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Sunk ROBOTICS

Medford Vocational Technical High School
Medford, Massachusetts, USA

TEAM MEMBERS

Matty Harris - Software Lead / CEO
Noah Gibson - Assistant Software Lead
Zack Bertocchi - Head of Marketing / CSO
Franklin Soto-Ortiz - Director of Training
Ben Santana - Graphics Engineer
Aaron BenDaniel - Hardware Lead
Ben Wirz - Lead Float Engineer
Scott Campbell - Lead Float Engineer
Tim Hunt - Hardware Engineer
Miles Hilliard - Hardware Engineer
Jonas Wirz - Pilot

TEAM MENTORS

Samuel Christy - MVTHS Instructor
Lisa Miller - MVTHS Instructor

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I. ABSTRACT

Sunk Robotics is an underwater robotics company that specializes in developing remotely operated vehicles (ROVs) that are tasked with performing complex missions in a variety of marine ecosystems.

This year (2024), Sunk Robotics released two new products, firstly, JONA ROV, a state-of-the-art remotely operated underwater vehicle, with eight thrusters and a six axis internal stabilization. Secondly, JENA Float, an innovative piston-compression profiling float with remote data operation. JONA, our second generation ROV, and JENA Float have been engineered through detailed planning, prototyping, analysis, and testing, resulting in two custom-built products designed to perform mission tasks efficiently and precisely.

Sunk Robotics' cutting-edge ROV, JONA, represents a significant leap forward from its predecessor, the STEVE ROV. The incorporation of two additional Blue Robotics T200 Thrusters, Raspberry Pi 5, a sleek, durable aluminum frame, and a modular PCB-designed system are clear indicators of the advancements made by Sunk Robotics in their latest ROV. Sunk Robotics' JENA Float also boasts significant improvements over its predecessors, including a larger enclosure, as well as custom electronics and software.

All products offered by Sunk Robotics have been specifically engineered to contribute to the global community through collecting ocean data, servicing marine infrastructure, and assisting in understanding ocean processes.

Photo 1. Sunk Robotics Team Members
Photo: Jay Campbell

II. PROJECT MANAGMENT

A. Company Profile

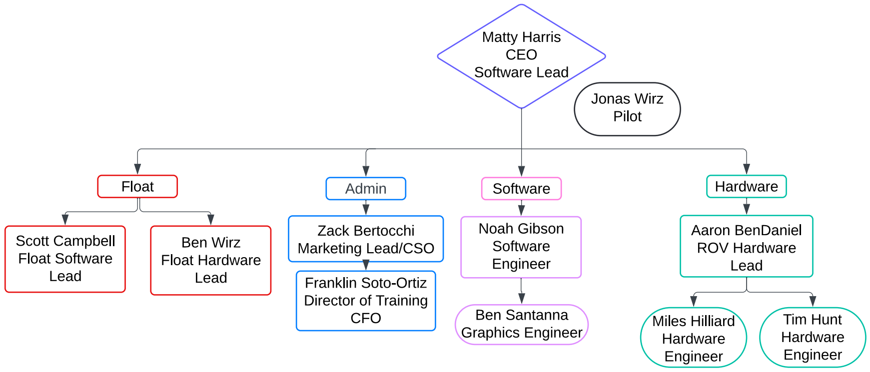


Figure 1. Sunk Robotics Organization
by Zack Bertocchi

Sunk Robotics, founded in 2021, is based in Medford, Massachusetts. It specializes in creating submersible robots designed to address issues impacting global marine ecosystems, such as climate change and pollution.

Sunk Robotics' workforce consists of eleven students from the Medford Vocational High School. This includes three students from the Programming and Web Development program and eight students enrolled in Robotics and Engineering.

The team is organized into three separate departments: Software, Hardware, and Administration. (see Figure 1) While the company is structured hierarchically for technical development, we employ a flat structure for management and team decisions. In an effort to be more organized, we break each team down into separate categories based on skill and general assignment.

Our Lead Hardware Engineer, Aaron BenDaniel, oversaw the development of Hardware and electronics on the ROV. As seen in Figure 1, JONA ROV's external hardware and manipulators were developed by two of the team's first year students. JENA was developed by our two Lead Float Engineers, Ben Wirz, focusing on mechanical development and Scott Campbell, working on software and electronics.

Matthew Harris, our Lead Software Engineer, manages the team's software, assisted by our Assistant Software Lead, Noah Gibson, and Graphics Engineer, Ben Santana. Members of this team are responsible for custom ROV code and Client UI.

The Administrative section includes our Marketing & Documentation team, CSO, Director of Training & CFO. CSO Zack Bertocchi is primarily responsible for documentation, communications and team safety. Director of Training, Franklin Soto-Ortiz oversees pilot training as well as the teams funds.

B. Company Organization

For the 2024 season, Sunk Robotics decided to implement strategies that would improve project organization, help keep the team on task, and on track to accomplish our goals in a timely manner.

In previous years, we have utilized strategies such as using Google Sheets to create checklists for team members and their subteams. While this strategy was manageable, it became difficult to track changes and coordinate operations.

This year, in an effort to improve our productivity, we implemented the use of Notion, a note-taking application (Figure 2.) that allows teams to easily collaborate on tasks, track changes and document work. Using this software has allowed Sunk Robotics to efficiently keep track and manage what tasks have been completed, what needs to be completed, and what is in progress.

Sunk Robotics technical and administrative teams meet weekly in the Medford Vocational Technical High School's Robotics & Engineering lab. In addition, individual members work throughout the week in their vocational classes and working from home. Sunk Robotics hosts bi-weekly staff meetings to discuss goas and current tasks being pursued.

Sunk Robotics uses Discord, an instant messaging platform, for team communication, Google Calendar to track events and Google Drive for file storage. All code is regularly committed to Github the industry standard in version control software.

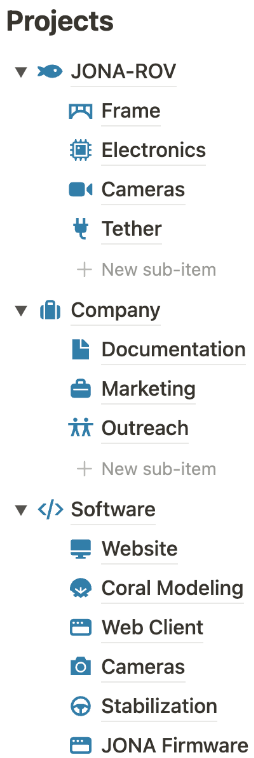


Figure 2. Sunk Robotics Notion Account
Credit: Ben Santana

Team Training

Sunk Robotics selected Jonas Wirz, a first-year student, as the team's new ROV pilot for the 2024 MATE ROV season.

Jonas is mentored by our previous pilot of two years and current CEO, Matty Harris. The decision to make a first-year student this year's pilot stems from the team's goal to build the younger team members' skills and ensure the team's success for future years.

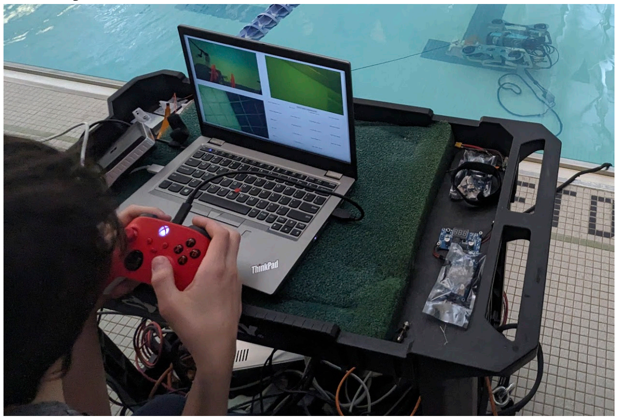


Photo 2. Jonas Wirz Pilot Practice
Photo: Aaron BenDaniel

As the team learned from past experience, a main focus of the 2024 season was making sure adequate time and resources were allocated to pilot training. Sunk Robotics CEO Matty Harris advised the team about the importance of building all props from mission tasks the team would be attempting at the 2024 MATE ROV Competition. In order to do this, Sunk Robotics elected returning team member Franklin Soto-Ortiz as this year's Director of Training. Franklin was tasked with assembling a parts list and developing the props necessary for this year's training regiment.

During the initial development of JONA, the team had no access to a testing pool due priority being given to the schools swim team. Finally in the spring of this year, the team was able to negotiate pool time allowing our pilot to begin a training routine.

