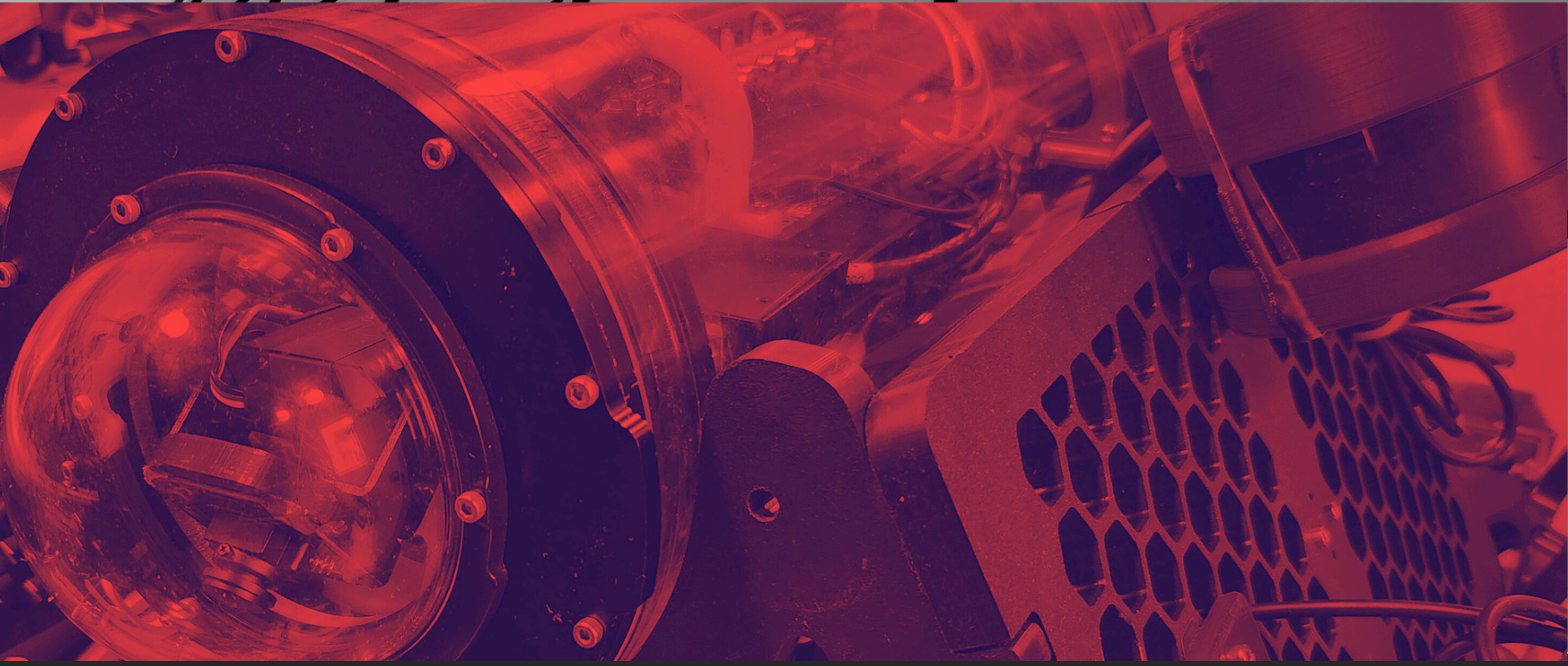
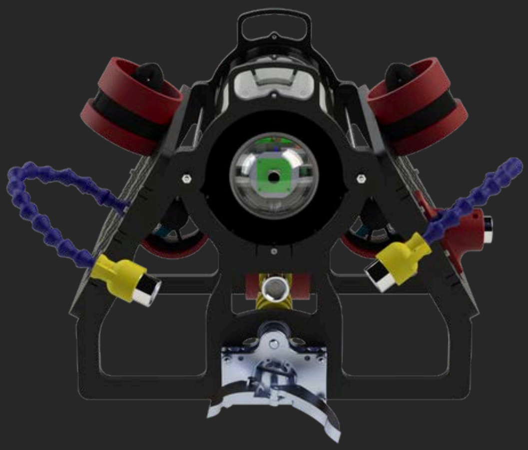


LBCC ROV



Long Beach City College (LBCC)
Viking Explorers

Long Beach, California, USA 90806

TEAM

Mechanical

JOSEPH RAMIREZ - MANUFACTURING ENGINEER
JASON BECKHAM - PRODUCTION/ELECTRICAL
VICTOR SALAS - PRODUCTION/ELECTRICAL
HAYDEN LUCSIK - DESIGN ENGINEER
CODY HUTTON - QC/PRODUCT DESIGN
SERGIO CASTANEDA-MEDINA - DESIGN

Mentors

SCOTT FRASER - TEAM COACH
TARA WILLIS - TEAM MENTOR

Electrical

AUBREY YUEN - ELECTRICAL ENGINEER
NAM LE - ELECTRICAL ENGINEER

Software

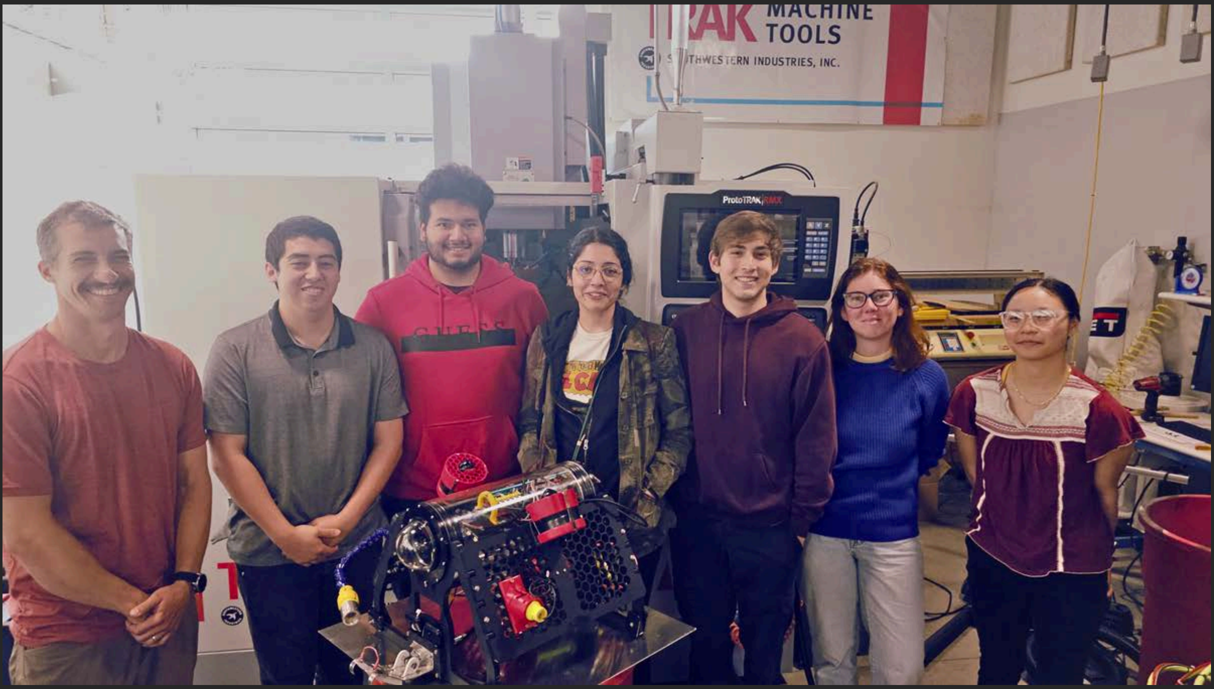
AUBREY YUEN - PHOTOGRAMMETRY DEVELOPER
ALLISON LOWE - PHOTOGRAMMETRY DEVELOPER
CAMI GANN - FLOATER DEVELOPER
SARAH KHAN - FLOATER DEVELOPER
GAVIN TOM - ROV SYSTEMS DEVELOPER
MATTHEW HANLEY - ROV SYSTEMS DEVELOPER

LONG BEACH, CA

2024

ABSTRACT

The LBCC Viking Explorers return to MATE with the Oden ROV and Thorpedo water column profiler.



Long Beach City College Viking Explorers Team Picture (From left to right): Jason Beckham, Joseph Ramirez, Sergio Castaneda-Medina, Sarah Khan, Cody Hutton, Cami Gann, and Aubrey Yuen.

Our company has worked on developing products that will be sold in the SeaMate store and building upon the SeaMate ROV Control board. An entirely new ROV simulator was built and used for the development of control software while the ROV was being fabricated. In addition, an IO expansion card was built that allowed the company to expand the number of cameras in the ROV up to five and provides control of two additional DC motors.

Our focus was a modular approach to ROV chassis and tool development shown by our three sets of grippers that can be swapped out according to need. The development of the Thorpedo was completely from scratch and we also extended the simulation concept to the controls to allow for software development of the Thorpedo control system in parallel with the hardware development. The use of the simulation systems resulted in minimum integration time with hardware and software and earlier into the water. The company is anxious to demonstrate their two systems and hopes that their concept of parallel software and hardware development will help others in the industry bring products to market faster.

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PROJECT MANAGEMENT

MECHANICAL

Our mechanical team has an advantage of having members of diverse backgrounds and experiences. We had several experienced draftsmen (i.e. Hayden Lucsik, Cody Hutton, Sergio Castaneda-Medina), working on different CADs in parallel. The entire sub-team, including Scott Fraser, would participate in weekly design-reviews where suggestions would be made to improve part quality and ease of manufacturing. When a design was ready, the draftsmen would talk with a technician (i.e. Jason Beckham, Joseph Ramirez, Victor Salas) and plan the manufacturing methods (i.e. machining, rapid-prototyping), tolerances, and assembly instructions. Lastly, all sub-team members would participate in the pressure testing and leak detection of our systems.

SOFTWARE

Software needs were assessed using a top down decomposition approach. Major software components were then assigned to sub-teams. Software implementation involved a stepwise approach in which major functional components would be defined alongside control flow design. Initial software versions were subject to group/peer software reviews for mission objective alignment and optimization.

