
- ***Noah Lewkowitz*** - Robotics and Engineering - MVTHS Instructor

Sunk Robotics Roles:

- **CEO** - *Matthew Harris*
- **CFO** - *Noah Gibson*
- **Government Affairs, Chief Marketer and Fundraiser**- *Zachary Bertocchi*
- **Electrical Project Lead, Lead Systems Engineer** - *Scott Campbell*
- **CAD Project Lead, Lead Design Integrator** - *Aaron BenDaniel*
- **Research and Development, Lead ESG Researcher** - *Benjamin Wirz*
- **Prop Design, Testing Lead** - *William Tseng*

Design Rationale

Engineering and Design Rationale

As we built our ROV we took into careful consideration how each change and component would affect our overall performance. Overall we focused on simplifying our designs from last year to make them more reliable and easy to maintain. We knew at the beginning of the year that we wanted to completely redesign the camera, networking systems, and remove the Arduino Uno that we had last year in order to reduce complexity. We simplified our gripper so that instead of a complex moving part, we have a simple hook based manipulator. Our navigation cameras could be placed with less specific consideration because of their wide viewing angle, minor changes to their location would have no functional impact.

Innovation

We created many original solutions to the problems we encountered during the construction of our ROV. For example, our manipulator is extremely simple and while this does reduce its functionality, it is much cheaper, easier to use, and more reliable than a complex mechanical gripper. Some systems in our ROV, specifically our networked cameras, were inspired by other teams' systems. During our participation in the 2022 World Championship we talked extensively with other teams and learned about new methods and ideas that we believed we could employ ourselves. For example, our camera system was inspired by Jesuit Robotics's camera system.

Problem Solving

When a member of our team encountered a brainstorming road-block, other members of our team would convene a brainstorming session to attempt to find a solution for whatever problem was currently being faced. When faced with multiple solutions to a problem, we would carefully consider many factors including cost, time to build, complexity, reliability, and repairability. Oftentimes, we would end up going with the simplest solution as it is usually a good balance of our criteria.

Systems Approach

All team members at Sunk Robotics worked closely with each other to ensure seamless integration of our systems. We always conversed with other team members to ensure that changes would not negatively impact other elements of our ROV. Every component that needs a wire to enter or exit the electronics compartment is a possible vector for leakage..

Vehicle Systems

We selected our materials and components with careful consideration to cost, size, and performance. Because of our access to a laser cutter, many of our parts could be made from low-cost materials such as acrylic sheets. When it came to components such as Raspberry Pis, we would usually go for higher cost but more reliable components due to their high importance and difficulty to replace. We made many modifications to our ROV to better adapt its structure to this year's tasks and requirements. An example of this is how we have specially designed our manipulator to be able to interact with this years' props. We have a hook that is specially designed to hold the half-inch PVC pipe used in the competition.

Software & Control System

Effective software is absolutely critical to having a well-functioning ROV capable of performing complex tasks. While high-quality software, such as ArduSub, does exist, we have instead chosen to develop our own custom software from the ground up. We believe this approach offers us greater flexibility by allowing us to customize our software to work effectively and efficiently with our specific hardware, without all the bulk and bloat of a one-size fits all solution. Additionally, we've found that developing our own software has been an incredible learning experience and has greatly improved all of our software development capabilities.

The "brains" of our ROV is a single Raspberry Pi 4 located inside of an electronic enclosure. The Raspberry Pi runs a custom built Python program called steve-rov that serves as a bridge between the sensors, cameras, motors, and pilot.

The pilot can send commands to the ROV by using an Xbox controller. The Xbox controller connects to a program we've written called steve-controller. steve-controller processes controller inputs and sends this data to steve-rov, which then translates the commands from the controller into the commands that have to be sent to each thruster.

Software & Control System (Continued)

Motion Control

Effective and versatile movement is incredibly important for completing tasks quickly and efficiently. As mentioned later in the propulsion section, our ROV is capable of rolling, yawing, and moving in the X, Y, and Z directions. We've written our own motor control library that converts the coordinates of the joysticks on the game controller into vectors that correspond to movement in a certain dimension, which can then be converted into specific motor movements.

Networking

We chose to have a central, wired network to connect all of our components together. All components, including the Raspberry Pi, cameras, and top-side client are connected to this network. A central ethernet switch located outside of the main electronics tube manages these physical connections. Taking a networked approach ensures very low latency communication and greatly simplifies our wiring.

Camera Visuals

Each camera has a dedicated Raspberry Pi Zero 2 W which runs another custom-built Python program called steve-eye. steve-eye takes camera data, encodes it using Motion JPEG, hosts a WebSocket server that the top-side client can connect to, and sends each frame up to the client. Last year, we struggled with having a higher-latency, low-quality camera feed. This year, having a dedicated computer for each camera module, combined with our homegrown, efficient camera software ensures sub-200ms latency and very high framerates, which has made the pilot's experience much more fluid and responsive.

Stability and Positioning

While versatile movement is incredibly important, stable movement and positioning can greatly aid in the pilot's ability to complete tasks that require focus and precision.