Photo 3. Sunk Robotics Props
Photo: Jonas Wirz

Brainstorming

The design process centered around group brainstorming, with the entire hardware team coming together to pitch and review ideas. Lists of potential solutions would be made and the pros and cons of each design highlighted. Group evaluation would continue until a single design remained.

Cost Effectiveness

A number of tradeoffs were made to ensure the overall cost of the JONA did not become too great, while still maintaining acceptable functionality. For example, one reason we built our own software for JONA was to enable the usage of Raspberry Pi hardware. Ardusub does not support low-cost general-purpose computers such as an RPI and instead requires an expensive flight controller such as a 3DR Pixhawk 1, which we found was priced in excess of $300. Another example of a cost-reducing decision was the choice to use a static manipulator system. Buying a pre-built mechanical gripper for underwater use, or the components to build one ourselves would be very expensive. The Bluerobotics Newton gripper is $640 and underwater servos or linear actuators are over $150 each.

Vehicle Building Schedule

Sunk Robotics began work on this year's products in mid-October and aimed to have the design completed by late November. After a full review of the design, manufacturing could then commence. We planned to have the ROV fully built and ready by the end of January. Once the ROV was completed, the pilot would practice as much as possible, while recommending changes. Additionally, problems were found during our testing, and many changes needed to be designed and implemented throughout the testing phase. We aimed to stop making any hardware changes by May 3 (one week until the regional) and use all the remaining time for practice.

III. DESIGN RATIONALE

A. Design Objectives

Sunk Robotics continues to follow three overarching design principles to guide the engineering process in the 2024 season. These principles are reliability, modularity, and quality craftsmanship. Sunk Robotics has identified three discrete objectives to accomplish in the 2024 season.

1. Construct an upgraded frame to enable pitch control, greatly increasing flexibility and maneuverability.

2. The need to upgrade the main computer to a Raspberry Pi 5, providing the necessary computational resources to deploy advanced computer vision programs to address new mission tasks.

3. The need to develop enhanced automatic stabilization algorithms to increase the ease and efficiency of piloting JONA.

B. Design Methodology

Before designing a product at Sunk Robotics, the main focus is on solving a problem. This ensures that the ROV is optimized for completing specific tasks while at the same time ensuring that the ROV remains flexible enough to be successful when faced with unforeseen challenges.

Employing the principles of iterative development and testing, an initial design is prototyped and repeatedly tested. Improvements are integrated into the design and the cycle is continued until the best possible part has been developed.

When possible, Sunk Robotics prioritizes two-dimensional design in all of its custom parts. 2D parts are far simpler and cheaper to manufacture and faster to iterate. When 3D parts are needed, 3D printing is the first option due to cost and efficiency. Though in cases where higher precision or strength are required subtractive manufacturing technologies such as CNC turning or milling are employed.

Thruster Configuration	
6 Thrusters	**8 Thrusters**
Pros	
Decreased power consumption	Pitch control
	Increased vertical thrust
Cons	
No pitch control	Increased power consumption
Decreased vertical thrust	
Main Computer	
Raspberry Pi 4	**Raspberry Pi 5**
Pros	
Decreased power consumption	2x average performance gain
Able to connect front camera directly	Able to run computer vision program
	20-30s faster boot time
	Bigger number
Cons	
Not enough performance to run computer vision program	Driver issue adds ~500ms latency to camera, requiring separate Raspberry Pi Zero to host front camera

Figure 3. Sunk Decision Organizer by Matty Harris

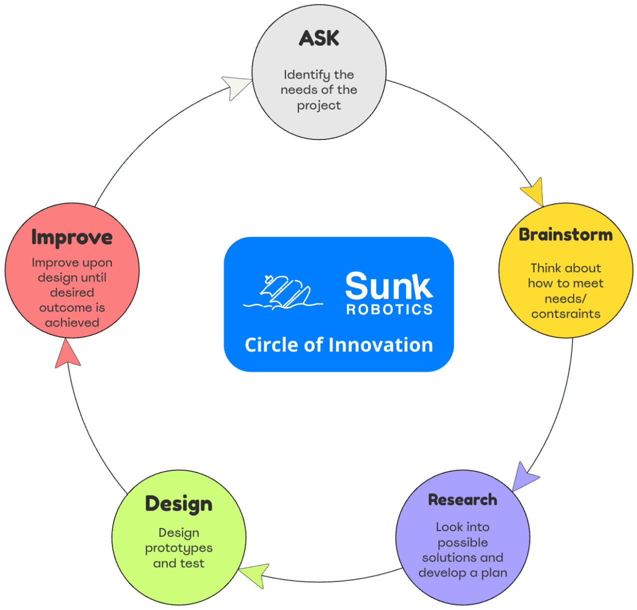


Figure 4. Sunk Robotics Circle of Innovation by Aaron BenDaniel

C. Parts Sourcing

Sustainability is of the utmost importance to Sunk Robotics. As a result, Sunk Robotics values recycling and reusing parts, and a large majority of JONA ROV's parts were made locally and resourcefully in-house. Our decision to create a completely new ROV this year was based on the desire to keep last year's ROV to be used for training and presentation purpose. Because of this, Sunk Robotics was unable to reuse many parts from last year and needed to build or buy entirely new hardware. While this doesn't follow our goals of reuse, we feel that having a separate ROV for training and educational usage, was ultimately beneficial for the team and it's overarching goals.

Sunk Robotics prides itself on custom engineering a vast majority of its electrical and mechanical components including a custom frame, control tubes, circuit boards, connectors and cables. Parts are purchased only in the case that we don't have the tools or time to custom fabricate. For example, Sunk Robotics considered manufacturing our own tube flanges, but it was significantly more expensive to buy the materials to turn our own flanges than it was to buy them pre-made from Blue Robotics. We decided that cost-effectiveness was more important than in-house manufacturing for that part.

Budget

Before design began, we created a preliminary budget to help estimate and manage funds based on what hardware we knew we wanted in the ROV. We knew that eight T-200 thrusters would be $1600, eight ESCs would be $288, the RPis would be $145 in total, the ethernet switch would be $125, and our disconnectable tether would be $480. This established a rough estimate, although this budget plan did not include materials such as nuts, bolts, and other mounting hardware. Additionally, it did not include the cost of the PCBs, as prices can vary greatly depending on the PCB design and we had not developed our PCB system at the time. We roughly estimated that we would spend $500 on other materials. Our preliminary estimate for the cost of JONA was $3138.

D. Mechanical Systems

JONA ROV is Sunk Robotics' next-generation ROV specifically engineered to meet the call to action from MATE while remaining easy to modify for future requirements. JONA features an aluminum frame, eight thrusters (four horizontal, four vertical), a central electronics tube with a modular PCB-based electronics system, and a static manipulator system that prioritizes reliability and modularity.

Frame

The process of designing JONA ROV's frame was meticulous and driven by two primary improvements: The incorporation of pitch control and a modular PCB electronics system. Sunk Robotics dedicated substantial time to evaluating various frame designs, considering their suitability for product missions. Each design was carefully compared, weighing their respective advantages and disadvantages, until a single, optimal design was made.

Sunk Robotics' first generation ROV, STEVE, had only six thrusters allowing for X, Y, Z, roll and yaw control but not pitch control. When designing JONA, Sunk Robotics decided to add two additional thrusters, this added control for pitch and allowed for increased thrust in the vertical direction.One of the goals for JONA's electronic system was to make the design more robust, reliable and flexible. Employing custom and modular printed circuit boards (PCBs) seemed the best way to achieve this. To accommodate this change JONA's tube was enlarged from a 10cm tube to 15cm one. This requirement played a significant role in determining how to design the new frame, as a 15 cm tube is significantly taller than a 10 cm tube.

JONA ROV's frame is constructed from eighth inch sheet aluminum. This decision took a significant amount of research and consideration. Researching common ROV frame materials led to two choices: High-Density Polyethylene (HDPE) and aluminum. Many examples of metals used for ROV construction were found, from aluminum to steel to nickel-titanium alloys, but most were too expensive or corroded easily. Sunk Robotics concluded that if we were going to make JONA out of metal, it would need to be aluminum due to its extreme resistance to corrosion, high machinability, and low cost. Between HDPE and aluminum, the team eventually decided on aluminum because of its negative buoyancy. HDPE is a common choice for ROV frame construction because it is almost neutrally buoyant. This is usually a desirable trait, but JONA is very positively buoyant because of the electronics tube's high buoyant force. Because the ROV as a whole must be neutrally buoyant, weights are needed to counteract the buoyant force of the tube. Making the frame out of a denser material such as aluminum reduces the required mass of the weights, as much of that mass is in the frame itself.