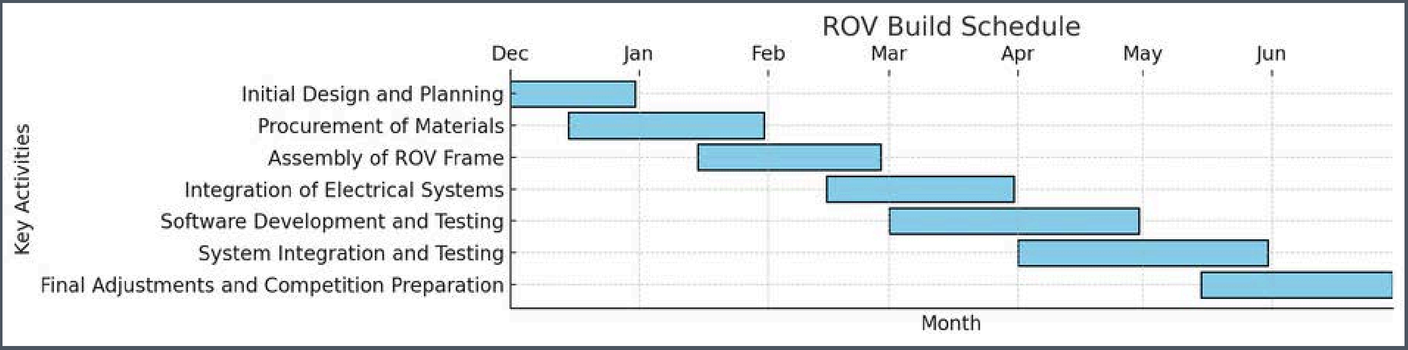
ELECTRICAL

At the very beginning of the season, our team knew our vertical profiler would need two custom circuit boards. They were a high-priority and were completed by the end of January to accommodate the software team. Nam Le designed the float's power distribution system and Aubrey Yuen designed the float's control board. Additionally, they were responsible for all the soldering, terminal crimping, and wire routing for the ROV and float whenever queued by mechanical or software members. In addition, very early on we built the SeaMate provided circuit boards for the ROV control and the three 48V to 12V power supply boards. These were all tested and operational early in Fall 2023.

OPERATING PROCEDURES

Upon the release of the Competition Manual, our team met to develop a timeline for deliverables. First, we all overviewed the Explorer-Class Mission Tasks and decided which methods of scoring to prioritize. This would inform what our system capabilities should be. After some weeks we decided our biggest projects would be a versatile gripper, a reliable vertical profiler, and our photogrammetry software. Next, we discussed reasonable timeframes for sub-teams to achieve deliverables. We estimated the dates to beta-test all our desired features. Sub-teams organized their own plans to have their deliverables ready for testing on schedule.

BUILD SCHEDULE



DESIGN RATIONALE

ENGINEERING DESIGN RATIONALE

The design rationale for our ROV centered around an agile base model with modular tools to adapt to a variety of applications. We outfitted our frame with purpose-built tools for 3 main objectives: 1) To collect and provide data to better understand the ocean, its complexity, and how it is changing; 2) To equip transoceanic telecommunications cables with sensors to provide insights into the state of the ocean; and 3) To map coral reefs for monitoring and rehabilitation. Completion of these key missions depends most upon a reliable vehicle that is easy to pilot; therefore, we designed an ROV with high maneuverability and high payload capacity.

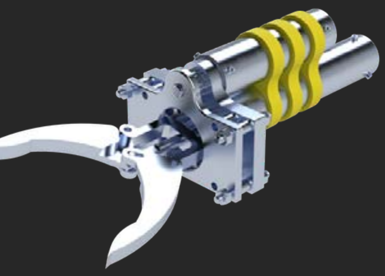
Vehicle Chassis Rationale

Our initial focus was on a chassis that is wide and robust yet hydrodynamic. A wider base increases the moment of inertia of the vehicle, so the propulsion and environment have a less extreme effect of unwanted motion of the vehicle. Our propulsion would determine which degrees of freedom are most accessible to our pilot. Having too much directional freedom would overcomplicate piloting, yet insufficient directional freedom would make certain maneuvers harder to execute. We decided the best piloting experience would be achieved by prioritizing the elevation, forward/backward, crabbing (translating left/right from FPV) and yaw (rotating left/right from FPV) axes. These capabilities are essential for aligning the gripper with flexible cables or a valve, navigating around and over obstacles for photogrammetry and precisely maneuvering tools into small areas.

CHASSIS WITH HEX PATTERN

Tool Package Rationale

While the chassis allows for a variety of tools to be added for specific applications, our mission goals required 3 main capabilities: 1) High-Resolution Multi-Camera System for observation, data gathering/analysis, and photogrammetry, 2) Versatile and Precise Gripper to precisely move objects and interact with the underwater environment and 3) Robust and Reliable Power System to ensure consistent performance and the ability to handle multiple tasks simultaneously. Together, this package enables our ROV to conduct thorough environmental monitoring, precise deployments, and secure installations; all essential for expanding ocean observing systems and protecting marine ecosystems.



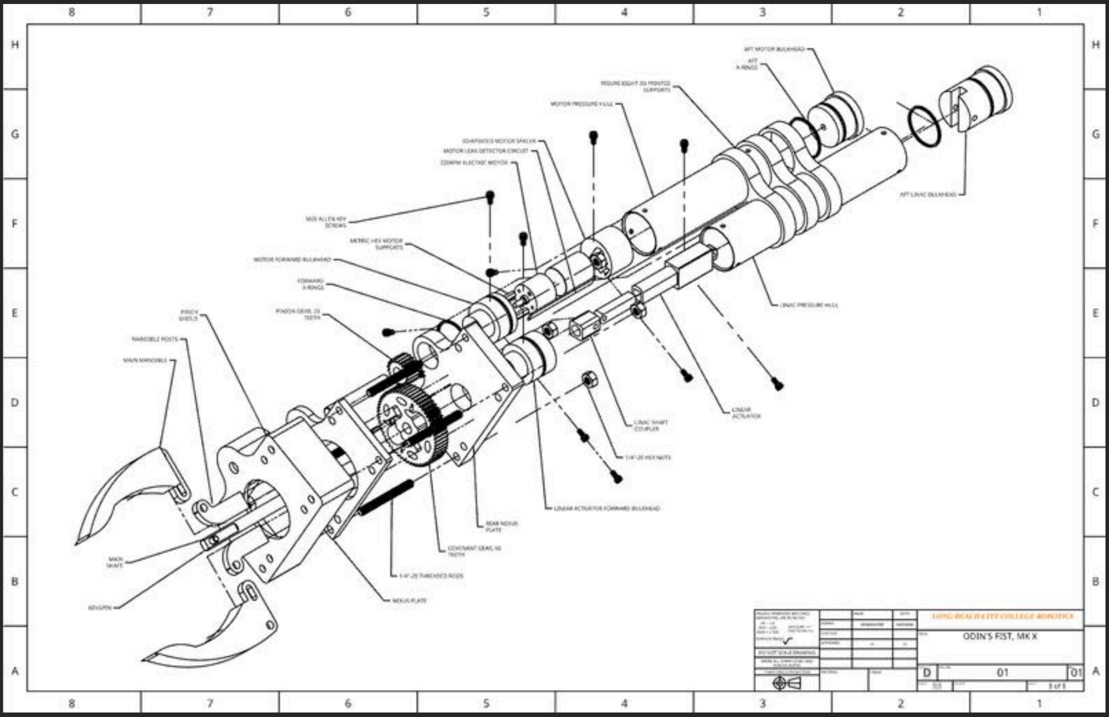
GRIPPER DESIGN

Software Rationale

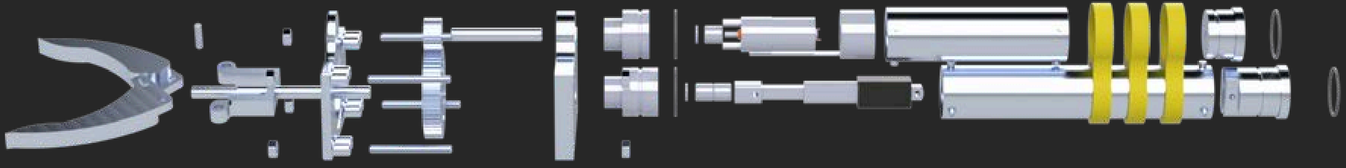
Our software design ensures the ROV can efficiently complete complex underwater tasks through precise control and real-time feedback. The ROV software leverages the PyGame library for intuitive control via a video game controller, converting inputs into JSON packets that the Arduino processes to control the thrusters, gripper, and camera systems. This setup allows for flexible and responsive maneuvering, essential for accurately navigating and manipulating objects underwater.

INNOVATION

In previous years, our manipulators did not have the ability to rotate or precisely grab items in the water. These prior variants were pneumatically driven, and were clunky in their design. To meet the demands of the industry and the rigors of the competition, a new manipulator was required. This new manipulator needed the ability to not only grab with great precision, but to rotate a full 360° as well. To this end, a new gripper was designed to meet these evolving needs of our client. It was discovered in the initial R&D phases that no commercially available gripper existed with these desired characteristics. For example, a BlueRobotics Newton manipulator costs around $640, and does not rotate despite having relatively high precision. Due to the high cost and low availability, we decided upon the creation of a homebrew manipulator that could meet our clients demands.



GRIPPER DIAGRAM



GRIPPER ASSEMBLY

For every upgrade to the design, we considered several key factors; would it be feasible to machine? Are the bulkheads reliably watertight? Will the addition of screws make it more modular/field-repairable? By revisiting critical components, we were able to maximize the utility and ruggedness of our claw module, while improving its overall form to meet the needs of our clients.

PROBLEM SOLVING

Our approach to problem-solving within the ROV development team is rooted in systematic, data-driven methodologies and collaborative brainstorming sessions. This ensures that we tackle challenges effectively and implement the most robust solutions.

BRAINSTORMING & IDEATION

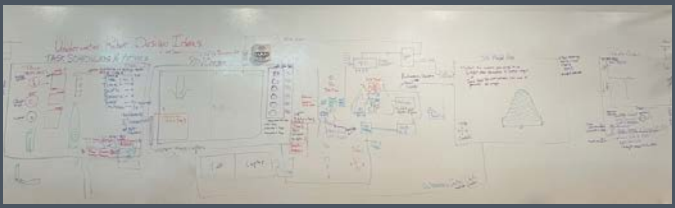
When faced with a problem, our first step is to conduct a brainstorming session involving team members from various disciplines including mechanical, electrical and software disciplines. While informal, these sessions allow us to design parts with all systems in mind to alleviate potential design issues that could cause issues during the build phase. We utilize tools such as whiteboards and digital collaboration platforms like Teams to capture and visualize ideas. This process not only helps in generating a broad range of solutions but also ensures that all perspectives are considered. When developing our camera system we continuously had issues and we had to come up with multiple solutions to resolve the issues.

EVALUATION PROCESS

Following the brainstorming phase, for key decisions we assessed the viability through multiple iterations & testing, conducting a trade study and feasibility analysis.