Top-Side Client

The top-side client consists of a laptop running Linux that connects to a game controller used to control the ROV and the central wired network via ethernet. The software on the top-side client consists of a simple web client we've written using plain HTML, CSS, and JavaScript that displays our three camera feeds and the steve-controller program that handles input from the game controller. Rather than having an elaborate top-side control setup with multiple monitors and joystick inputs, we chose to have just one simple laptop and game controller. This greatly simplifies our setup, helps to decrease setup time, and reduces the number of things that can break.

Software & Control System (Continued)

Depth Stabilization

In order to stay at a stable depth, we've developed our own Proportional Integral Derivative (PID) controller written in Python using data from our Blue Robotics Depth Sensor. Our depth stabilization algorithm allows the pilot to turn on a "vertical anchor" that locks the ROV at a specific depth. This specific depth then becomes the set point, and any deviation from it is known as the error. The algorithm combines three different terms: a proportional term responds based on the current error, an integral term which considers previous error in its response, and a derivative term which considers how quickly the ROV is approaching its target depth and reduces its response in order to avoid overshooting the target. Each term has its own gain values that need to be tuned in order to produce an effective response. We hand tuned these values through trial and error to produce a very effective algorithm that keeps our ROV at a stable depth.

The algorithm can be modeled by these two equations:

e(t) = target depth - current depth
Equation 1 - Calculating the error
u(t) = proportional gain * e(t) +integral gain * 0te()d+derivative gain * de(t)dt
Equation 2 - Calculating the vertical motor response

Electrical System

Our electronics are mainly housed on a wooden board inside of a single acrylic tube. We chose to have only one tube because it makes connecting electrical components significantly easier. The wooden electronics board has mounting holes in it that allow for our components to be securely mounted. Inside of the tube we have a 12V to 5V DC converter that allows us to power our logic circuits.

Tether Design

We kept our tether design mostly the same as last year, with the exception of the wire gauge we chose for our zip wire. Last year, we used 16 AWG wire, which, because of its higher resistance, was unable to handle high amounts of current. This led to an issue where the voltage would drop when we would attempt to run our thrusters at full speed, causing our entire system to shut down. As a result, we were forced to reduce the speed of our ROV, negatively impacting our ability to complete tasks. This year, we chose 10 AWG wire, which is able to handle much higher current, allowing us to run our motors at full speed without any issues.

Like our previous design, communication from the ROV to the surface is done through a single Cat 6a ethernet cable, allowing for a thinner overall cable than many competing ROVs.

Trade Offs

When faced with trade offs between power consumption, cost, performance, and mission requirements we have attempted to keep an even balance. We have been able to keep the total cost of our ROV at a reasonable level while also having sufficient performance. We have, admittedly gotten less practice than we'd hoped with piloting the ROV due to our lack of regular access to our high school's pool.

When deciding which camera design to use, we needed to make a compromise between size and reliability. We designed many different cameras that were smaller than what we ultimately went with, but most of them were unreliable.

We opted to use lower gauge wires in our tether. Although this makes the tether heavier and less nimble, it solved the problem we were having with voltage drop when delivering large amounts of power. This change made our ROV more reliable and allowed us to run our thrusters twice as fast.

Build, Reuse, Buy Philosophy

Sustainability is of utmost importance to us at Sunk Robotics. As a result, we value recycling and reusing parts, and a large majority of Sunk's STEVE ROV consists of parts made locally and resourcefully in our Robotics and Engineering shop. Many of our components from last year, such as our thrusters and Raspberry Pi, were thoughtfully designed and work efficiently, so we embraced the philosophy of "if it ain't broke, don't fix it." While we try to build as many of our own parts as possible, there are some situations where we may have to buy certain parts for the ROV. For example, if there is a part that we do not have the ability or time to produce, then we may have to purchase whatever it is that we need.