Hydrodynamic efficiency was an important factor during the design process of our frame. Computational Fluid Dynamic simulations indicated that our prototype JONA ROV impeded the flow of water too much and limited its maximum velocity (Figure 5). To increase water flow and decrease drag, holes were cut into the panels of the frame in non-essential areas, allowing water to flow through the frame unimpeded without compromising functionality or structural integrity.

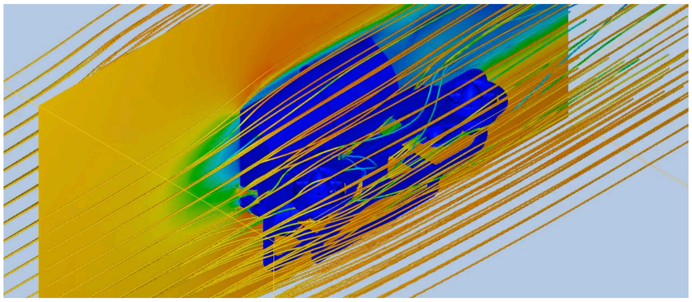


Figure 5. JONA Computational Fluid Dynamics by Ben Wirz

Electronics Housing

JONA has a single 15 cm diameter acrylic tube that houses all drive and control electronics. In previous years, a 10 cm diameter tube was used, but the tube needed to be fairly long to fit all components onto the board. Sunk Robotics wanted to reduce the length of our tube and make the electronics more condensed, and switching to a shorter but wider tube was the best way to do it.

The electronics enclosure is structured with an internal frame that houses a complement of custom designed PCBs. Each PCB is strategically placed in the frame, and is organized based on the specific functions it serves in the ROV. This method of organization not only simplifies the wiring process but also minimizes potential points of failure.

On one end of the electronics enclosure is a transparent acrylic plate for JONA's front-facing camera. All of JONA's wiring is connected to the exterior of the tube through penetrators on the other end, allowing for an easily serviceable system. There is space for 19 M10 penetrators, although only 15 are currently in use.

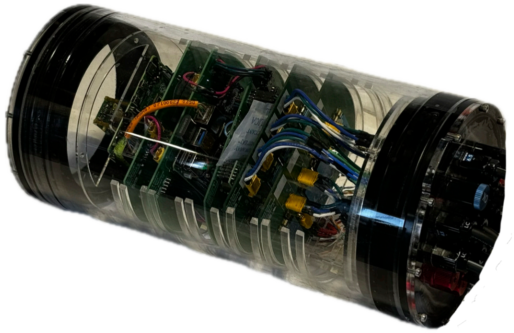


Photo 4. JONA Electronics Enclosure
Photo: Zack Bertocchi

Ten Blue Robotics Wetlink Penetrators are used for JONA's eight thrusters and two cameras, three Blue Trail Engineering Cobalt Connectors (two 3-pin power for 12V and GND to the tether and one 8-pin for ethernet to the tether), one Blue Robotics Enclosure Vent and Plug, and one Blue Robotics Depth Sensor. The Blue Trail Engineering connectors are fully watertight and easily detachable. This enables the complete removal of the tether from the ROV and reduces the difficulty in transporting JONA.

The ends of the enclosure are sealed with Blue Robotics 15cm Tube Flanges. The hardware team considered manufacturing the flanges in-house with a lathe but ultimately decided it would not be cost-effective. It was cheaper to buy the tube flanges than the stock needed to make them.

Figure 6. JONA End Cap Render
by Aaron BenDaniel

Thrusters

One of the biggest improvements incorporated in JONA was the addition of two extra thrusters. With a total of eight Blue Robotics T200 thrusters, JONA ROV can move in all six axes.

Eight thrusters is a common configuration and the Sunk Robotics design team researched other ROVs for inspiration on how to arrange them.

Sunk Robotics' electronics team wrote out the various advantages and disadvantages of each design but settled on 4 vertical thrusters and 4 angled horizontal thrusters. Horizontal thrusters were angled 30° inwards, as the pilots wanted more of the thrust to contribute to forward and backward movements, rather than side-to-side. A six-thruster configuration requires less power than eight thrusters but also significantly reduces our mobility. Additionally, more thrusters add to the cost of the ROV. We ultimately decided that the increased cost and current consumption were worth it in order to achieve enhanced mobility.

Buoyancy

Aluminum was chosen for the ROV's weights because aluminum stock was readily availible, it's easy to machine, and the materials extremely low reactivity with water, chlorine, or salt.

In order to calculate buoyance the team used both mathematic analysis and the aid of fluid dynamic CAD software to optimize a design that required no additional weights. In addition, JONA has depth control PID to make precise corrections.

We were able to tune JONA ROV's weight by adjusting the width of several supports in the frame. If we needed additional masses the structural zones of the frame would be thickened, and if less mass was needed they would be slimmed down. We maintained a minimum thickness to ensure that sufficient mechanical strength was maintained at all times.

Volume	(cm^3)	Density of Water:	1 g/cm^3
Tube	7,963 cm^3	Mass of Displaced Water	11.4 kg
Frame	1,369 cm^3	Mass of ROV	11.2 kg
Thrusters	1,541 cm^3	Extra Mass Required	0.2 kg
Cameras	544 cm^3	Density of Aluminum	2.7 g/cm^3
Total volume	11,417 cm^3	Volume of Extra Aluminum Required	74 cm^3

Figure 7. JONA Buoyancy Calculations by Aaron BenDaniel

E. Electrical Systems

Main Control

Sunk Robotics utilizes a a single laptop, as its main control system. Instead of the typical bulky and complex custom control boxes, Our system is highly portable and can run on any laptop. A simple familiar and robust Xbox One is used as the main control interface.

Photo 5. Lenovo Thinkpad & Xbox Controller Photo: Aaron BenDaniel

Tether

A high-quality tether is a must for allowing robust communication, power delivery, and maneuverability underwater. To maximize flexibility, JONA ROV features a slim tether with only a single CAT 6A Ethernet cable for communication and two 10 AWG ultra-high strand count wires for power delivery wrapped in a thin jacket. This slim design greatly reduces cable drag on the ROV, making JONA easier and faster to maneuver.

Although the tether contains three separate cables, they are all wrapped into a single line using a braided cable sheath. This sheath helps to organize the tether, as managing one cable is easier than managing multiple.

Because of the metallic nature of the tether, it weighs far more than the water it displaces and consequently is negatively buoyant. This is a very undesirable trait, as the tether will drag along the bottom of the pool, get caught in props, and pull the back of the ROV down. Our solution was to add flotation to the tether. Lengths of foam pipe insulation are affixed to the tether at regular intervals. This insulation makes the tether positively buoyant, which means that the tether will float along the surface and stay away from any props.

A major innovation this year was the addition of easily-disconnectable underwater cable connectors, using three Blue Trail Engineering Cobalt Connectors. This modular design allows the tether to be easily disconnected from JONA, making tether management and organization easier and more streamlined.

During the deployment of JONA ROV, Sunk Robotics requires at least two deck attendants to manage the tether. One attendant controls how much tether is in the water, and tries their best to avoid it getting tangled. The other attendants make sure the remaining tether on the surface is untangled and ready for deployment, is not snagged on anything, and makes sure it is not a tripping hazard.

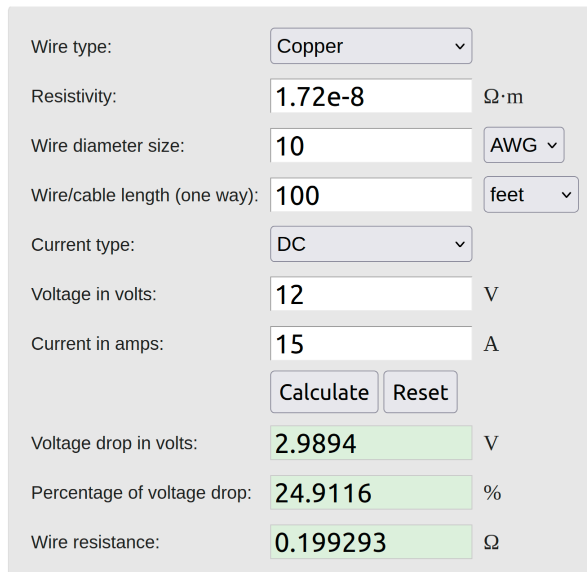


Figure 8. Tether Calculations
by Matty Harris

Photo 6. JONA ROV Tether
Photo: Miles Hilliard

ROV Electronics

When determining the plan for JONA ROV's electronics system, the electronics team started with the goal of improving reliability, modularity, and flexibility. It was decided to design our own custom Printed Circuit Boards (PCBs) as they are less prone to failure and easier to troubleshoot. The team was faced with the problem: "what if something breaks?" and knew that a single large PCB was not the correct solution as it could jeopardize the ROV as whole. Components are split into different PCBs (Photo 9 & 10) and then stacked horizontally so that parts can be easily serviced and/or repaired.