1. **Data Collection:** Gathering all relevant data that can impact the decision. This includes technical specifications, environmental constraints, cost implications, and time.
2. **Rapid Prototyping:** Utilizing our 3D printers, we were able to create multiple prototypes quickly, test the components and make revisions based on potential issues that arise.
3. **Feasibility Analysis:** Analyzing the feasibility of each solution, considering the current resources, capabilities, and technological constraints.

After evaluating the alternatives, the team convenes to discuss the findings and make informed decisions. The implementation is closely monitored, reviews are conducted to ensure that the solution is effective. If issues arise during implementation, the team is prepared to revisit the problem-solving process, leveraging lessons learned to refine the approach.



DESIGN IDEAS WHITEBOARD

CONTINUOUS IMPROVEMENT

Our problem-solving approach is iterative, emphasizing continuous improvement. A great example of this is overhauling our auxiliary camera system after finding some slight issues with water intrusion. We decided to replace the cameras with higher resolution ones and redesigned the housing and connectors to avoid any potential water issues. After project completion, we conduct a post-mortem analysis to identify what worked well and what could be improved. This reflective practice not only enhances our immediate project outcomes but also contributes to the long-term improvement of our problem-solving capabilities.

One of the tougher challenges we faced during our inspections was persistent leaks that constantly evaded our vacuum and snooping tests. One of the leaks was severe enough that during a seaworthiness trial, one of our thruster power modules became non-operational. We spent over 2 weeks tracking down these leaks only to continue to find water after passing a vacuum test. One of the main problems we encountered that we learned some lessons from was a missing O-ring on one of the connectors. Our team had assumed that when it was assembled, the O-ring was properly installed, but really we should have done a check of all of the seals as a first step to our troubleshooting. This however, did not resolve the problem completely, we continued to find small amounts of water in the main capsule. After further testing we found that there was water being siphoned through a cable insulation jacket of a cable that would eventually power the gripper.

SYSTEMS APPROACH

Our company's philosophy in designing the ROV is centered around a balanced and integrated systems approach. This methodology ensures not only the effective operation of each individual component but also their seamless interaction with each other, enhancing the overall functionality and reliability of the vehicle.

Our design allows each sensor, from cameras to environmental sensors, to communicate efficiently with the central control system allowing us to complete a variety of tasks effectively. The modular nature of our design means sensors can be easily added, removed, or upgraded, allowing our ROV to adapt to new missions or technological advancements without requiring a complete redesign. A great example of this is when we had to replace a power supply for 1 of the thrusters, minimizing the ROV downtime to less than 1 hour. Another example of our systems approach is the ability to have 5 different camera angles, allowing us to have many perspectives for many different tasks in the same dive.

SOFTWARE DESIGN AND CONTROL FLOW

In software development, we employ a stepwise design approach that adheres to the principles of top-down design and Object-Oriented Programming (OOP). Our software architecture is structured around a state machine control flow, which clearly defines various states the ROV can be in during a mission, such as navigation, data collection, or emergency shutdown.

```
# GUI window setup
sidebarwidth = 220
pygame.init()
pygame.display.set_caption ('ROV Control')
size = width, height = 160+sidebarwidth, 320#size of GUI

#setup displays in GUI
screen = pygame.display.set_mode(size)
onstatus=widgets.toggleable("FULL POWER",sidebarwidth)#label and size toggle
zslider=widgets.sliderdisplay("Z",75,160)
mleftslider=widgets.sliderdisplay("Leftslider",75,160)
mrightslider=widgets.sliderdisplay("Rightslider",75,160)
temp_display=widgets.display("Temp (C)",sidebarwidth)
th_up_display=widgets.display("Servo Up",sidebarwidth)
th_left_display=widgets.display("Servo Left",sidebarwidth)
th_right_display=widgets.display("Servo Right",sidebarwidth)

#open serial com to Arduino
ser= serial.Serial(port='COM4', baudrate=9600, timeout=.1,dsrdtr=True)#dsrdtr=True stops Arduino Mega from autoresetting

#init joystick
joystick = None
if pygame.joystick.get_count()==0:
    print ("No joystick Detected")
else:
    joystick = pygame.joystick.Joystick(0)
    joystick.init()#initalize joystick
    js_axes = joystick.get_numaxes()
    js_buttons = joystick.get_numbuttons()
    print("axes ",js_axes," buttons ",js_buttons)

loopCntr = 0
loopTime = 0
#Main Loop
while True:
        # Get input from joystick and keyboard
    pygame.event.pump()
    key = pygame.key.get_pressed()
    for event in pygame.event.get():
        if event.type == pygame.QUIT:
            running = False
        if event.type==pygame.JOYBUTTONDOWN:
            if event.button ==11:
                onstatus.toggle()
```

ROV CONTROL CODE

Top-Down Design: This method helps in breaking down the software development process into manageable pieces. By starting with the most general functions and progressively detailing into finer functionalities, we ensure that each software module meets its specific requirements while aligning with the overall system objectives.

Object-Oriented Programming (OOP): Using OOP, we encapsulate related functions and data together into objects. This encapsulation not only makes the code more modular and easier to manage but also enhances the reusability of components. For example, a 'MotorControl' object would handle all functionalities related to thruster operation, simplifying modifications to control algorithms or hardware changes.

State Machine Control Flow: Our control system's logic is based on a state machine model, which enhances the ROV’s responsiveness and reliability. Each state corresponds to a distinct operational mode, and transitions between states are triggered by specific sensor inputs or operator commands. This model simplifies complex decision-making and ensures consistent behavior under varying operational conditions.

MODULARITY AND SIMPLICITY

Consistent with our design philosophy, the ROV's architecture is straightforward yet robust, facilitating ease of maintenance and scalability. The modular design allows for straightforward integration of new technologies and quick adaptation to different mission requirements without extensive overhauls. This simplicity extends to field repairs and upgrades, significantly reducing downtime and operational costs.

VEHICLE STRUCTURE

CHASSIS:

The chassis consists of five interlocking HDPE panels that are held together by ten nuts and bolts. The chassis was designed to breakdown into flat panels for ease of transport; it can be carried by one person.

MATERIALS:

The use of HDPE for the chassis provides a rigid structure without any weight penalties. The density of HDPE is slightly lower than water, resulting in more control of our weight distribution and higher payload capacity.

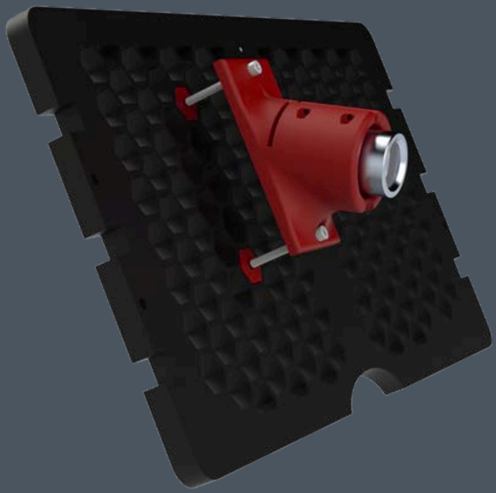
DYNAMICS:

We made sure to add plenty of speed holes to improve our hydrodynamics, which improves the traverse speed available to pilots, control against current, and power efficiency. Our front and back panels are almost completely hollow and include clearance in the profile of our horizontal thrusters. A hex grate spans both side panels which make crabbing and turning more swift and responsive.

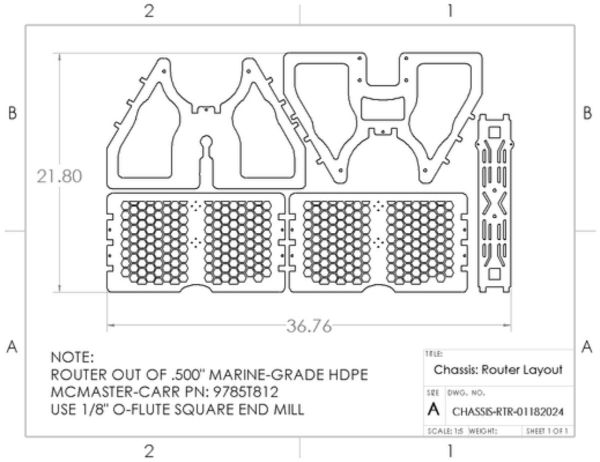
MODULARITY:

Another strength of our ROV is modularity. We wanted an easy way to mount our hardware to our vehicle without drilling into our panels, which may compromise structural integrity and weight distribution. The honeycomb grating allowed for items to be easily installed and removed anywhere on the hull.

ROV CHASSIS



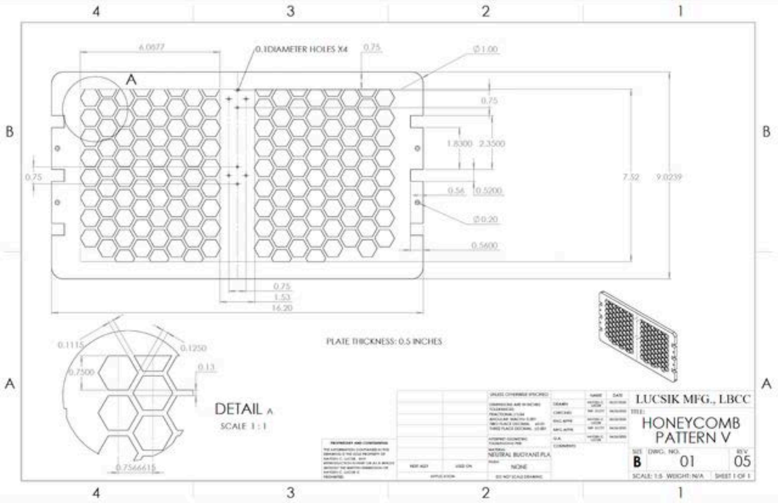
HONEYCOMB CHASSIS WITH CAMERA MOUNT



NOTE:
ROUTER OUT OF .500" MARINE-GRADE HDPE
MCMASTER-CARR PN: 9785T812
USE 1/8" O-FLUTE SQUARE END MILL

Chassis: Router Layout
A CHASSIS-RTR-01182024

THE ROV CHASSIS PANELS ARE CNC ROUTER CUT IN FROM A SINGLE 2'X4' SHEET OF MARINE-GRADE HDPE.