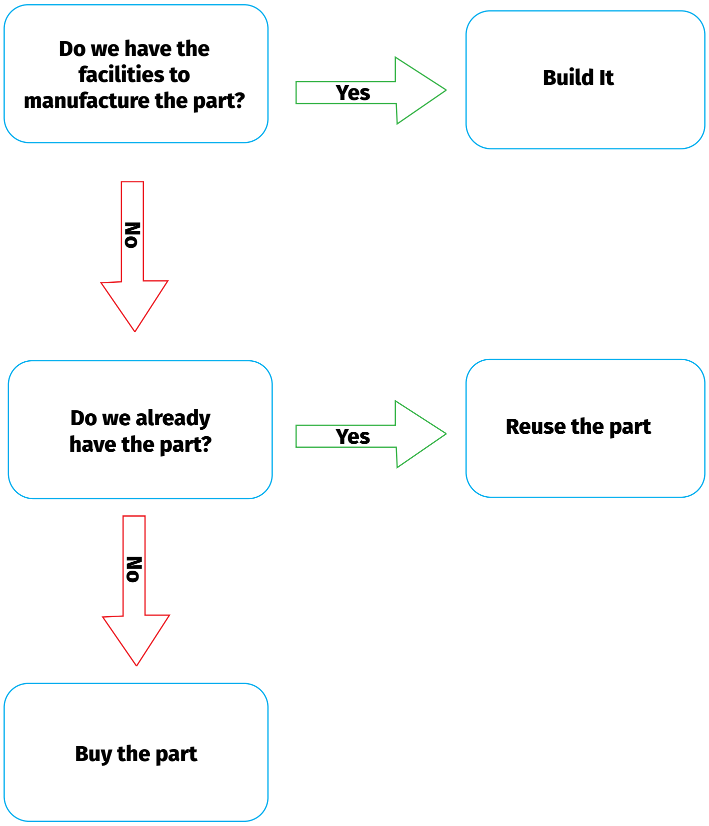

Figure 1: *Build, Reuse, Buy Flowchart*

Body

The STEVE ROV frame was designed in the Robotics and Engineering shop at MVTHS. This year we reused the frame made of two side panels made out of green 6mm acrylic and connected using a structure constructed using four 80/20® modular T-slotted profiles. In addition, we reused the electronic tray from last year with modifications for the addition and removal of certain components. Mounted on top of our seals are clear acrylic end caps cut using our laser cutters. We opted to make these end caps not only to save some money, but by manufacturing them ourselves, we can make them custom to our needs. This year we have also reused our 100mm acrylic enclosure, which was purchased from Blue Robotics and cut to size here in shop. The only two pieces of the structure that were not manufactured or manipulated in shop are the O-ring Flanges and the Blue Robotics penetrators. Our reason not to manufacture these parts was because we did not feel confident in manufacturing penetrators as they a crucial to the survival of the ROV and need to be very precise; next year we plan on attempting to make our own O-ring flanges in shop.

This year’s structure contains a few new components. For the 2023 competition, we have added:

External camera housings
External waterproofed ethernet switch
Modular manipulator system

All of the new components listed above were both designed and manufactured in the shop. Theability to manufacture our own parts significantly reduces the cost of each part and as such, many parts are far cheaper to produce than if we had bought them.

Figure 2: *CAD Model of STEVE ROV Frame*

The Ethernet Switch

All of our cameras and our central Raspberry Pi 4 communicate with each other and the surface control station over ethernet. In order to connect all of the devices together, an ethernet switch is required. We use a stripped-down TP-Link 8-port Ethernet Switch. We removed the plastic casing to reduce the component's size. The bare PCB is housed inside an SLA resin printed housing. Each ethernet cable, in addition to the power cable for the switch, is epoxied to the housing in order to maintain a water-tight seal. A transparent window, which also allows for interior access, is present on one of the sides. The window is made of laser-cut 6mm acrylic and is fastened to the housing with M5 fasteners with a silicone gasket to maintain the water-tight seal.

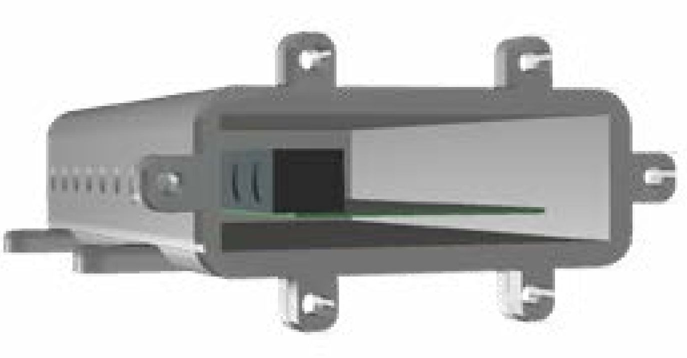

Figure 3: *CAD Model of Ethernet Switch*

The Tube

STEVE ROV has one central tube that contains most of our electronics. The tube is 100 mm inner diameter and 559mm long. This tube contains the electronics tray, which holds all of our electrical components other than the cameras and the ethernet switch. The electronics tray is made of laser-cut 6mm plywood. The top of the tray holds the Raspberry Pi 4, 12V to 5V Power Converter, 12 Channel PWM Controller, 12V to 9V Power Converter, and a small 5V power bus. The bottom holds two aluminum U-shaped rods that function as our positive and negative 12V power rails. The bottom also holds our 6 Electronics Speed Controllers (ESC). The Raspberry Pi 4 uses I2C to connect to the PWM controller. Each ESC is connected to the PWM controller and can be controlled through the Raspberry Pi. The 12V to 5V Power Converter provides power for the Raspberry Pi 4, the external Raspberry Pi Zero 2 Ws, and the PWM Controller. The 12V to 9V Power Converter provides power for the ethernet switch, and the ESCs are directly connected to 12V power.

Buoyancy

Buoyancy is a crucial aspect of any submersible vehicle. Too much positive or negative buoyancy will make piloting much more difficult and reduce accuracy when trying to complete tasks. Because of this we have taken great care to ensure that STEVE is neutrally buoyant or at least very close to it.

Neutral buoyancy is when the mass of the water displaced by our ROV and the mass of the ROV are equal. Our electronics enclosure is relatively light, but displaces a high volume of water (276 in^3). In order to mitigate this, we cut four 5 cm aluminum cubes. The cubes act as weights, or as we affectionately call them, “inverse buoyancy modules.”