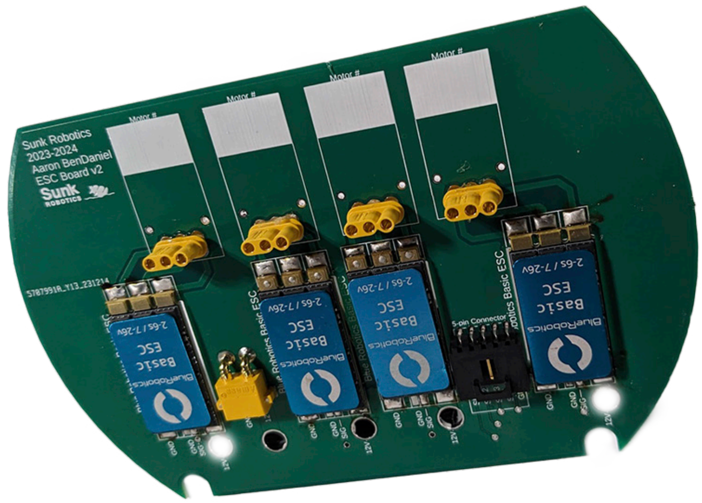


Photo 7. JONA ROV Motor Board
Photo: Aaron BenDaniel

JONA's control circuitry is divided into five individual PCBs representing, Logic, Networking, Power Distribution, and two Motor Boards

JONA ROV's Motor Boards each have four Blue Robotics Electronic Speed Controllers, power input, signal input, and motor output connectors.

Power from the tether first goes to our Power Distribution PCB. This board distributes 12V power to both Motor Boards and has a 12V to 5V converter which supplies power to all of the logic/control components. A 4-channel ADC is used to measure current and voltage of the 12V system and 5V system. This PCB also has a 16-Channel PWM Controller. Although the PWM controller does not relate to power distribution, the Power Distribution PCB is directly adjacent to the Motor Boards. If the PWM Controller was instead placed on the Logic Board, signal wires would need to run from the Motor Boards to the Logic PCB past the Power Distribution PCB. This would be a messy and cluttered solution, so the team decided to make use of the unutilized space on the Power Distribution PCB and put the PWM Controller on it.

The Logic PCB contains a 5V power bus, an I2C bus, our Raspberry Pi 5, and a 9-axis Inertial Measurement Unit. All of JONA ROV's components are connected via either I2C or ethernet.

The Networking Board connects all of the ethernet devices together. It has a power input connection and five RJ45 ports. Three of the ports are wired with 100Mbps ethernet and 5V power, and two are wired with 1000Mbps ethernet. We use a SwitchBlox - Gigablox Ethernet Switch to connect all of the ethernet devices.

ROV Sensors

JONA ROV features a minimalistic sensor array that is tailored specifically to the requirements of the call to action. JONA ROV has a Blue Robotics Bar02 pressure and temperature sensor that can calculate depth, which is used for navigation and in Task 2. A BNO085 9-axis IMU allows JONA to sense its orientation in 3D space, which enables autonomous navigation capabilities for Task 3. Finally, the array of cameras JONA ROV hosts gives the pilot and any computer vision applications the ability to see the surroundings of the ROV in three low-latency video feeds.

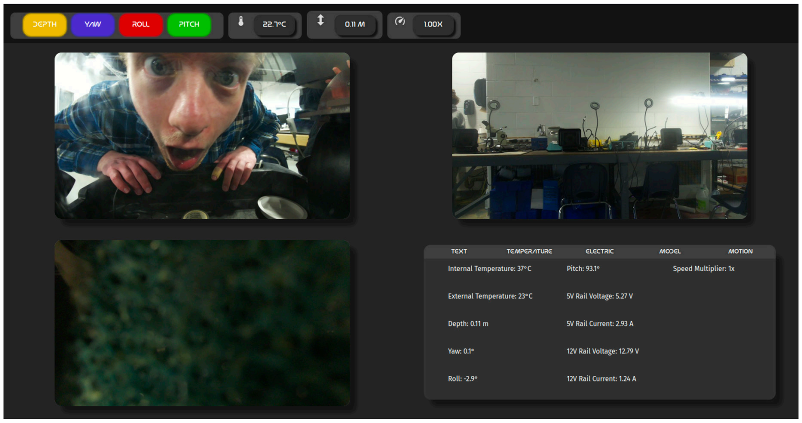


Figure 9. JONA ROV Client
by Ben Santana

F. Software

Frontend

The pilot user interface is built on an intuitive and responsive front end to ensure that even a novice pilot can easily control the ROV. To ensure rapid, responsive controls, an Xbox One game controller is plugged into the top-side laptop over USB. JONA begins communicating with the laptop as soon as it is launched. The frontend client displays low-latency, high frame rate video feeds from each of the three cameras, affording the pilot maximum awareness of their surroundings. The client also displays a variety of sensor data, including power monitoring data, orientation data, temperature data, and depth data, allowing the pilot to easily ensure proper and safe operation of the ROV. A brand new innovation this year is the addition of a 3D model of the ROV that rotates based on the ROV's absolute orientation, helping the pilot orient themselves to their surroundings faster and more efficiently.

This year, Sunk Robotics chose to serve the web client from the ROV, rather than having a separate file on the top-side laptop. To connect, the pilot simply plugs in the tether's ethernet cables and connects to a server on a laptop from any web browser. This decision ensures maximum compatibility with any device in the event of technical difficulties with the top-side client and helps minimize complexity and startup time. The frontend is served from the ROV over Ethernet.

The client was made entirely from scratch using Vue.js, a framework for building graphical user interfaces on the web and TypeScript. The software team developed a custom solution for decoding and displaying video feeds from three different cameras with minimal latency. Other libraries and frameworks used include: Tres.js for displaying the 3D model of the ROV and Chart.js for creating graphs of sensor data. In previous years, the team has used bare HTML, CSS, and JavaScript for the web client. While relatively simple to work with, the team quickly encountered scalability issues upon trying to add more features to the client. To solve this, the team opted to use Vue.js, greatly simplifying the process of developing a thoughtfully designed and visually appealing user interface.

Server Side

The "brains" of JONA ROV is a single Raspberry Pi 5 centrally located in the electronics enclosure. The Raspberry Pi runs a robust, custom-built Python main server program that serves as a bridge between the sensors, cameras, motors, and the top-side client. The main avenue of communication between individual software components is WebSockets. WebSockets provides secure, robust communication channels that are easy to interface with. The main server hosts a WebSockets server and establishes a secure connection with the top-side client. All camera connections are made over WebSockets as well.

Precise and versatile movement of the ROV is incredibly important for completing tasks quickly and efficiently. The main server receives game controller input data from the top-side client and forwards this to the motor control system. The software team has developed a custom motor control library to efficiently convert game controller inputs into vectors that correspond to movement along a certain dimension (X, Y, Z and Roll, Pitch, Yaw). The motor library then sums these vectors into one movement vector

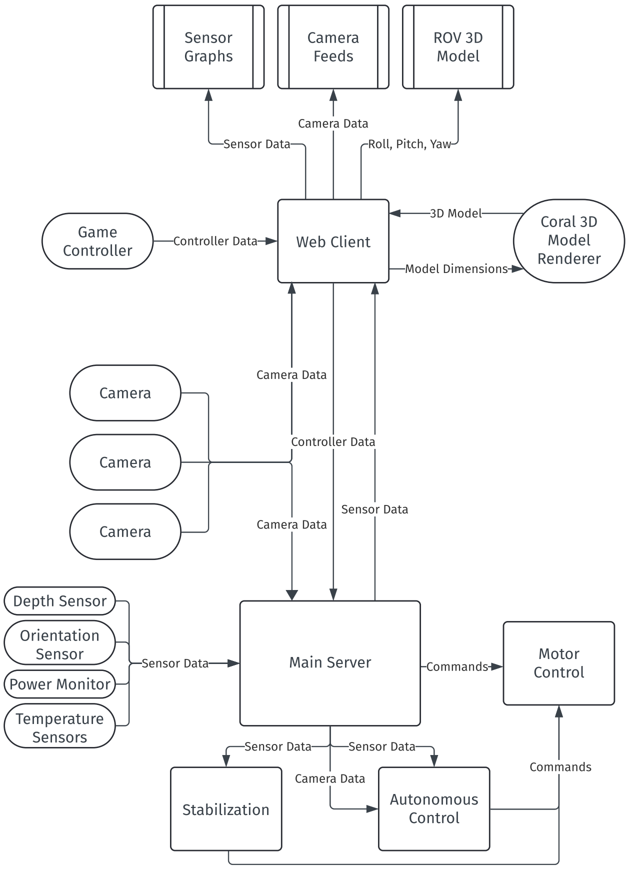


Figure 10. Software SID by Matty Harris

which can then be turned into commands to send to individual ESCs using PWM.