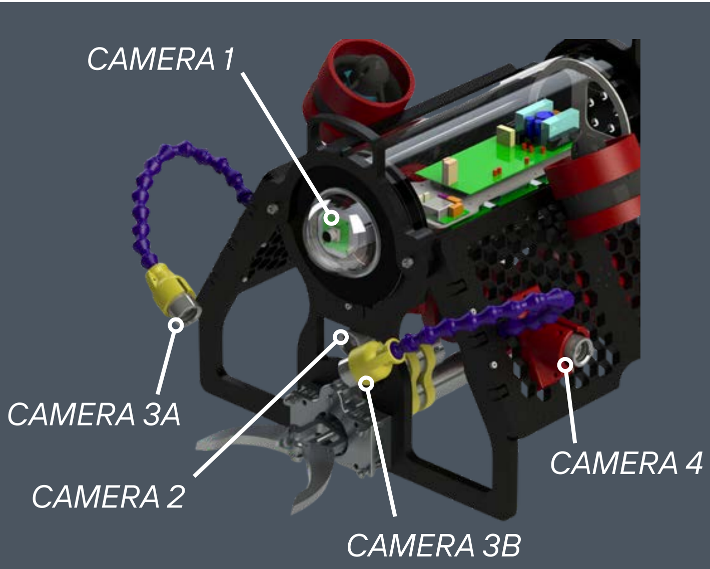


SIDE PANEL TECHNICAL PATTERN

VEHICLE SYSTEMS

CHASSIS AND PROPULSION:

Our vehicle is optimized for easy piloting and efficient task execution. The vehicle only moves in desired degrees of freedom (DOFs) due to the design of the chassis and propulsion and resists unwanted motion. The side panels and vertical thrusters are swept by 30 degrees, which resists undesired motion in the roll and lateral DOFs.



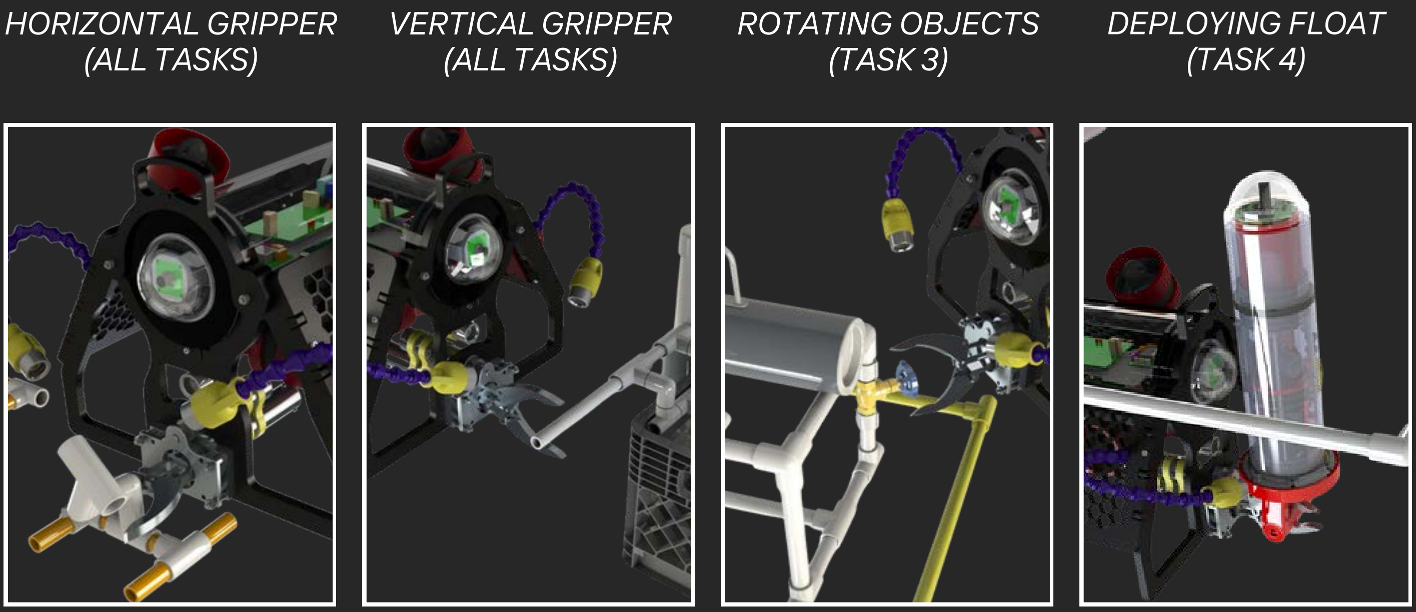
CAMERA PLACEMENT ON ROV

CAMERAS:

The vehicle has five cameras available for the pilot. Camera 1 is on a gimbal for looking above or below. It's optimal for navigating the underwater environment. Camera 2 is dedicated to aligning the gripper with payloads by crabbing or turning. Camera 3 (A or B) is on an adjustable plastic pipe that can be angled before or during a mission while the vehicle is topside. It can mount into any hex grate on either side of the chassis. Its commonly used to get a side view of the gripper to help align with payloads in the forward/backward and up/down directions. Camera 4 also mounts in the hex grating to give a view off the port for obstacle avoidance and photogrammetry.

GRIPPER:

ODIN'S FIST can rotate 360 degrees continuously while providing high grip-strength. It can grab every object involved in the mission, whether the object is horizontal, vertical, or in an unpredictable orientation. It configures between horizontal and vertical in only three seconds, so its always ready for use.



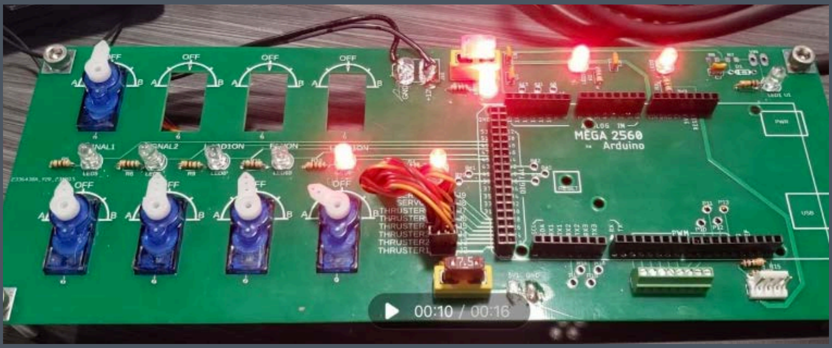
RENDERS OF ROV PERFORMING TASKS

CONTROL & ELECTRICAL SYSTEMS

SOFTWARE

Software implementation involved a stepwise approach in which major functional components would be defined alongside control flow design. Pair programming and team coordination via GitHub were also used in collaborative efforts. Initial software versions were subject to group/peer software reviews for mission objective alignment and optimization.

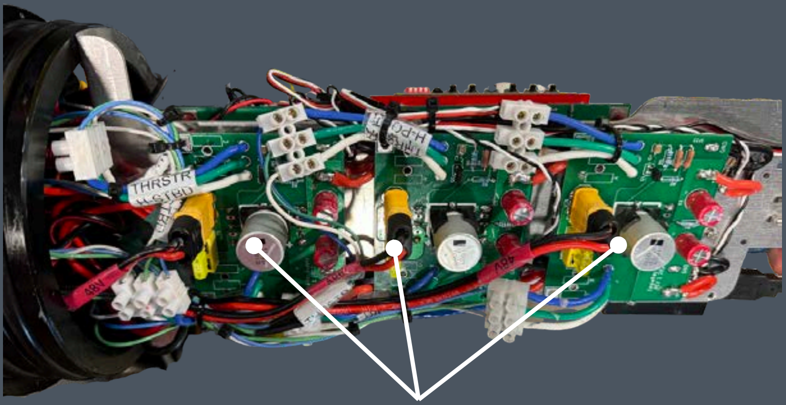
The company also made extensive use of hardware simulation for the parallel development of the control software and the ROV and floater hardware. This was essential in maintaining the timeline and minimizing system integration time. We developed a circuit board shown below to mimic the ROV using RC servos as stand-ins for the thrusters. This was possible due to the servos and the thrusters using the same RC control signal. After the competition, we will make this board available to SeaMate for use by teams implementing the EagleRay ROV kit.



ROV SIMULATOR BOARD

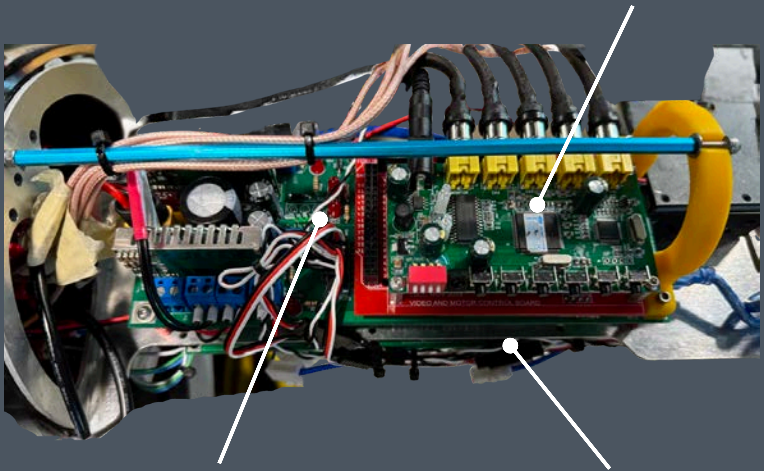
ELECTRICAL SYSTEM

Our ROV's electrical system is designed for robust performance and efficiency, centered around a 48V power input. This input powers the thrusters through three 48V to 12V converters, each protected by a 20A fuse, supplying six electronic speed controllers (ESCs). Additional converters step down the voltage to 5V for USB cameras, 12V for the ESCs, and 9V for the Arduino Mega. The Arduino Mega manages the gripper via H-bridges, handles the video multiplexer, and interfaces with NTSC cameras. This setup ensures precise control and reliable operation for complex underwater tasks.



48V TO 12V THRUSTER POWER SUPPLIES

VIDEO CONTROL BOARD



SEAMATE EAGLERAY CONTROL BOARD

ARDUINO MEGA

PROPULSION

The propulsion system of our ROV is intricately designed to maximize efficiency and adaptability under a variety of conditions. Our system consists of five strategically placed thrusters, each capable of adjusting between full and half power settings with the push of a button. This adjustability is crucial for precise movements and varying application needs.

THRUSTER CONFIGURATION:

The configuration of our thrusters is deliberately chosen to optimize the ROV's maneuverability and stability:

- **Vertical Thrusters (2 Units):** Vertical thrusters control ascent and descent, which is crucial for navigating through different water depths.