We sized our inverse buoyancy models in order to make this equation true.

$$\textit{Volume of the ROV in m3} * 997 = \textit{Mass of ROV in Kilograms}$$

We originally made these cubes last year, and have since modified the components of our ROV. We found, however, that our modification did not have a major impact on the buoyancy of the ROV and did not feel it was necessary to re-make our weights. As a result, our ROV is very slightly negatively buoyant.

Propulsion

STEVE is equipped with six Blue Robotics T200 thrusters, strategically positioned in the same configuration as the BlueROV2. We believe this configuration offers the best balance between forward-backward, side-to-side, and vertical movement. Four of these thrusters are angled at 45 degrees, providing horizontal propulsion, while the remaining two are positioned vertically for upward and downward movement. This six-thruster configuration enables our ROV to move along the X, Y, and Z axes, as well as rotate around the Roll and Yaw axes. With these advanced propulsion capabilities, our ROV is capable of performing a wide range of underwater tasks with precision and efficiency.

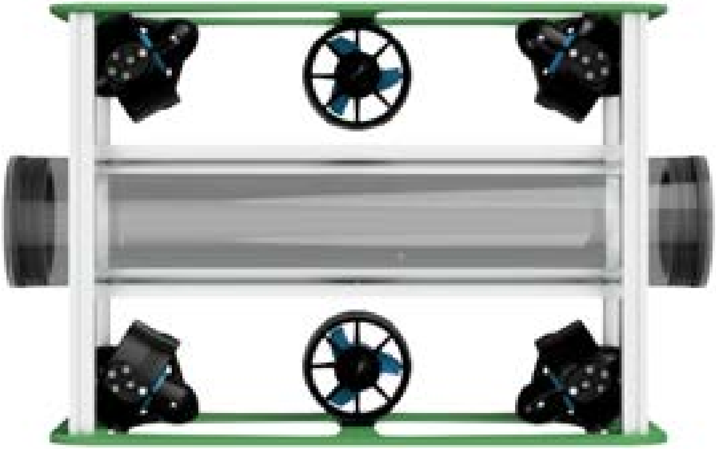

Figure 4: *STEVE ROV Thruster Configuration*

Manipulator

Our manipulator is extremely simple compared to last year. This year, we have only two pieces of laser cut acrylic that form two hooks. These pieces of acrylic are properly sized and spaced to be able to hold the ½ inch PVC pipes that many of the props are constructed out of. They were cut from clear acrylic, but we quickly realized that it was difficult to see the clear acrylic underwater and we spray painted them red for better visibility. Our manipulator has a modular design that will allow for very easy expandability in the future. Every attachment is connected to a mount via magnets and can be very easily removed, replaced, or reoriented. Although this year we have only one attachment, if, in the future, we need another attachment it will be exceptionally easy to mount it.

Figure 5: *CAD Model of STEVE ROV Manipulator*

Cameras

STEVE ROV has three cameras that allow the pilot to see both forwards, backwards, and towards the gripper. This year, we chose a modular design for our cameras to allow us to have more flexibility in positioning our cameras without negatively impacting performance. Each camera enclosure has a Raspberry Pi Camera Module 3, its own Raspberry Pi Zero 2 W to manage and process the camera feed, and an ethernet connection.

Although a few different designs were prototyped, we settled on one design that we call the "tube camera." The ethernet HAT is placed directly on top of the Pi Zero 2W and the two together are screwed into a PLA 3D-printed tray that we manufactured with one of our Fusion3 3D Printers. The Pi Camera is also screwed into the tray.

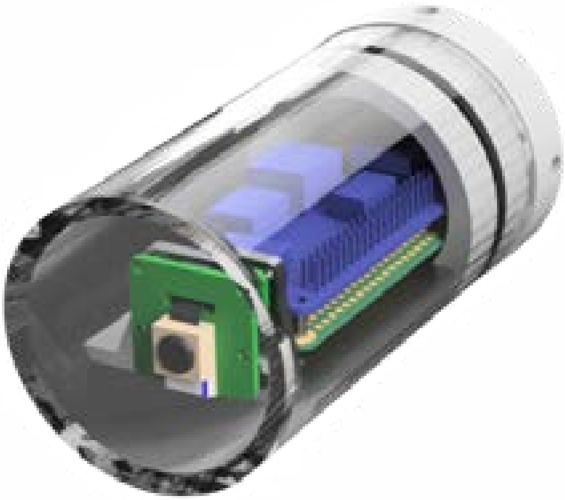

Figure 6: *CAD Model of "Tube Camera" Design*

The Camera is connected to the Pi with a ribbon cable and the whole tray slides into a 50mm diameter, 100mm long clear acrylic tube. One end of the tube is sealed with a circular 3mm thick clear acrylic plate with a diameter of 50mm. The plate was attached to the tube to create a water-tight connection with WELD-ON Acrylic Adhesive. The other end of the tube has a custom SLA resin-printed tube flange printed with one of our Formlabs Form3 resin printers with Grey Pro resin.