Delivering high-quality sensor data in real time is of utmost importance for ensuring safe operation of the ROV. The main server receives sensor data from a variety of sources: a 9-Axis Orientation Sensor, which provides acceleration and rotational position; a depth sensor, which provides extraordinarily accurate depth readings; and power monitoring circuitry, which provides current and voltage readings; and various temperature sensors within these components. The main server then packages these data points into a JSON string and sends them to the top-side client via WebSockets.

```python
    def drive_motors(
        self,
        x_velocity=0,
        y_velocity=0,
        z_velocity=0,
        yaw_velocity=0,
        pitch_velocity=0,
        roll_velocity=0,
    ):
        # reset all the velocities to 0
        for i in range(len(self.motor_velocities)):
            self.motor_velocities[i] = 0

        self.calc_x_velocity(x_velocity)
        self.calc_y_velocity(y_velocity)
        self.calc_z_velocity(z_velocity)
        self.calc_yaw_velocity(yaw_velocity)
        self.calc_pitch_velocity(pitch_velocity)
        self.calc_roll_velocity(roll_velocity)

        for motor_num in range(len(self.motor_velocities)):
            if self.motor_velocities[motor_num] > self.speed_limit:
                self.motor_velocities[motor_num] = self.speed_limit
            elif self.motor_velocities[motor_num] < -self.speed_limit:
                self.motor_velocities[motor_num] = -self.speed_limit

        for motor_num, velocity in enumerate(self.motor_velocities):
            self.drive_motor(motor_num, velocity)
```

Figure 11. JONA ROV Motor Code
by Matty Harris

Stabilization

Stable and precise positioning is imperative to performing tasks quickly and efficiently. In years past, performing tasks that required incredible precision often proved difficult, as the pilot would frequently have to compensate for drifting or instability due to shifting water currents, taking the pilot's attention away from the task at hand. To address this, the software team has developed several, original stabilization algorithms to "anchor" the ROV in place, letting the pilot focus on performing tasks with precision. There are four different stabilization algorithms that help stabilize the ROV's depth, as well as its roll, pitch, and yaw orientation. Each stabilization algorithm is based on PID, or Proportional-Integral-Derivative control.

A PID controller is a mathematical tool that allows a system to quickly and efficiently reach a set value of a measurement, such as depth or temperature, and maintain that value over time. PID controllers adjust the strength of an output variable, which in the case of the ROV, is the speed of the motors. The algorithm calculates the difference between a target value and the actual value, and responds in proportion to this error. How strongly the algorithm reacts to this error can be adjusted.

The algorithm also includes an adjustable integral term that sums the error over time, and can help avoid oscillating between large and small error values. Finally, the algorithm also includes an adjustable derivative term that calculates how fast the controller is approaching the set point, which can be subtracted from the output to avoid overshooting. These three terms are added together to produce a variable output.

The software team implemented its own custom PID algorithm that takes a specific depth, roll, pitch, or yaw value as a set point and adjusts the motor outputs to achieve the desired set point. The team hand-tuned the adjustments, or gain, of each term of the PID equation to deliver the optimum response. The stabilization code is a component of the main server and can be easily toggled with a press of a button on the game controller. The four algorithms all work in conjunction with each other and can all be enabled at the same time to stabilize the ROV in place. When testing the algorithm, team members found that the ROV responds rapidly upon being disturbed from its set position. This is critical to ensure rock-solid stability and precision in the water.

```python
pid.py
    def compute(self, process_value):
        current_time = time.time()
        d_time = time.time() - self.last_time
        self.last_time = current_time

        # difference between the target value and measured value
        error = self.set_point - process_value
        # compute the integral ∫e(t) dt
        self.integral += error * d_time
        # compute the derivative de/dt
        d_error = (error - self.last_error) / d_time
        self.last_error = error

        # add the P, I, and the D together
        output = (
            self.proportional_gain * error
            + self.integral_gain * self.integral
            + self.derivative_gain * d_error
        )
        return output
NORMAL  main!  pid.py                                   pyt…  41%  ln :32/78
```

Figure 12. PID Code
by Matty Harris

G. Cameras

Hardware

JONA has three low-latency camera modules that allow the ROV pilot to view and interact with their surroundings efficiently. The digital nature of JONA's camera system also allows for easy image processing and computer vision applications.

Each camera has its own dedicated Raspberry Pi that performs all of the image processing and data transmission. This allows for almost unlimited expandability as the camera system is not limited to the processing power of a central computer.

JONA ROV's front-facing camera is a major improvement from our ROV from last year, as it needed two separate cameras facing forward, one for navigation and one for viewing the gripper. JONA ROV's single front-facing camera consolidates both functions into one piece of hardware and significantly reduces the complexity and number of failure points.

Unlike the Raspberry Pi 5 inside the tube, the peripheral cameras have Raspberry Pi Zero 2 Ws. These are ideal for modularity since they are smaller and therefore more compact. While they do have less processing power compared to other models of Raspberry Pi, they do less processing because they only run a camera server.

JONA ROV also has a downwards-facing and a rear-facing camera. Both of these "Tube Cameras" (Photo. 11) have a small airtight enclosure to contain their electronics, and all of their power and data transmission needs are provided through a single Cat 5E cable.

The basic design for the Tube Camera was reused from last year. During the 2022 MATE ROV World Championship, we were inspired by Jesuit Robotics' camera system. We adapted their idea of Pi Cameras paired with Raspberry Pi Zeroes into our current camera system. The Tube Cameras' housing and electronic connections are fully designed in house.

Sunk Robotics' 2024 Tube Cameras have been significantly improved compared to the 2023 cameras. The new modules require a single cable to connect them, instead of separate data and power connections. This involved creating a custom low voltage Power Over Ethernet (POE) design taking advantage of spare wires within the existing ethernet cable.

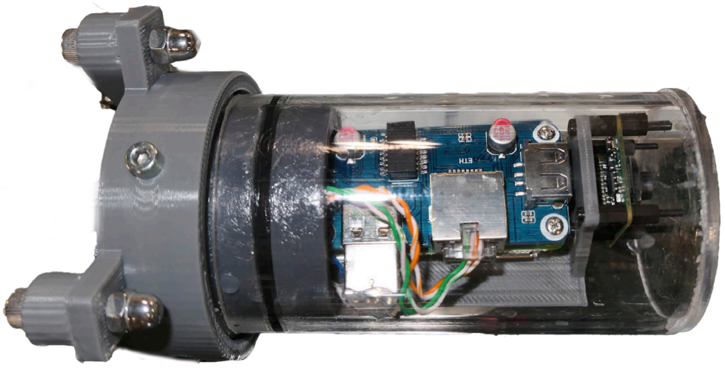


Photo 8. JONA ROV Tube Camera
Photo: Aaron BenDaniel

Software

Our custom software provides low-latency video feeds on all cameras to ensure the pilot has maximum awareness of their surroundings. While many solutions exist for live-streaming video, few meet the latency requirements for piloting an ROV in real-time. As a result, the software team decided to craft its own software. Each Raspberry Pi in each camera runs a custom Python script that uses Picamera2, a Python API for interfacing with Raspberry Pi cameras. The software encodes a video stream using MJPEG, a standard, computationally efficient protocol for ultra-low latency video streaming. The software then establishes a WebSocket connection with the top-side client, and sends over each video frame. Although MJPEG requires more bandwidth than other video codecs, it can be encoded and decoded extremely quickly with very little overhead, minimizing latency. Upon testing, the software team has found camera latency to be <170 ms. This is extraordinarily fast, and ensures the pilot can respond to stimuli as quickly as possible.

H. Mission Tasks

Static Manipulator System

JONA relies primarily on a static hook for accomplishing a variety of its assigned tasks. While mechanical grippers can be more versatile, they are slower to operate, more prone to failure, and more expensive. JONA implements a static manipulator system that has no moving parts and is easily replaceable. The system is modular in design and uses a hot-swappable magnet and a T-Slotted bar system to allow for the quick deployment of tools during the product demonstration.