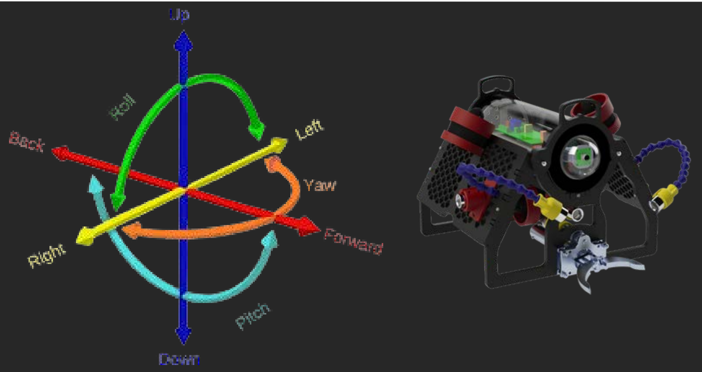
- **Horizontal Thrusters (2 Units):** Positioned on the center of mass, these thrusters provide forward and backward propulsion without pitching. They can also drive differentially to carefully turn to adjust heading. This setup is essential for covering larger areas during surveys or when positioning the ROV in currents.

- **Crabbing Thruster (1 Unit):** This uniquely positioned thruster enables lateral movement, allowing the ROV to move side to side without rolling or yawing. This capability is useful for sidestepping obstacles and precisely positioning payloads.

TRADEOFFS & CONSIDERATIONS:

- **Power Consumption vs. Performance:** The dual power setting on each thruster allows us to optimize power consumption. For routine tasks or in low-current environments, operating at half power reduces energy use, extending mission duration. Full power is reserved for resisting strong currents or long straightaways.

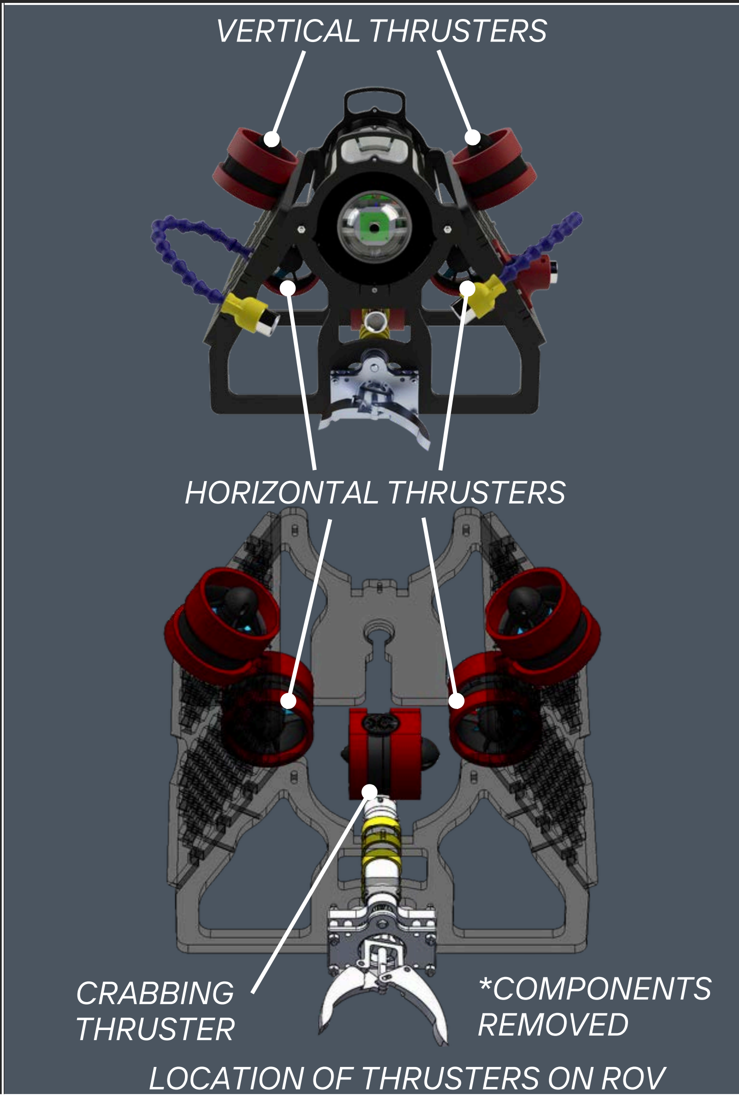
- **Cost vs. Efficiency:** We selected a five-thruster system as it provides a balance, offering significant control and flexibility without excessive costs or overly complex maintenance requirements.



LEFT: AXIS DIAGRAM. RIGHT: ROV

DEGREES OF FREEDOM (DOFs):

Our vehicle offers all translational DOFs and yaw. Our vertical thrusters are vectored 30 degrees to provide additional crabbing capability.



LOCATION OF THRUSTERS ON ROV

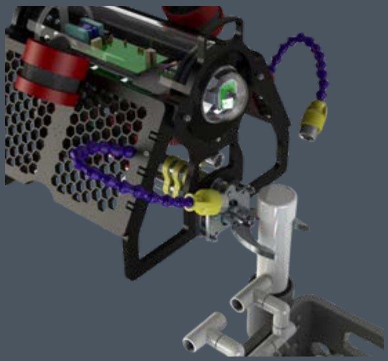
BUOYANCY & BALLAST

ROV :

Our target buoyancy for the ROV was to be the minimum positive buoyancy to reliably hold an altitude using low power on the vertical thrusters. When turning off propulsion, the vehicle must be buoyant enough to always float to the surface for recovery. Yet if the buoyancy is too high, it would consume more power using the vertical thrusters. We sought after these conditions by experimenting with the ballast and finalized a buoyancy of 72.7 grams.

Item	Mass (g)	Displacement (g)	Net Weight (g)
Chassis	-3855.5	+3991.6	+136.1
Bottle	-5669.9	+9162.6	+3492.7
Thrusters	-2041.2	+1496.9	-544.3
Ballast	-3311.2	+299.4	-3011.8
Total	-14,877.8	+14950.5	**+72.7**

ROV RENDERED IN CAD



ROV GRIPPER EXAMPLE

FLOATER :

The Thorpedo's buoyancy engine has a capacity of 500mL of water. Therefore, the device must have a buoyancy no higher than positive 500g. Although, its preferable to get the buoyancy as close to zero as possible to reduce the power consumed by the pump, allowing for more data collection cycles. We settled upon a target buoyancy of 158.8g, as the device descends after intaking 200mL which only takes 8 seconds of pump runtime.

ASSEMBLED FLOATER (THORPEDO)

Item	Mass (g)	Displacement (g)	Net Weight (g)
Enclosure	-3374.7	+4808.1	+1433.4
Ballast	-1197.5	+108.9	-1088.6
Ballast Trim	-208.7	+22.7	-186.0
Total	-4780.9	+4939.7	**158.8**

PAYLOAD AND TOOLS

Our ROV is equipped with a sophisticated camera system designed to maximize field of view and enhance underwater navigation and data collection capabilities. This system comprises five cameras, strategically positioned to provide comprehensive visual coverage in a variety of underwater environments.

MAIN CAPSULE CAMERA

At the heart of our visual system is the main capsule camera, which is distinct for its versatility and advanced capabilities. This camera is mounted on a servo motor, allowing for precise, controlled movements. The servo mechanism enables the camera to tilt about 150 degrees on the Z axis giving the ability to focus on specific areas of interest without the need to reposition the entire ROV. This functionality is crucial during delicate operations, such as close inspections of underwater structures or marine life.

AUXILIARY CAMERAS

Complementing the main camera are four smaller cameras with 160 degree field of view, each housed in a robust, waterproof casing designed to withstand the pressures and conditions typical of underwater environments. These cameras are fixed in position but are strategically located (after using flexible mounts to find the proper placement during underwater trials) around the ROV to eliminate blind spots and provide the pilot with a full view around the vehicle as well as specific applications. The design of these cameras emphasizes not only durability but also clarity, with high-resolution capabilities that ensure detailed image capture, critical for both navigation and data analysis.

ODIN'S FIST MANIPULATOR

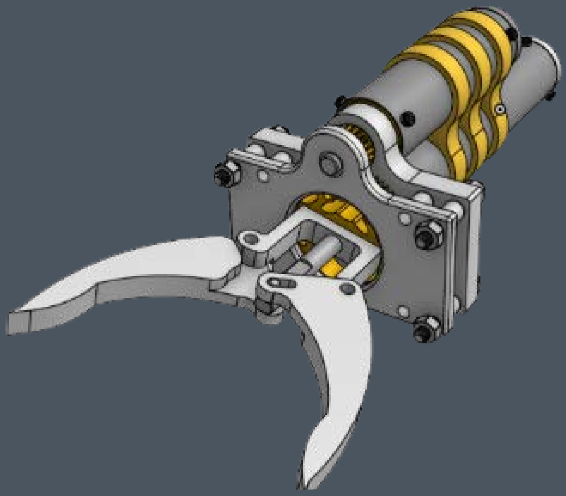
At the forefront of our ROV is the ODIN's FIST manipulator, the culmination of over seven months of research and development. The challenges with design came from several limiting factors:

1. Device rotates 360-degrees with precision
2. All internal components would be electrical, such as the linear actuator and turning motor
3. All of this needs to be waterproof
4. The claw module needs to be fully modular with integrated sections for ease of repair.
5. The claw must retrieve river stones, moving cables, and delicately manipulating plugs and valves.

FINAL WATERPROOFED CAMERA WITH ENCLOSURE

INTEGRATION AND FUNCTIONALITY

All cameras are integrated into our ROV's control system via a multiplexer, allowing operators to switch views seamlessly between the different cameras from the surface control station. The images captured by these cameras are transmitted in real-time, providing operators with immediate feedback and situational awareness, which is vital for effective mission execution.



FINAL ITERATION, JAN 2024-PRESENT

During the initial R&D phases, ODIN's FIST took many forms before it finally came to its current iteration. Over 169 parts and assemblies were constructed between the four prototypes, using a variety of CAD software in a collaborative effort. Our ROV is equipped with a 360-degree manipulator, which allows the operator to rotate the claw seamlessly with precision.

PART SOURCING

OFF-THE-SHELF COMPONENTS:

In 2016, the ROV team received a local grant for ROV work and a number of BlueRobotics ROVs were purchased. Rather than putting forth a BlueRobotics based ROV with their control system, we only reuse their thruster, enclosure, and end cap components. LBCC also has been developing the SeaMate EagleRay ROV kit platform and those components fit well with the kit.

LEFT: BlueRobotics 4" ID Enclosure used on float
PART COST: $402

RIGHT: BlueRobotics 6" ID Enclosure used on ROV
PART COST: $478

BlueRobotics Flange (4"):
Making this part in house would be more expensive, lower quality, and labor intensive.