Cameras (Continued)

A 49mm O-Ring is fitted into the tube flange in a trough. There are 4 screw holes in the flange that allow for it to be connected to mounting hardware. Two Blue Robotics potted penetrators are fitted into the flange. One of the penetrators has nothing running through it and has a cap that can be unscrewed to equalize the pressure within the tube. Without it, when the tube flange is inserted the air inside is pressurized and pushes the tube flange out. The other penetrator has a CAT 6 ethernet cable and two small wires for DC power and ground. The cables are epoxied into the penetrator using JB Weld to keep water from leaking in. The relative pressure difference in conjunction with the friction caused by the O-Ring keeps the tube attached to the tube flange, so the whole camera module can be secured with mounts only connected to the tube flange.

Our cameras are mounted in various locations on the ROV. One of them faces down and is mounted with a laser-cut piece made of acrylic mounted onto the structural bars of the ROV. Another is mounted forwards and tilted down in order to see the manipulator. It is mounted using a custom 3D printed mount that holds the camera at the correct angle. A mount similar to the manipulator camera's but not angled down is used to mount the directly front-facing camera.

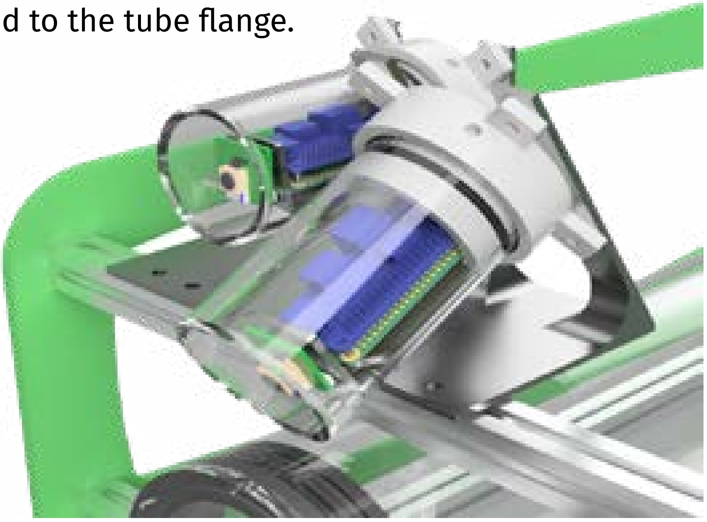

Figure 7: *CAD Model of Front and Manipulator Cameras*

System Integration Diagram

Fuse Calculations:

6 T-200 Blue Robotics Thrusters ~17A each = 102A

3 Camera Modules ~.15A each = .45A

Raspberry Pi 4B = 1A

Total Current 103.45A * 150% = 155.175A

ROV uses a 25A fuse

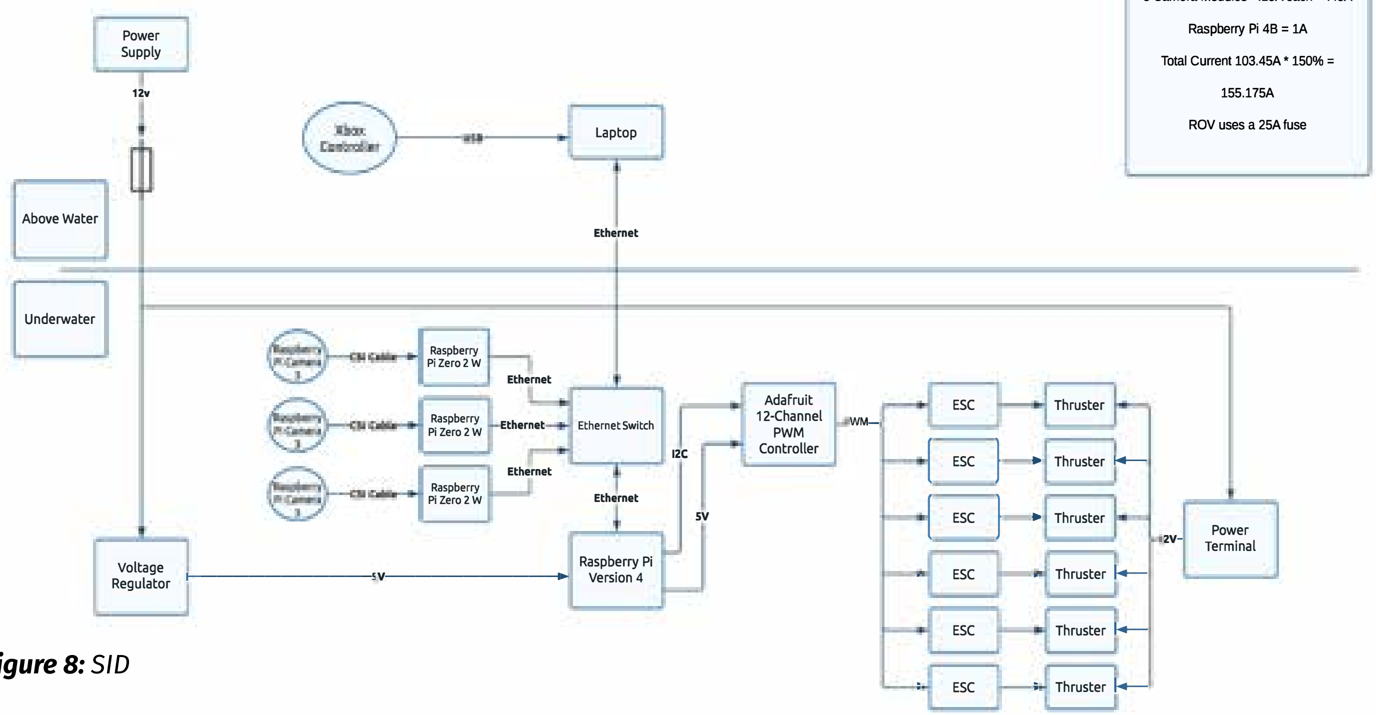

Figure 8: *SID*

Safety

Sunk Robotics takes safety extremely seriously. Early on we established clear safety standards while using dangerous tools such as saws, or handling toxic materials such as acrylic weld. An example of this is how we required all members to use a respirator when handling dangerous carcinogenic chemicals, which cause cancer even outside of California. Some notable safety features on our ROV are our avid use of cap nuts which prevent lacerations on divers handling our ROV, and our motor shrouds which keep items from entering the thrusters and getting damaged or tangled.

While operating our ROV, we always made sure to use our safety checklist:

- Make sure all wires are not touching water (except tether)
- Make sure our DC 12V power supply is not in a dangerous location such as in water, near water, or perched on top of something in an unstable manor
- Ensure the thrusters are clear of debris before moving the motors
- Ensure all team members are in safe positions (not actively drowning, etc)
- Make sure there is a lifeguard on staff

Hazard	***Solution***
Overcurrenting	Installed a 25A fuse
Sealed tube can build up pressure underwater	All tubes have flanges that get pushed out under positive pressure
Things getting caught in the propellers	Install a motor shroud and keep strings and such away from the thrusters
Drowning	Always have lifeguard present and exercise caution around the pool

Critical Analysis

When testing our ROV and components relating to it, we usually begin with verifying that the electronic and mechanical aspects work, before testing for leaks using a vacuum pump. Assuming everything worked well and no leaks were noticed, we declare a part “working” and “thoroughly tested.”

If electrical or mechanical problems were found, we would carefully inspect each subcomponent in order to isolate the problem. If leaks were detected we would positively pressurize the components using a hand-pump and look for where bubbles would come out. We also used soapy water to determine the specific location of leaks. Once we found where the leaks were we would seal them by either tightening fasteners or applying more epoxy.

We tested many different prototypes of components, usually by building a preliminary prototype and seeing how it performs. Electronics were tested especially thoroughly, oftentimes being put through a “shake test” where we shake the electronics as hard as we can and see if they break. This test can rapidly simulate weeks worth of vibration and rotation and determine the long-term resilience of parts.

Challenges

Throughout the development process of our camera system, we encountered a number of difficulties. Many different designs were proposed but only a few were built. In the end, however, only one design was proven to be reliable enough for us to use. Other designs such as the “stick camera” were much smaller than the “tube camera” (the one we ultimately used), but the connection between the Raspberry Pi and the ethernet HAT was too unreliable to be useful.

We also had many issues with creating small, but reliable water-tight seals. The “tube camera” is very unique in that it has its own small tube, similar to how our primary electronics enclosure is sealed. This custom tube flange has proven to be extremely reliable and quick to assemble, whereas a major drawback of using fasteners is that they can take a long time to assemble and disassemble the seal.

Building the float was a challenge for us mainly because it seems like it would be relatively simple. This caused us to not allocate enough resources to it until it was too late. We will put more resources towards the non-ROV task next year.

What We Learned

During the construction of the ROV, we learned the many struggles of designing and building such a complex system. We also learned a lot about making and sealing water-tight enclosures, and this will allow us to refine our methods for faster and better construction of water-tight vessels. The MATE ROV competition has been most educational, and all our team members have become far more experienced in constructing remotely operated vehicles.

We learned that the delegation of tasks is very difficult, and that in general, more people were needed to help with tasks. This was especially true with the float, as the two people who built the float found it difficult to balance their time between building the float and other personal endeavors. Next year, we will attempt to balance the distribution of work to better take into account peoples' availability.

Float

Design Philosophy

Our goal in designing this float was to keep things simple. To achieve this, we created a single sealed container with a pressure release as the only opening. The float's overall volume can be changed by moving a linear seal, which makes the float negatively buoyant at atmospheric pressure.

Communication

We utilized a Raspberry Pi Pico W to control the electronics in the float, and its WiFi module to communicate with the surface. A WiFi network is created and a web server is then started. The current time can be inserted into the WebUI using server-side processing.

Buoyancy Engine

The buoyancy engine works by changing the volume of the float using a piston that moves up and down, with a dynamic o-ring seal to keep the water out. We avoid putting any positive pressure on the craft, by equalizing the pressure in the tube on the surface, when the volume is the smallest, such that when the piston moves down, and increases the volume, density of the craft decreases and it rises.