This also allows for new tools to be built and be easily swapped in to fit whatever task the ROV must complete. This system is task-oriented and is easily modified to give JONA ROV's pilots the tools they need for the tasks they will attempt.

The Hook

JONA's primary tool is a curved hook that allows pilots to interact with many of the competition's props. The hook is carefully designed to facilitate maximum functionality from a singular tool as possible without compromising performance. It allows pilots to interact with both positively and negatively buoyant objects and is specifically sized to interact with the ½" PVC that many of the props are constructed from.

Photo 9. Sunk Robotics Hook
Photo: Aaron BenDaniel

Sediment Sample Collector

In order to efficiently collect sediment samples, (task 3.4), JONA uses an aluminum soop that is used to pick up objects that cannot interact well with the hook. It features an array of cut-out hexagons that reduce weight and allow the scoop to be easily maneuvered underwater. The holes allow water to flow unimpeded through the scoop and stop it from acting like a sail.

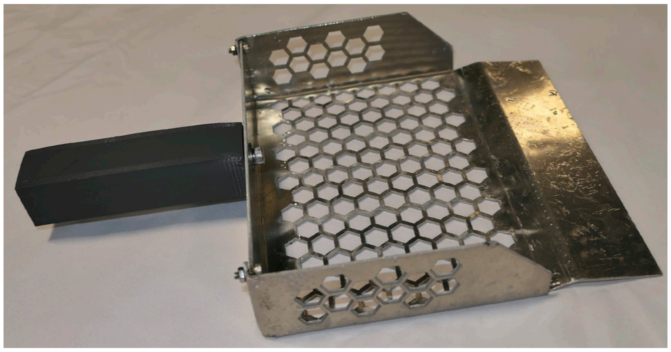


Photo 10. Sediment Sample Collector
Photo: Aaron BenDaniel

Carabiner Deployment Device

When tasked with attaching cables to underwater nodes, JONA is able to hold a carabiner in a purpose built holder. To complete this task, a repurposed rubber broom holder can be affixed to the frame of JONA. This broom holder is the perfect size to carry the carabiner and is neither too difficult to engage with the prop, nor is it too easy to drop it.

3D Modeling

Sunk Robotics has developed innovative software to autonomously generate a 3D model of the coral restoration area. On the top-side client, the pilot takes a picture of the coral restoration area and automatically calculates the variable lengths of the site using known lengths as a reference.

To generate a 3D model, the software team developed a custom script using Cadquery, a Python code-based parametric 3D modeling program. The software team spent countless hours painstakingly modeling the restoration site in CAD, and created a function to easily scale the model according to the specified dimensions. The program then renders a 3D model and sends it up to the top-side client where it can be displayed. Crucially, once the dimensions have been calculated, the pilot no longer needs to interact with the program. The 3D model is generated and displayed completely autonomously.

Autonomous Brain Coral

One of JONA’s most innovative features is the ability to autonomously transplant brain coral in challenging underwater environments. The software team wrote original code to tackle autonomously transplanting a sample of brain coral. The custom built algorithm receives a live video feed and uses OpenCV and Python to process each image. Using image segmentation, the algorithm calculates the center of the designated red square and uses two separate PID algorithms to keep the red square in the center of the ROV’s vision. Using Perspective-N-Point calculation, the ROV calculates the distance from the red square. When the distance falls below a set amount, the ROV goes into “landing” mode and changes its approach to place the brain coral down, despite vision of the red square being obscured.

JENA Float

The JENA underwater autonomous profiling float was designed and built fully in house. Rather than using a more traditional design where oil is moved from an internal hard bladder to an external soft bladder to change buoyancy, a simpler and safer pneumatic design is used. In the design, air is compressed and decompressed in a hard cylinder that doubles as electronics housing. The core of JENA is a 61 cm long acrylic electronics tube. It is the housing for all other components and acts as a pressure vessel.

JENA does a profile starting at the surface. It then takes on water by retracting the piston and sinking, then pushes the water out causing it to rise again.

A Pololu GB37-150 motor moves the Float's dynamic seal. This motor was chosen because it has enough torque to move the seal while under the pressure created by being four meters underwater, and it runs off of 12v.

JENA is powered by eight AA batteries housed in a custom battery holder in order to comply with MATE rules for non-ROV devices. They are placed in series and voltage is regulated for different parts of the main board.

The Float team wrote custom firmware using the Arduino Programming Language (a superset of C++). The electronics use an external Wi-Fi Antenna that is attached through the top cap with a custom, no-pot sealing method.

Using the antenna for communication, the board hosts a WebSockets server. With all of our components working together, JENA can successfully traverse the water column while using very little power

Photo 11. JENA Float
Photo: Scott Campbell

I. Design Evolution

JONA is Sunk Robotics' second generation ROV. Although improvements were made to STEVE over the years, many proposed changes were too complex to be applied to an existing robot. This opportunity allowed us to build a next-generation robot that is highly robust, better organized, and more efficient than its predecessor, STEVE ROV.

The primary changes that separate JONA from STEVE are an all-metal, aluminum frame, eight Blue Robotics T200 thrusters, and a modular PCB-based electronics system. The construction of JONA ROV required new skills to be added to the team's repertoire. Skills such as water-jet cutting, advanced PCB design, and surface-mount soldering were new to the team, but they are now well understood and can be used in the construction of any new hardware Sunk Robotics develops.

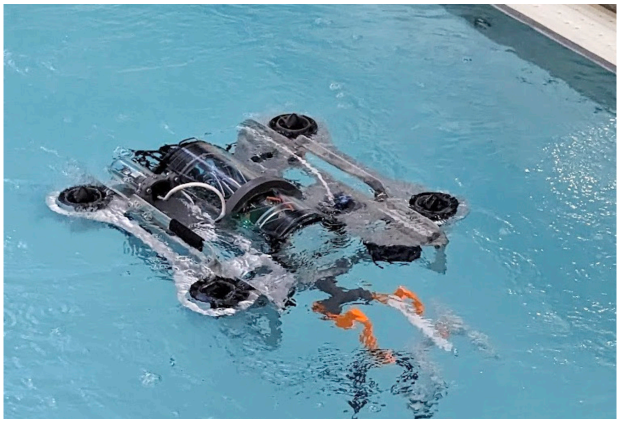


Photo 12. JONA ROV In MVTHS Pool
Photo: Aaron BenDaniel

IV. TESTING & TROUBLESHOOTING

Sunk Robotics regularly runs mechanical and safety tests of all components of JONA ROV. During every team meeting, the hardware, software, and electrical team leads run through every function of the robot and assess their performance.

During the development process of JONA and JENA, electronics, software and water seal testing were an important part of verifying the integrity of the system. In order to aid in electrical system testing, we designed a custom QC software program that runs each motor individually in a predefined order. This process highlights any broken motor and verifies that the control system knows which motors are which.

Testing of new PCBs was done in multiple stages. Each part would be tested in isolated simulations of real functionality. For example, each PCB was connected to the necessary components (power, data, etc), and functions were tested independently before integration into the ROV. After the component passed the preliminary tests, it would be installed into the ROV and a full systems test would be conducted.

JONA's simple static manipulation system requires very little testing, but strength tests are conducted on all attachments to ensure they meet the requirements of the task(s) they were designed to complete.
Test pads are present on the PCBs of JONA ROV to allow for easy voltage measurements, testing the voltages on all of the PCBs is one of the first tests conducted when something appears to be broken.

When electrical issues arise and their cause/solution is not found with the simple preliminary tests, systematic isolation of the PCBs is used to determine the specific area that is causing the problem. From there, individual components are checked and software is reviewed to determine the specific source of the issue.

V. SAFETY

At Sunk Robotics safety of our customers is our first priority. Sunk Robotics utilizes thorough safety protocols in every step of product development, testing, and operation.

JONA ROV was designed according to Sunk Robotics and MATE Safety standards. All electrical components of JONA are completely secured and watertight, any potentially sharp edges have been deburred, and strain relief is implemented to reduce the risk of on-deck accidents

With the guidance of team mentors, Sunk Robotics conducts regular safety training to equip team members with the knowledge to avoid injuries and prevent accidents. Each member is trained in pool safety, electrical safety, tool safety, handling hazardous materials, machine operation protocols, and promoting safe organization efforts.

All Sunk Robotics team members must practice basic safety by wearing appropriate clothing, proper PPE, and tied-back hair when applicable (Photo 17).