Notable Features:

1. *O-ring Seals*
2. *Anodization*
3. *Bolt Patterns*

PART COST: $45

The BlueRobotics T200 is a powerful waterproof thruster
PART COST: $200

BlueRobotics' switch simplifies powering the float without opening the enclosure
PART COST: $25

PROPRIETARY COMPONENTS:

Our lab has a variety of manufacturing methods available. We have 3D-printers, a CNC router, CNC mills, and a CNC lathe. This gives us the liberty to design more proprietary systems like our vertical profile device and our ODIN'S FIST MANIPULATOR. Besides this, we modified some off-the-shelf parts to create simple and effective systems. For example, our camera housings utilize scuba flashlights modified to hold a camera.

Milling an endcap for the float. It's compatible with BlueRobotics flanges while accommodating penetrators of various other sizes.

This part (red) was 3D-printed because of its unique form-factor. It holds the float's pump (black) centered in the 4" enclosure tube with nearly zero tolerance.

Proprietary gears used to rotate our gripper. they were outsourced to another dept. to be cut on a fiber-laser out of aluminum billet.

VERTICAL PROFILING FLOAT

AKA "THORPEDO"

OVERVIEW:

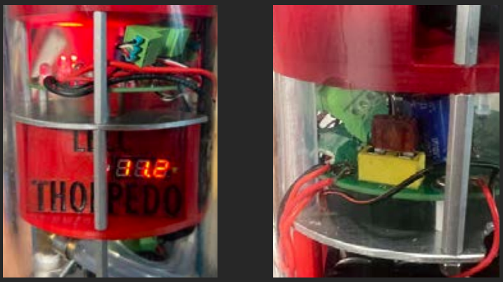
Our vertical profiler consists of six stages organized in vertical tiers. This is an autonomous device with its own 12-volt power supply in its enclosure. Our buoyancy engine involves two actuators: a water pump and a normally-closed valve.

ENCLOSURE:

Our enclosure uses 4" acrylic pipes, flanges and a dome from BlueRobotics. The bottom is a custom aluminum end-cap shown below.

POWER STAGE:

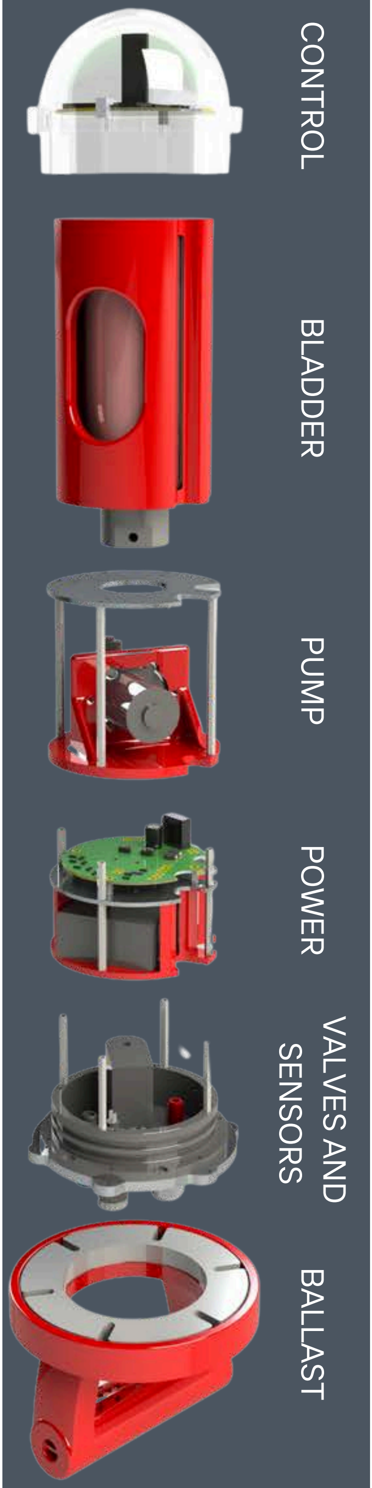
Our power source is eight alkaline AA batteries to supply 12-volts. Our custom power distribution board includes an accessible 7.5 amp fuse (right) and a voltmeter (left) easily visible from outside the enclosure along with two H-Bridge controls for the pump and valve. This stage was placed between our two actuators to minimize the EMI from high-current wires.



Left: Floater Voltmeter. Right: Fuse

BALLAST STAGE:

See Page 14 for our buoyancy calculation. Most of the ballast is a casted lead plate. We perfected our buoyancy experimentally with lead shot stored in the handle for the ROV to grab for deployment.



Exploded View of Floater

CONTROL STAGE:

A custom PCB interfaces an Arduino NANO, memory chip, and bluetooth transceiver. The transceiver is positioned upright to peak above the water line and get signal. The water line never comes higher than the base of the acrylic dome.

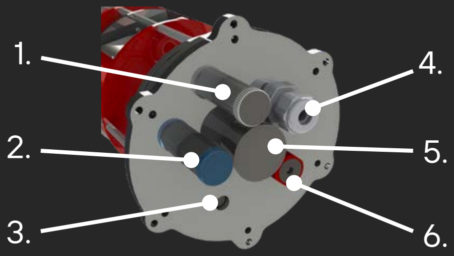
BLADDER STAGE:

Our bladder is a flask that stores 500mL, yet we only intake 200mL of water. It's a durable nylon material that is tear-resistant to protect against compromising the enclosure.

PUMP STAGE:

The pump is an OEM replacement part to coffee-makers where it's used to move water from a storage tank to a boiling unit. To profile, the pump intakes for 8 seconds to starts descent, waits a specified length of time, and expels water for 8 seconds to ascend.

VALVES AND SENSORS STAGE:



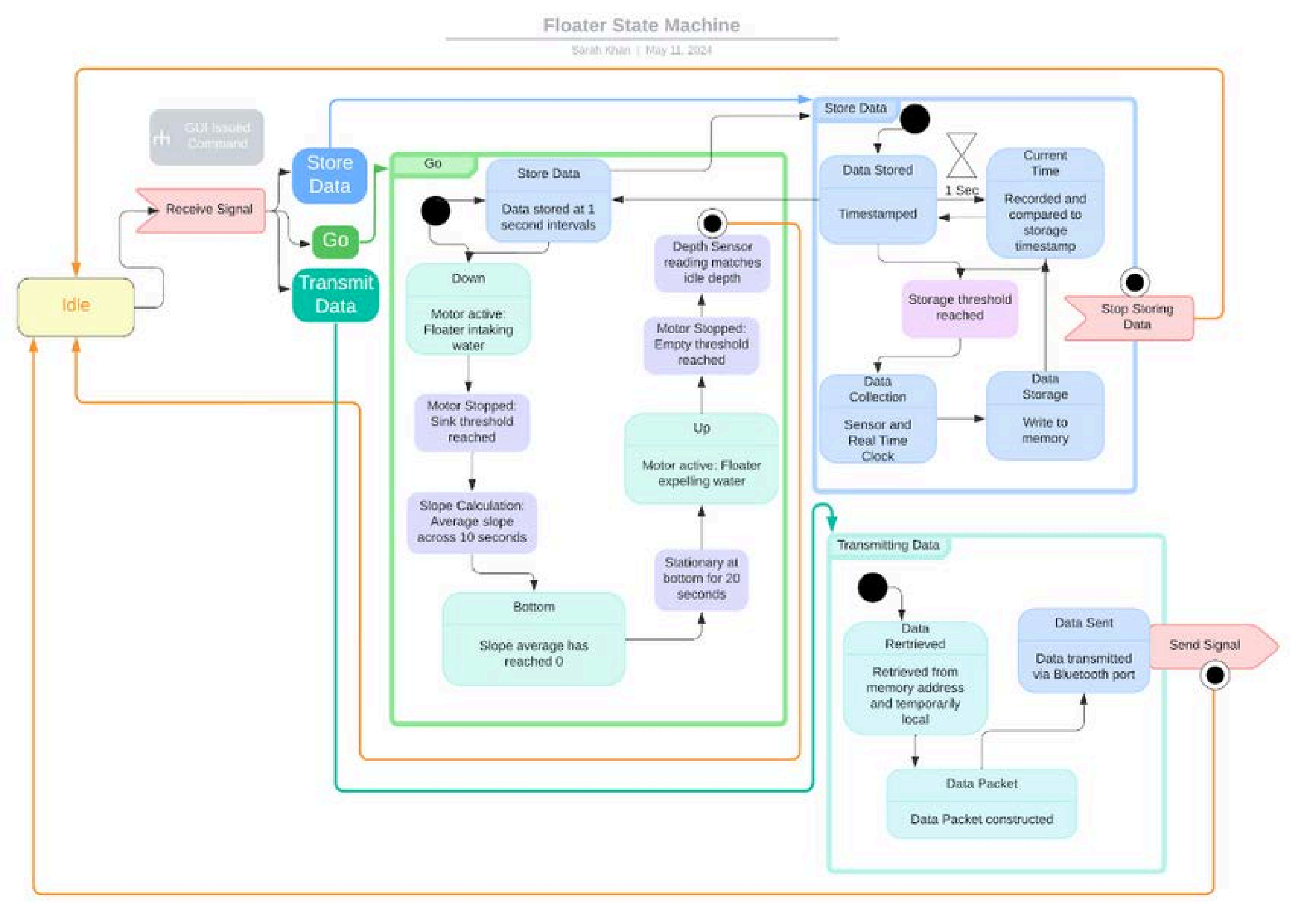
FLOATER VALVES

1. Pressure Testing Vent
2. ON/OFF Switch (BlueRobotics)
3. Water Intake (to valve, pump, bladder)
4. Ethernet Gland (Development Only)
5. Pressure Relief Plug
6. Temperature/Depth Sensor

SOFTWARE:

An autonomous state machine was written in the C++ based Arduino IDE and connected to the Python based GUI via Bluetooth connection port. Internally specific constants, such as idle depth, time to fill bladder, and time to expel bladder were obtained via device testing and written in. The profiler collects data at 1 second intervals, shuts off the motor pump autonomously, and registers it has reached the bottom via a mean slope calculation across 10 depth data points. This mean slope calculation is allotted a small margin, but the device automatically reverses and starts the motor to expel the bladder at the defined time length in order to make its ascent. The GUI interface sends signals and receives data transmission via Bluetooth connection.

The floater needed to be able to collect temperature, pressure, and depth. Given those points, PYQT5 was used to display all three graphs IDLE, RUN1, and RUN2. After the floater was done collecting its data, once it reached the surface bluetooth was used to gather the information needed. The reason PYQTGraph was chosen is because it runs faster than matplotlib and it’s more customizable. To create the many y-axes necessary, extra viewboxes were created and then connected to each other. Once all the viewboxes were connected, they were then added to the layout and the already existing y-axis. Given the numbers received from the floater, we had each point plotted to its designated graph. Doing so allowed us to show all the information collected and how it affected each individual graph.