Safety

To ensure safety, we use AAA alkaline batteries to power the electronics. The end cap is designed so that it cannot hold a positive pressure differential, and a rubber stopper pressure release was installed as a redundancy. The float is designed to never undergo positive pressure because we keep it negatively buoyant by default. These safety measures combine to ensure that, even if multiple things fail, the float cannot put anyone in danger. Additionally there are 2 fuses in line with the 2 different battery leads in order to protect everything from cover currenting. This being said we have never experienced the motor draw over 150 milliamps

Float (Continued)

Construction

Our float uses a variety of construction methods, from 3d printed parts, to plasma cutting. The end cap, electronics compartment, and piston were all 3D printed from resin, with the exception of the electronics holder, which was FDM printed, and fits inside the electronics shroud. The float has 2 laser cut parts in the form of plates that are acrylic welded to the inside and outside of the acrylic tube. The float utilizes a modular weight system to act as ballast in order to allow it to maintain the correct mass to be able to vertically profile correctly. This comes out to 4 plasma cut steel rings that are attached to one of the aforementioned laser cut plates, acrylic welded on to the outside. All of the electronic components are combined in a custom PCB that we milled in house.

Figure 9: *The Float*

Float SID Diagram

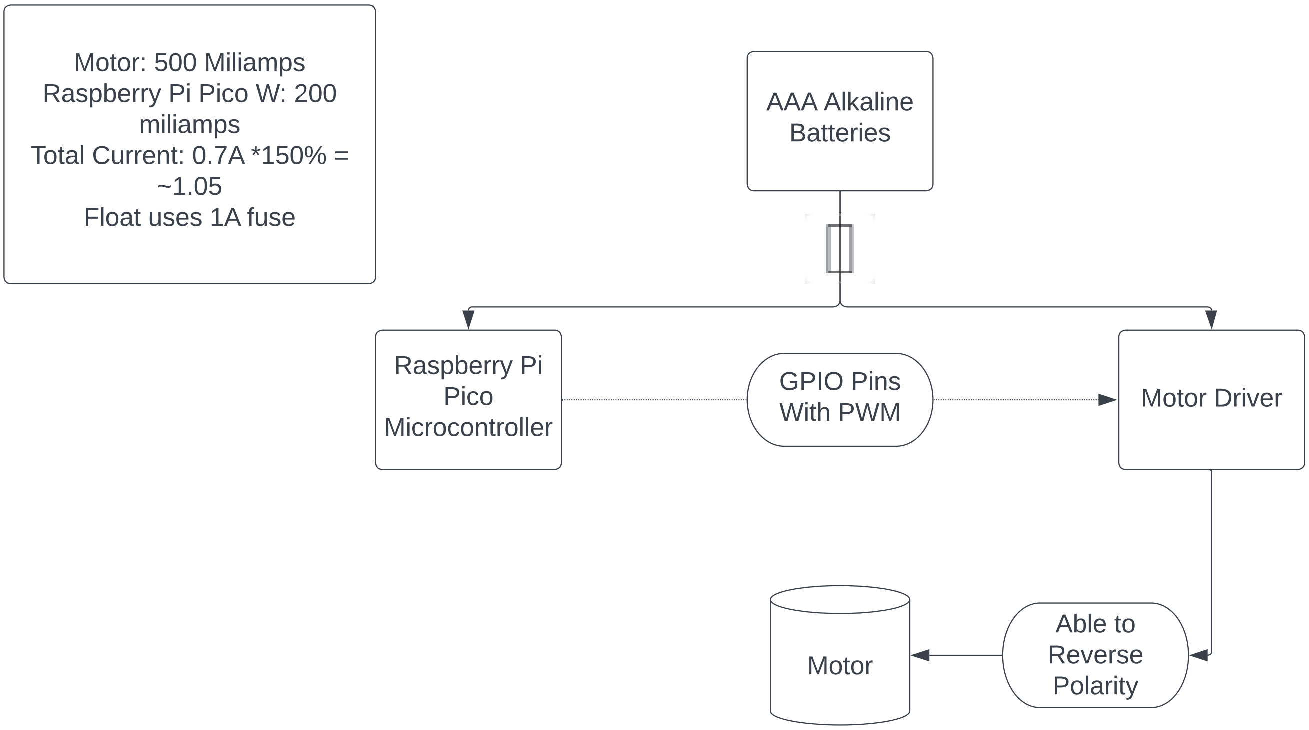

Figure 10: *Float SID*

Finances

While building STEVE ROV, we saved much of the cost incurred by other teams through the fabrication of most of our components. We made heavy use of our Epilog Laser FusionPro laser cutter, our Fusion3 410 3D printers, our Bantam Desktop PCB Milling Machines, and our Formlabs Form3 Resin 3D Printers. This has also had the added benefit that we can fix most of our parts in-house. However, there are some things that we simply do not have the facilities to make, such as computers, motors, and cameras.