Gloves, masks, ear protection, and safety glasses are required to operate tools and handle certain materials and machines while working in the MVTHS Robotics & Engineering shop. All team members are trained and supervised by the team Chief Safety Officer, as well as Robotics instructor and Sunk Robotics mentor Samuel Christy when operating potentially dangerous machinery.

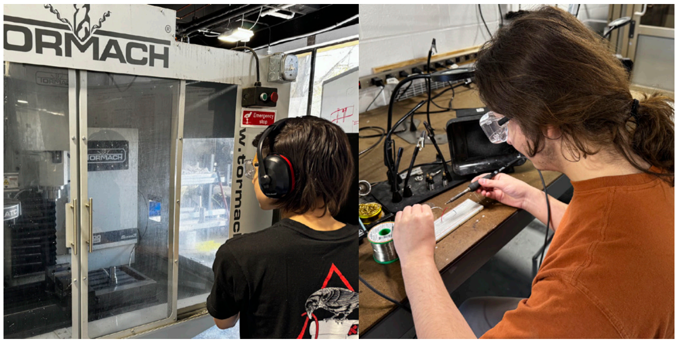


Photo 13. Team Members Working on ROV
Photo: Zack Bertocchi

At Medford Vocational Technical High School, all vocational students must complete an OSHA 10-hour industry course; this means that all members of Sunk Robotics conduct themselves according to the United States Occupational Safety and Health Administration guidelines.

To ensure safety during pool practices, Sunk Robotics team members follow a detailed checklist (Appendix B.) developed by Sunk Robotics CSO Zack Bertocchi. When working near water, team members always secure any electrical cords or devices away from moisture.

Any member on deck communicates with the ROV pilot and tether manager, and the ROV is thoroughly dried after all operations. The team's laptop and PSU are placed on an elevated platform during all pool operations to eliminate the risk of electrocution. To maintain safe poolside practice, all members on deck must practice setting up, mission operations, and clean up.

VI. ACCOUNTING

Income:							
Type:	Source:	Amount:	Notes:				Running Total:
Coorperate Sponor	Watts Water Technologies	$ 7,000.00	Left over from previous year				$ 7,000.00
Coorperate Sponor	Watts Water Technologies	$ 10,000.00					$ 17,000.00
Community Donations	GoFundMe	$ 1,200.00					$ 18,200.00
Expenses:							
Type:	Date:	Company:	Name:	Quantity:	Unit Price:	Total:	Running Total:
Donated	4/22/2023	Blue Robotics	T200 Thruster + Basic ESC - WON FROM 2023 REGIONAL	2	$ 238.00	$ 476.00	$ 476.00
Purchased	9/14/2023	Blue Robotics	T200 Thruster + Basic ESC	6	$ 238.00	$ 1,428.00	$ 1,904.00
Purchased	9/14/2023	Blue Trail Engineering	Waterproof disconnectable connector	2	$ 32.20	$ 64.40	$ 1,968.40
Purchased	9/14/2023	Blue Trail Engineering	Waterproof disconnectable connector	1	$ 45.50	$ 45.50	$ 2,013.90
Purchased	9/14/2023	Blue Trail Engineering	Waterproof disconnectable connector	2	$ 34.30	$ 68.60	$ 2,082.50
Purchased	9/14/2023	Blue Trail Engineering	Waterproof disconnectable connector	1	$ 49.70	$ 49.70	$ 2,132.20
Donated	6/16/2023	Lenovo	Thinkpad L13 Laptop	1	$ 174.99	$ 174.99	$ 2,257.49
Purchased	9/27/2023	Digikey	Polarized power connector	20	$ 0.31	$ 6.20	$ 2,138.40
Purchased	9/27/2023	Digikey	Polarized power connector	20	$ 1.66	$ 33.20	$ 2,171.60
Purchased	9/27/2023	Digikey	.1 inch 5-pin polarized connector	20	$ 1.39	$ 27.72	$ 2,199.32
Purchased	9/27/2023	Digikey	.1 inch 5-pin polarized connector	20	$ 0.36	$ 7.16	$ 2,206.48
Purchased	9/27/2023	Digikey	Polarized 3-pin power connector	20	$ 0.34	$ 6.80	$ 2,213.28
Purchased	9/27/2023	Digikey	Polarized 3-pin power connector	20	$ 0.11	$ 2.18	$ 2,215.46
Purchased	9/27/2023	Digikey	Crimp Part for A1411-ND	20	$ 0.12	$ 2.34	$ 2,217.80
Purchased	9/27/2023	Digikey	Crimp Part for XARP-03V	20	$ 0.05	$ 0.94	$ 2,218.74
Purchased	10/2/2023	Blue Robotics	Cast Acrylic Tube 6" 298mm	1	$ 150.00	$ 150.00	$ 2,368.74
Purchased	10/2/2023	Blue Robotics	6" Tube Flange	2	$ 84.00	$ 168.00	$ 2,536.74
Purchased	10/11/2023	eBay	Plastic 60 Degree Brackets	2	$ 12.06	$ 24.12	$ 2,560.86
Purchased	10/12/2023	The O-Ring Store	3m CS x 44mm ID NBR O-Ring	10	$ 0.67	$ 6.70	$ 2,567.56
Purchased	10/14/2023	Digikey	RJ JACK, 1 PORT, 8P8C, 30U, SHIE	10	$ 2.02	$ 20.17	$ 2,587.73
Purchased	10/17/2023	Digikey	220uf capacitor for the PWM controller	10	$ 0.32	$ 3.20	$ 2,590.93
Purchased	10/17/2023	Ebay	12V to 5V Regulator	1	$ 3.81	$ 3.81	$ 2,594.74
Purchased	10/18/2023	TotalBoat	Marine Epoxy	1	$ 24.99	$ 24.99	$ 2,619.73
Purchased	10/23/2023	Polar Wire	Black 10awg 105/30 100ft wire	1	$ 71.41	$ 71.41	$ 2,691.14
Purchased	10/23/2023	Polar Wire	Red 10awg 105/30 100ft wire	1	$ 71.41	$ 71.41	$ 2,762.55
Purchased	10/23/2023	Polar Wire	Anderson Powerpole Conector Crimps	20	$ 0.59	$ 11.80	$ 2,774.35
Purchased	10/24/2023	Digikey	Anderson Powerpole Connector	25	$ 0.55	$ 13.67	$ 2,788.02
Purchased	10/24/2023	Digikey	Anderson Powerpole Connector	25	$ 0.56	$ 13.99	$ 2,802.01
Purchased	10/24/2023	Pololu	ACS711EX Current Sensor Carrier -31A to +31A	5	$ 3.63	$ 18.15	$ 2,820.16
Purchased	11/8/2023	McMasterCarr	M3 8mm Corrsion Resistant Screws	1	$ 13.12	$ 13.12	$ 2,833.28
Purchased	11/8/2023	McMasterCarr	M3 Washer	1	$ 4.88	$ 4.88	$ 2,838.16
Purchased	11/15/2023	Digikey	.1 inch 2-pin polarized connector	30	$ 0.32	$ 9.69	$ 2,847.85
Purchased	12/4/2023	eBay	1/2in Cable Sleeve	1	$ 11.44	$ 11.44	$ 2,859.29
Purchased	11/27/2023	eBay	Cable Thimble	2	$ 7.98	$ 15.96	$ 2,875.25
Purchased	11/27/2023	LANShack	Cat 5e Ethernet Cable	1	$ 23.47	$ 23.47	$ 2,898.72
Purchased	11/27/2023	Blue Robotics	Blue Robotics 6.5mm LC Wet-Link Penetrator	1	$ 50.00	$ 50.00	$ 2,948.72
Purchased	12/4/2023	eBay	XT30 2 Pos Right Angle Pair 10pcs	1	$ 19.59	$ 19.59	$ 2,968.31
Purchased	12/4/2023	eBay	XT30 3 Pos Right Angle Pair 10pcs	2	$ 11.84	$ 23.68	$ 2,991.99
Purchased	12/4/2023	eBay	XT30 3 Pos Straight Pair 10pcs	2	$ 6.97	$ 13.94	$ 3,005.93
Purchased	12/7/2023	Blue Robotics	Enclosure Vent and Plug	3	$ 9.00	$ 27.00	$ 3,032.93
Purchased	12/7/2023	Blue Robotics	Basic ESC	2	$ 36.00	$ 72.00	$ 3,104.93
Purchased	12/7/2023	eBay	O-Ring Lubricant	1	$ 17.45	$ 17.45	$ 3,122.38
Purchased	1/12/2024	eBay	5mw 650nm Laser	1	$ 4.76	$ 4.76	$ 3,127.14
Purchased	2/15/2024	Adafruit	12-Bit ADC	2	$ 9.95	$ 19.90	$ 3,147.04
Purchased	2/15/2024	Pololu	Voltage Regulator	2	$ 24.95	$ 49.90	$ 3,196.94
Purchased	2/15/2024	Digikey	LT6654BIS6-2.5#TRMPBF	5	$ 4.52	$ 22.60	$ 3,219.54
Purchased	2/15/2024	Digikey	CMF60250R00BHEB	10	$ 0.79	$ 7.87	$ 3,227.41
Purchased	2/22/2024	Adafruit	Raspberry Pi 5 FPC Camera Cable	5	$ 2.00	$ 10.00	$ 3,237.41
Purchased	2/22/2024	Digikey	53.6KΩ SMD Resistor (1.6mm x 0.85mm)	20	$ 0.08	$ 1.62	$ 3,239.03
Purchased	3/17/2024	Digikey	Optoisolator	5	$ 4.14	$ 20.70	$ 3,259.73
Purchased	3/17/2024	Digikey	RJ JACK, 1 PORT, 8P8C, 30U, SHIE	10	$ 2.02	$ 20.17	$ 3,279.90
Purchased	3/27/2024	Samsung	Small form factor USB stick 128 GB	3	$ 14.99	$ 44.97	$ 3,324.87
Purchased	4/3/2024	The Home Depot	1/2 in. x 6 ft. Foam Pipe Insulation	4	$ 1.78	$ 7.12	$ 3,331.99
Purchased	4/3/2024	rovmaker	Underwater High Torque Servo Motor	1	$ 139.00	$ 139.00	$ 3,470.99
Purchased	4/3/2024	eBay	Short Body Cat 5 RJ45 plug	3	$ 6.00	$ 18.00	$ 3,488.99
Purchased	4/3/2024	eBay	16 Channel PWM Controller	2	$ 4.92	$ 9.84	$ 3,498.83
Purchased	4/3/2024	Adafruit	BNO055	1	$ 29.95	$ 29.95	$ 3,528.78
Purchased	4/4/2024	eBay	Thinkpad L13 CMOS Battery	4	$ 5.98	$ 23.92	$ 3,552.70
Purchased	4/12/2024	Digikey	2mF Electrolytic Capacitor	10	$ 0.85	$ 8.52	$ 3,561.22
Purchased	4/12/2024	The Home Depot	Zipties	2	$ 5.95	$ 11.90	$ 3,573.12
Travel Expenses:	Amount:		Notes:			Value of Reused Parts	$ 650.99
Gas Money	$ 680.00		1700 miles / 10 mpg * $4 per-gallon			Travel Expenses for International:	$ 7,780.00
Hotel	$ 4,100.00					Ice Cream (If We Win):	$ 55.00
Food	$ 1,500.00		$15 per-person-per-meal * 2 meals-per-day * 10 people * 5 days			Total Expenses:	$ 11,408.12
Shirts	$ 1,000.00						
Supplies	$ 500.00		Pre-allocated for items bought in Tennessee			Total Income:	$ 18,200.00
Total Travel Expenses	$ 7,780.00					Remaining Balance:	$ 6,791.88