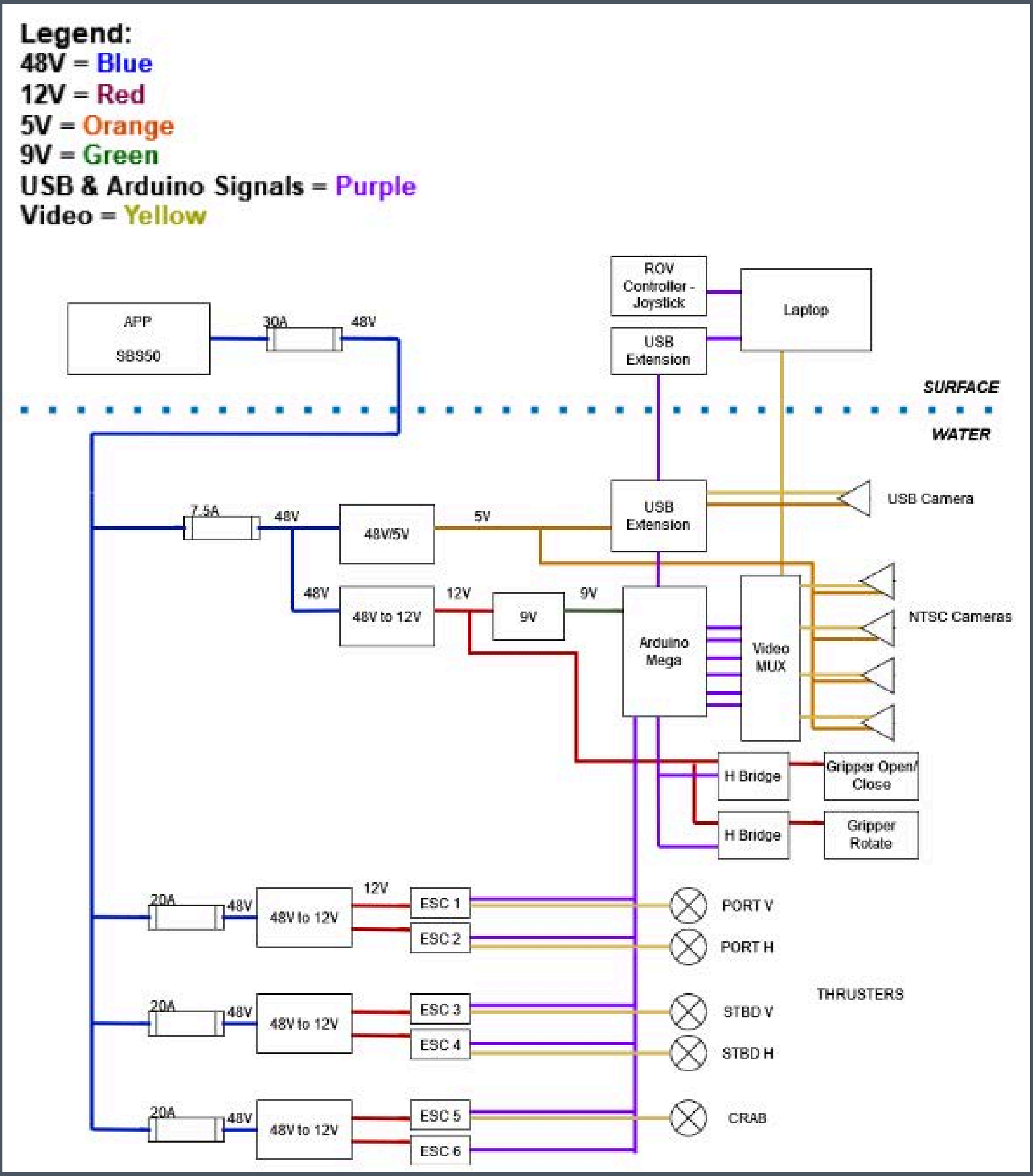


SID

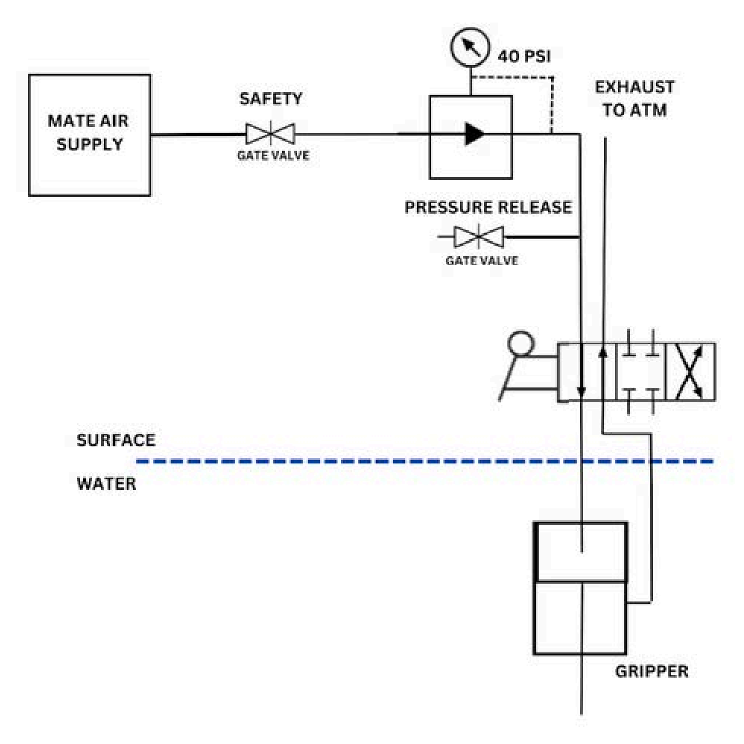
ODIN ROV SID

Condition: Full Down Thrust, Full Forward Thrust

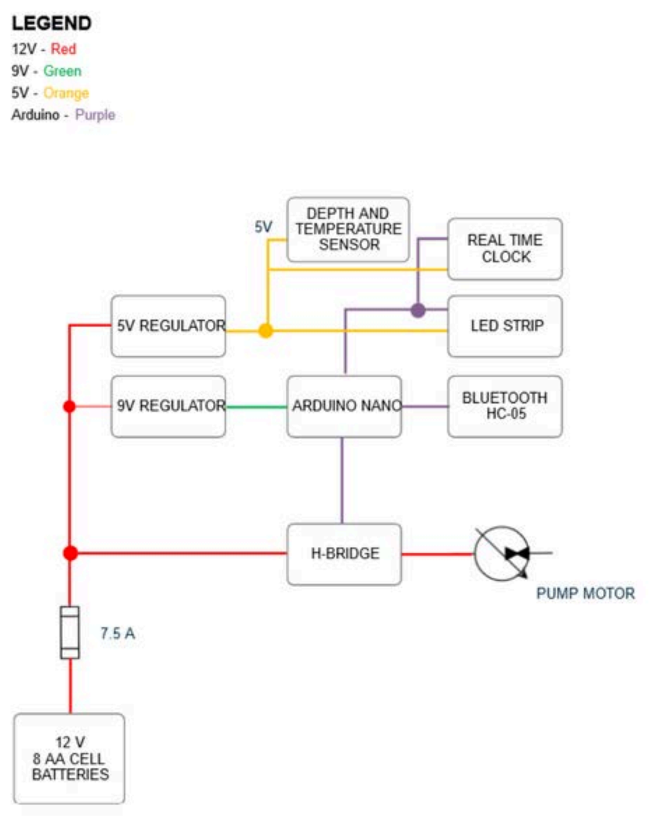
FLA = 22.5 Amps; 22.5 Amps*150% = 33.75A, therefore max 30A fuse is utilized



FLUID POWER SID



THORPEDO SID



SAFETY

Our team's approach to safety focuses around 3 main areas: Personnel, Equipment, & Operational. Firstly, we'd like to express how important safety is to our team. With electrical and pneumatic parts around water as well as the heavy machines that we use to build it, ensuring that we are not injured or putting anyone else at risk is our top priority. From the first day, we had a safety briefing and continue to focus on these 3 main principles as we progressed through the development of our ROV.

SAFETY RATIONALE

In establishing our ROV team, we prioritize safety above all to protect our personnel, safeguard our equipment, and ensure operational integrity. Before starting any work, we began with a comprehensive safety training for all team members, encompassing general safety principles, specific guidelines on personal protective equipment (PPE), and detailed instructions on the proper use of each piece of equipment involved in our projects. For example, before any member can operate shop tools or participate in the assembly process, they must be approved/trained by our instructor.

We extend our safety measures to include rigorous pre-use checks of all equipment. Each tool and piece of equipment undergoes a full inspection for integrity and safety compliance before use. We also enforce strict procedures for the handling and storage of materials to avoid accidents and potential equipment damage. Operational safety is further reinforced through standardized operating procedures for critical tasks, such as battery handling and water testing.

VEHICLE-SPECIFIC SAFETY PRECAUTIONS

As for our vehicle-specific safety precautions, we have implemented several layers of safety measures focused on assembly and operational procedures. Each team member receives specialized training on the tools they will use, which includes practical demonstrations like a soldering tutorial that emphasizes safety practices and proper techniques.

Special attention is given to the ROV's waterproofing and structural integrity. We employ advanced techniques like resin to ensure thorough sealing and conduct regular pressure tests to verify hull integrity.

Additionally, we check the weight and balance of the ROV each time it goes in the water to avoid any operational instability, which could pose risks during missions.

By integrating these practices, we aim not only to build efficient underwater robots but also to create a safe and dynamic environment for innovation and learning. Our commitment to continuous improvement in safety standards is unwavering, as we regularly update our procedures and training materials to incorporate new technologies and feedback from our operations.

SAFETY PROCEDURES

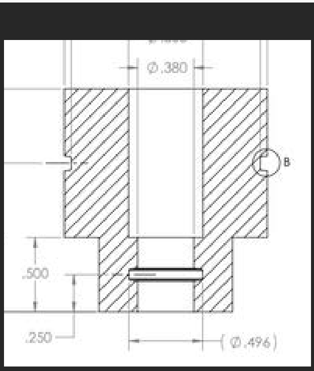
A full checklist can be found on page 24 in the appendix, but our overall philosophy is to ensure a safe, reliable operation that reduces risks to our team, instruments and operational area.

ROV TEAM MEMBER WORKING ON THE FLOATER WEARING THE PROPER PPE OF SAFETY GLASSES.