Date	Type	Category	Expense	Description	Sources/Notes	Amount (USD)	Total Cost (USD)
November 1, 2021	Re-used	Hardware	4x Blue Robotics T200 Thrusters	Thrusters to propel ROV	Re-used from last year's ROV	$850.00	$850
February 1, 2023	Purchased	Hardware	2x Blue Robotics T200 Thrusters	Thrusters to propel ROV	Bought to replace two T100 thrusters	$212.00	$1,062
November 1, 2021	Re-used	Electronics	6x Blue Robotics Basic ESCs	Used to control thrusters		$216.00	$1,278
October 1, 2019	Re-used	Hardware	1x 4" Acrylic Tube	Housing for electronics	Used to keep electronics dry	$201.66	$1,480
October 1, 2019	Re-used	Hardware	1x O-Ring Flange	Cap housing for electronics	Used to keep electronics dry	$58.00	$1,538
February 1, 2023	Purchased	Sensors	3x Raspberry Pi Camera Module 3	To provide visuals		$80.00	$1,618
N/A	Re-used	Parts	PVC Pipe	Housing for various parts	Used for building components	$6.00	$1,624
N/A	Re-used	Parts	Aluminium	For making power terminals	Used for building components	$5.00	$1,629
N/A	Re-used	Parts	3D Printing Resin	For making cameras and ethernet switch housing	Used for building components	$50.00	$1,679
N/A	Re-used	Parts	PLA 3D Printing Filament	For making thruster covers and other things	Used for building components	$10.00	$1,689
N/A	Re-used	Parts	Acrylic Sheets	For making frame	Used for building components	$20.00	$1,709
October 1, 2021	Re-used	Electronics	Raspberry Pi 4	Used for interfacing with components and communicating with top-side client	(glad we bought it last year)	$35.00	$1,744
February 1, 2021	Re-used	Electronics	Voltage Regulator	Control voltage output to RPI		$4.98	$1,749
November 1, 2022	Purchased	Electronics	100 ft. 10 AWG power cable	Deliver power to ROV		$106.00	$1,855
February 1, 2021	Re-used	Electronics	Anderson Powerpole Connector	Deliver power to ROV from power supply		$1.20	$1,856
June 1, 2022	Re-used	Electronics	Cat 6a Ethernet Cable	Send data to and from ROV		$50.00	$1,906
N/A	Donated	Parts	Wood	Used to manufacture STEVE Electronics Board	Generously donated from our Robotics Shop	$5.00	$1,911
October 1, 2019	Re-used	Hardware	80/20® Bars	Provide structural support	6 rods in total	$25.00	$1,936
October 1, 2019	Re-used	Hardware	80/20® Mounts	Mount thrusters to 80/20 rods	16 L-Brackets	$10.00	$1,946
N/A	Donated	Parts	Screws	Connecting various components		$20.00	$1,966
January 1, 2022	Re-used	Hardware	Blue Robotics Wetlink Penatrators	Allow for wires to go through cap without leakage		$228.00	$2,194

Finances (Continued)

October 23, 2022	Purchased	Electronics	Ethernet Switch Power Converter	Provide 9V DC power for the ethernet switch		$13.08	$2,314
March 28, 2023	Purchased	Hardware	Acrylic Tubing	Primary Housing for the float		$67.20	$2,381
March 29, 2023	Purchased	Hardware	Acrylic Tubing	Primary Housing for the cameras		$44.46	$2,426
March 26, 2023	Purchased	Electronics	SD Cards	Stores OS & data for Pi Zeros 2 Ws		$44.90	$2,471
December 16, 2022	Purchased	Electronics	Pi Zero 2 Ws	For Cameras	Eye-wateringly expensive	$498.41	$2,969
April 22, 2023	Donated	Transportation	Large van and transportation	Transports ROV, supplies, and team members	Used our school's van	$200.00	$3,169
							$3,169
N/A	Cash Donated/Rasied	General		Funds donated by Mide Technology Engineering Corporation, BAE Systems, Watts Water Technologies, Financial Recovery Technologies, Inkbit, and raised from GoFundMe		-$15,000.00	
						Total Raised	$15,000
						Total Spent	$3,169
						Final Balance	$11,831

Travel Expenses

Expense	*Estimated Cost*	*Total (USD)*
Hotel	$3520.72	$3520.72
Van Rental	$1,221.83	$4,742.55
Food	$2000.00	$6,742.55
Shirts	$1000.00	$7,742.55
Supplies	$1000.00	$8,742.55
Airfare	$4,516.80	$13,259.35
Estimated Final Cost		***$13,259.35***

Acknowledgements

Sunk Robotics would like to thank the following corporations not only for their financial help, but also for providing our team with the tools and resources used to make the Sunk Robotics STEVE ROV. We are incredibly grateful and none of this would have been possible without the support provided.

Thank you.

Watts Water Technologies, Inc.
https://watts.com
815 Chestnut St
North Andover, MA 01845, USA

Mate Inspiration for Innovation
https://materovcompetition.org/
980 Fremont Street
Monterey, CA 93940, USA

Medford Vocational Technical High School
https://mhs-mvths.mps02155.org/
489 Winthrop Street
Medford, MA 02155, USA

References

www.realpython.com - Very helpful Python tutorials

www.raspberrypi.com - Lots of documentation

learn.adafruit.com - Lots of rich documentation and very helpful tutorials

https://pypi.org/project/websockets - Python WebSockets library

https://github.com/Arvamer/gilrs - Rust game controller library

Parker O-Ring Handbook - Useful information about using o-rings

https://www.rapidtables.com/calc/wire/voltage-drop-calculator.html - Tether Calculations

wikipedia.org - Source of all good knowledge

LibreTexts Engineering - PID Controllers - Helpful for understanding how PID controllers work