VII. CONCLUSION

A. Acknowledgments

Sunk Robotics is grateful to be fortunate enough to be a part of the MATE program once again. The team expresses its gratitude toward MATE, the Marine Technology Society, MATE II, Kingsport Aquatic Center, and all the people who continuously work hard to provide this opportunity for students worldwide.

Sunk Robotics thanks the following for their constant support:

- Watts Water Technologies for their continued financial support towards the team

- Sunk Robotics Mentors Samuel Christy and Lisa Miller, thank you for your patience, guidance, and time spent fostering an environment where students can thrive. Your dedication to Sunk Robotics means the world to the team.

- Medford Vocational Technical High School for supporting Sunk Robotics and allowing the team to utilize school resources and facilities.

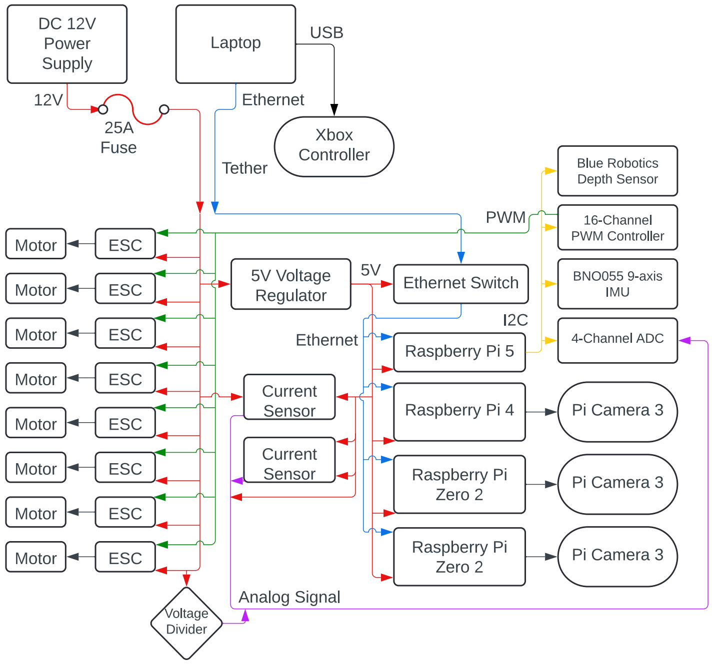
- Shane Colton, your assistance in educating members of Sunk Robotics in advanced PCB design practices was invalublе.

B. References

- https://datasheets.raspberrypi.com/camera/picamera2-manual.pdf
- 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

VIII. APPENDICES

A. JONA ROV SID



- 8 Blue Robotics T-200 Thrusters - 2.8A each: 22.4A
- 2 Raspberry Pi Zero 2s - 0.35A each: 0.7A
- Raspberry Pi 4: 0.575A
- Raspberry Pi 5: 0.54A
- 4 Low power I2C devices - 0.1A each: 0.4A

Total Current: 24.615A*150%=**36.9225A**

A 25A fuse will be used

B. Safety Checklist

Deck Check:
- ☐ Area is clear of hazards
- ☐ All personnel wearing personal floatation devices
  - Exception for divers
- ☐ ROV is unloaded and ready for power-on
- ☐ Tether is unspooled, untangled, and ready for deployment
- ☐ Props are organized and ready to be given to ROV
- ☐ Tools are organized and ready to be installed

Inspection:
- ☐ ROV motors are unobstructed
- ☐ Visual inspection of power supply reveals no damage
- ☐ Visual inspection of tether reveals no damage
- ☐ Visual inspection of ROV frame reveals no damage
- ☐ Visual inspection of ROV Electronics reveals no damage
- ☐ Visual inspection of Float reveals no damage
- ☐ All vent plugs are sealed

Power On:
- ☐ ROV power supply is plugged in
- ☐ Deck attendant announces that power on will begin
- ☐ Anderson Powerpole connectors are mated
- ☐ ROV indicator lights are illuminated
- ☐ ESC startup sound heard
- ☐ Webclient connected
- ☐ Camera feeds started
- ☐ Motor control started

ROV Launch:
- ☐ Deck attendants confirm ROV is ready for launch
- ☐ Pilot requests ROV launch
- ☐ ROV is lowered into the simulated moon pool
  - Deck attendants hold ROV in place
- ☐ Inspect all watertight enclosures for leakage
  - If leakage is detected, follow leakage procedures
- ☐ Pilot requests ROV release
- ☐ Deck attendants release ROV

Operational duties:
- ☐ Deck attendants manage tether
- ☐ Deck attendants retrieve objects from the ROV at the discretion of the Pilot
- ☐ Deck attendants give objects to ROV at the discretion of the Pilot

ROV Retrieval:
- ☐ Pilot bring ROV to simulated moon pool
- ☐ Pilot requests ROV removal
- ☐ Deck attendants remove ROV from water and set on Deck
- ☐ Pilot confirms ready for shutdown
- ☐ Anderson Powerpole connectors unmated
- ☐ Power supply unplugged

Leakage Detected:
- ☐ Immediately unplug Anderson Powerpole connectors
- ☐ Remove ROV from water
- ☐ Remove Main Tube vent plug
- ☐ Remove electronics frame
- ☐ Drain water from tube
- ☐ Testing concluded for the day
  - Main Tube given at minimum 6 hours to air-dry