CRITICAL ANALYSIS

TURNING ALUMINUM GRIPPER PARTS

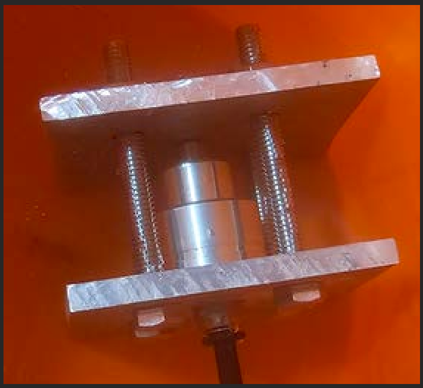
Much of the testing and troubleshooting went into our most ambitious system: ODIN'S FIST. This is such a challenging build because it demands IPX9 dynamic seals for two electric motors. Early in the design phase we decided if we wanted this gripper, someone would have to learn to turn aluminum on the lathe. The simplest way to create a dynamic seal is to put an O-ring groove inside the bore which holds a shaft; quite the maneuver for a beginner. It took some weeks just to properly measure tool offsets to create reliable ODs and external grooves, but by early April our team had successfully made an internal O-ring groove. We verified that this groove would create a proper dynamic seal with a pressure test. We seated the shaft engaged in the O-ring, but not through the entire part. The open end of the part was the perfect size to tap and insert a 1/4" push-connect pneumatic fitting. Then we threw together a quick fixture to prevent the shaft from disengaging the O-ring. We hooked up the fitting to an air compressor and tested up to 80psi, and the seal stayed air-tight. Testing past this pressure was unnecessary as it far-exceeded the depth rating of the rest of our vehicle's components.



The cross-section showing an internal O-ring groove. A specialty tool to cut such a groove costs $40; we only broke one.

Scrap parts and tools from the manufacturing of ODIN'S FIST totaling $300+ in damages.

The tolerance shaft nominal size is .374", so for a tight fit, the part needed a bore of .3765"-.3785".



Internal O-ring pressure test fixture under 80psi of pressure. It is submerged in water, as air bubbles would indicate failure of the seal.

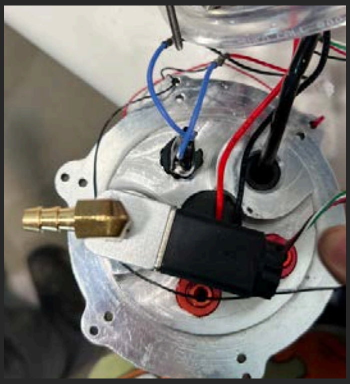
After months of scrapping parts, we finally have all machine components within specification.

CRITICAL ANALYSIS CONTINUED

BUOYANCY ENGINE

Our second large hurdle for our company was profiling a water column. This was challenging because we started the design from scratch, while much of the ROV hardware was directly inspired by our vehicle from past years. Our float featured a completely original buoyancy engine, so we had to overcome quite a few challenges on our own.






FIRST: Failed vertical profile.
SECOND: First successful profile with valve.
THIRD: Implementation of permanent ballast.
LAST: Adding valve to water intake.

IMPLEMENTING A VALVE

In mid-February, we conducted our first pool-test of an autonomous vertical profile. We took our time to pressure test the enclosure and add a precise amount of ballast, but when we ran an autonomous profile command, the device descended and never came back up. We pulled the float up and discovered some residual water was still in the bladder and tubes even though we expected them to be empty. We ran a profile command again, this time holding the float above the water line, and watched as the bladder filled during descent, pause, and drained completely during ascent. Here, we learned that our pump was working as expected and the problem had to do with the conditions of the float while running the profile. Our whole team talked and decided on the following speculation: the pump controls the flow of water while powered, but is completely passive when its not powered. Much of the time the device is descending, the pump is off. Since our water intake is facing downward, the descent of the device could be chasing water into its intake and possibly creating a siphon. During ascent, the reverse effect would not occur, since expelling water couldn't happen without the pump since the bladder is a dead-end and would create a vacuum. This is why our device would intake more water than it expels. We realized that if we wanted our device to ascend back up the water column, we needed to close our water intake when our pump is off. This is when we integrated our second actuator, a normally-closed valve. Although late, our it fit in seamlessly with our system because we only want an open intake while the pump is under power. We decided to connect the valve in parallel with the pump from the H-bridge since they should always run simultaneously. The software team did not need to integrate the valve into their code thanks to this simple integration. After adding the valve, our profiling command started to work reliably. Further testing occurred only to optimize the timing of the buoyancy engine and the logging of data.

ACCOUNTING

Date	Type	Location	Description	Amount	Balance
2022	Reused	ROV	BlueRobotics 6" EndCaps	$378.00	
2016	Reused	ROV	BlueRobotics Thrusters & ESC	$1,190.00	
2016	Reused	Thorpedo	BlueRobotics 4" O-ring flanges for Thorpedo	$150.00	
2016	Reused	Thorpedo	BlueRobotics Pressure Sensors	$150.00	
			Total of Reused Components, See Below	$1,898.00	

Reused items are from a 2016 Grant received and BlueRobotics Components were purchased and have been supporting the ROV projects since 2016. The 6" endcaps were part of the SeaMate project. Travel expenses paid by team members.

Date	Type	Location	Description	Amount	Balance
			Budget	$3,000.00	$3,000.00
8/1/23	Purchased	Development	ROV Simulator & IO Electronic Components	$135.85	$2,850.23
8/1/23	Purchased	Development	ROV Simulator & IO Expansion PCBs	$32.45	$2,814.45
8/1/23	Purchased	ROV	ROV HDPE Frame Material	$164.32	$2,633.29
8/1/23	Purchased	ROV	SeaMate Control Electronics Components	$823.56	$1,725.31
8/1/23	Purchased	ROV	Clear Epoxy Resin	$24.19	$1,698.64
8/1/23	Purchased	ROV	Gear Motor for Gripper	$8.58	$1,689.18
8/1/23	Purchased	ROV	Lapping Compound for gears	$17.52	$1,669.87
12/15/23	Purchased	ROV	3D Printing Filament	$95.28	$1,564.82
12/15/23	Purchased	ROV & Thorpedo	Aluminum for Gripper & Other parts	$137.32	$1,413.43
12/15/23	Purchased	ROV & Thorpedo	Misc Stainless Hardware	$35.00	$1,374.84
12/15/23	Purchased	ROV & Thorpedo	O-Rings	$25.00	$1,347.28
12/15/23	Purchased	Tether	12 AWG landscape wire for tether	$40.99	$1,302.08
12/15/23	Purchased	Tether	Braided cable sleeve for tether	$13.99	$1,286.66
12/15/23	Purchased	Tether	CAT5-e waterproof cable	$21.25	$1,263.23
12/15/23	Purchased	Thorpedo	Thorpedo - Neopixel Display	$19.24	$1,242.02
12/15/23	Purchased	Thorpedo	Thorpedo AA Batteries, alkaline	$22.48	$1,217.24
12/15/23	Purchased	Thorpedo	Thorpedo Battery holder	$6.99	$1,209.53
12/15/23	Purchased	Thorpedo	Thorpedo Circuit Boards	$28.42	$1,178.20
12/15/23	Purchased	Thorpedo	Thorpedo Electronics Components	$276.43	$873.43
12/15/23	Purchased	Thorpedo	Thorpedo Pump Motor & Bladder	$37.24	$832.37
1/1/24	Purchased	ROV	Temperature Sensors	$10.85	$820.41
1/1/24	Purchased	ROV	Video Splitter	$51.41	$763.73
2/1/24	Purchased	ROV	ROV Cables & Connectors for Cameras	$139.26	$610.20
2/1/24	Purchased	ROV	ROV Cameras	$55.96	$548.50
5/1/24	Purchased	ROV	Game Controller	$16.99	$529.77
			Subtotal	$2,240.57	
			Tax (10.25%)	$229.66	
			Total	$2,470.23	$4,562.77
			Budget	$3,000.00	
			Balance remaining	$529.77	

REFERENCES

The software team referenced open source libraries for open source hardware, GUI, and data visualization implementation, Chat GPT for debugging and graphic asset generation, Canva for document creation, and YouTube for system component implementation.

The references from the mechanical design team consisted of McMaster-Carr for general hardware, BlueRobotics for enclosures and buoyancy calculations, DigiKey for electronics, and TRAK Machine Tools as a sponsor who donated a mill and a lathe.

MCMASTER-CARR ORDERS

ACKNOWLEDGMENTS

The LBCC Vikings would like to thank Scott Fraser for his extensive technical and design guidance, boundless enthusiasm, and dedication to ensuring members achieved critical hands on experience and industry knowledge. Thank you to Tara Willis for her hands on guidance and skills coaching, nurturance of team members' academic and professional growth, and indefatigable reliability and diligence. Thank you to Ted Titus for the extensive support he's provided in manufacturing from equipment maintenance to development, sourcing parts and materials, and computer aided manufacturing.

We would also like to thank MATE ROV for the immense opportunity for the high-caliber engagement in the robotics industry provided by the world championship, as well as the LBCC Electrical Program for the incredible resources and facilities afforded to us for the development of our vehicles.

DONATED TRAK MACHINE

PROFESSOR SCOTT

APPENDIX:SAFETY CHECKLIST

Safety Checklist for ROV Construction and Operation

Tether Setup:
☐ Unroll the tether fully.
☐ Position the control box at least six feet away from the pool edge.
☐ Securely connect the tether to the control box.
☐ Attach and secure the strain relief to the control box to prevent accidental disconnections.
☐ Inform all team members about the location of the tether to avoid tripping hazards.
☐ Connect the airline to the ROV.
☐ Attach the air supply.
☐ Fasten the strain relief to the ROV to manage tether tension.

Tether Disconnect:
☐ Ensure all power is turned off.
☐ Safely disconnect the tether from the control box.
☐ Detach the airline from both the supply and the ROV.
☐ Neatly coil the tether for storage.

Deck Pre-Run Checklist:
☐ Verify all electrical power connections are secure.
☐ Ensure all cameras are operational and free from obstructions.
☐ Confirm all waterproof seals are intact and secure.
☐ Inspect thrusters for functionality and clear of obstructions.
☐ Check the gripper for proper operation.

Deck Checklist:
☐ Proceed with the tether setup protocol.
☐ Connect and turn on the power supply.
☐ Power up the ROV.
☐ Test all thrusters: vertical, horizontal, and rotational.
☐ Verify functionality of the grabber tool.
☐ Test camera views on the deck screens.
☐ Carefully place the ROV into the water.
☐ Ensure all deck team members signal "Ready" to the ROV pilot.

Post-Run Checklist:
☐ Turn off the power at the control box.
☐ Disconnect the power supply.
☐ Turn off the pneumatics supply.
☐ Bleed the pneumatics using the pressure release valve.
☐ Follow the tether disconnect protocol.
☐ Thoroughly dry the ROV and place it securely on the cart.
☐ Clean up the work area, ensuring all materials, props, and supplies are stored and the area is left clean.