2023-2024

TECHNICAL REPORT

ROVrunners

Linn-Benton Community College
Albany, OR USA

Frame	Dominique Klahold, Sara Leathers (COO), Dale Sydnam
Controls	Eric Anderson, Jason Fanger, Samantha Miles, Jackson Smith, Dean Upton
Electrical	Kye Blaser (CFO), Sierra Brightly (CEO), Fernando Salazar, Jake Terrell
Claw	Wade Johnson
Design	Asher Richmond
Vertical Profiler	Theon Abbott, Aren Mowreader, Hunter Niedens
Mentors	Greg Mulder, Heather Hill, Kathy Austin

Introduction

Figure 1. Linn-Benton ROVrunners Team Members

Abstract

Spike is the latest Remotely Operated Vehicle (ROV) developed by Linn-Benton Community College (LBCC) for the 2024 Marine Advanced Technology Education (MATE) competition. This EXPLORER-class ROV is engineered to address global underwater environmental crises with exceptional maneuverability and adaptability.

Designed with modularity in mind, Spike features custom waterproof housings and connectors to ensure that components like the tether, thrusters, cameras, and power converters are all detachable. These design choices facilitate easy repairs and upgrades, ensuring Spike remains at the forefront of technological innovation. The control system has been updated with new movement code and hardware, making Spike competition-ready and equipped to handle real-world challenges affecting aquatic environments.

A seventeen-member team (Figure 1) meticulously planned, designed, and tested Spike, ensuring strict adherence to safety standards. This thorough approach has led to the creation of a highly efficient and versatile ROV, capable of tackling various underwater tasks.

This technical documentation provides insight into Spike's development journey, showcasing its ability to meet competition requirements and address real-world aquatic environmental challenges. The innovative efforts and commitment to environmental conservation of the development team are evident in Spike's construction and capabilities, demonstrating a strong dedication to advancing underwater technology for a better future.

Table of Contents

Teamwork 4
Company Profile 4
Personnel 4
Resource Management 5
Planning and Scheduling 5
Design Rationale 6
Design Philosophy 6
Hardware -- Frame and Structure 7
Hardware -- Propulsion System 7
Hardware -- Electronics Housing 8
Hardware -- Manipulators 8
Hardware -- Analog Cameras 9
Electronics -- Tether 10
Electronics -- Connectors 11
Electronics -- Conoverters 11
Electronics -- Controls 11
Vertical Profiler 13
System Integration Diagrams 13
Spike System Diagram 14
Pneumatic Control Diagram 15
Vertical Profiler Diagram 15
Safety 16
Safety Philosophy 16
Company Safety Protocols 16
Vehicle Safety Features 16
Critical Analysis 17
Testing & Troubleshooting 17
Accounting 18
Budget 18
Conclusion 19
Acknowledgements 19
References 19
Appendix 20
A: Setup Plan 20
B: Operations Plan 21
C: Cost Accounting 22

Teamwork

Company Profile

The ROVrunners, operating from Linn-Benton Community College in Albany, Oregon, are pioneers in developing innovative technology to enhance underwater habitat health. Our team is deeply committed to community engagement, with a long-term program at the local Boys and Girls Club, where middle school students are introduced to technology, coding, engineering, and science. This initiative underscores our dedication to nurturing future STEM leaders and making a positive impact in our community.

At the ROVrunners, we embrace a collaborative and inclusive approach. We avoid traditional hierarchies, enabling all members to participate in every aspect of our projects. This structure allows natural leaders to emerge, fostering an environment where organization and accountability are shared responsibilities. Our projects often require diverse expertise, promoting a team-based effort to achieve our goals and meet deadlines efficiently. This cooperative ethos ensures that every member is fully engaged, leveraging our collective skills to their highest potential.

By integrating innovative technology with community outreach (Figure 2), the ROVrunners are not just building robots but also a brighter future for underwater ecosystems and young minds passionate about STEM.

Figure 2. ROVrunners at science night in community

Personnel

Name	Responsibilities
Theon Abbott	Pool Side Support, Vertical Profiler
Eric Anderson	Coding, Digital Cameras, Computer Systems
Kye Blaser	CFO, Grant Writer, Electrical Systems, Volunteer Co-Lead, Technical Writer
Sierra Brightly	CEO, Electrical System, Planning, Technical Writer, Grant Writer
Jason Fanger	Pilot, Coding, Digital Cameras, Computer Systems
Wade Johnson	Claw, Frame, 3D Designer
Dominique Klahold	Tether Operator, Shirt Designer, Frame
Sara Leathers	COO, 3D Designer, Frame, Thrusters, Claw
Samantha Miles	Safety Officer, Monitor Box
Aren Mowreader	Vertical Profiler
Hunter Niedens	Pilot, Vertical Profiler, Volunteer Co-Lead, Monitor Display Box
Asher Richmond	Logo and Marketing Display Designer
Fernando Salazar	Electrical System, Analog Cameras, Prop Lead
Jackson Smith	Coding, Computer Systems, AI, Photogrammetry
Dale Sydnam	Support for 3D design
Jake Terrell	Electrical System, Technical Writer
Dean Upton	Technical Assistant

Table 1. Members and Responsibilities

Resource Management

To make all company resources and knowledge available to every member of the company, the ROVrunners used Google Drive to manage and store all company files. The shared drive ensured a variety of company information, including employee training, past design proposals and outcomes, and vehicle operational procedures, were available to all employees at all times.

For day-to-day communication and problem solving, the team used a common Discord server so that all members could participate in conversations about how to best address each mission or issue as it came up.

Additionally, the team regularly met in-person in a common lab room where all materials and supplies were stored, so that all members had access to the vehicle and components as needed.

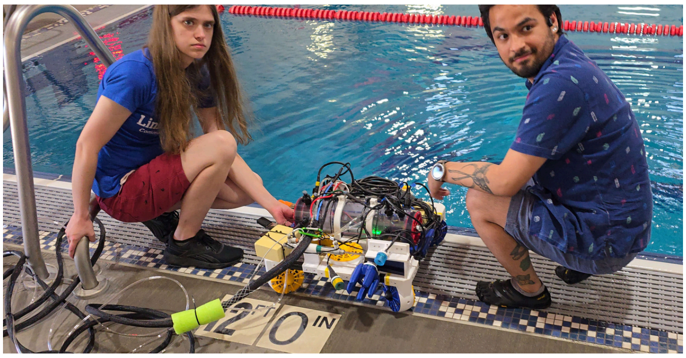

Figure 3. Sunday Pool Tests

Planning and Scheduling

The ROVrunners met twice weekly during the school term on Tuesdays and Sundays. The Tuesday meeting, organized by head mentor Greg Mulder, served to review what was completed the previous week as well as organize what will get done in the coming week. Round robin style, individuals or sub-teams would take turns explaining their plan, progress, and/or the hurdles they faced. If any assistance or collaboration with another sub-team was needed, it would be discussed at this time.

The Sunday meeting served as an in-person collaborative workday, and/or a day for testing, often at a local pool (Figure 3). These meetings would always end with a Tuesday-style group discussion of what had gone well, what hadn't gone well, and what direction to go next. Sub-teams and individuals often planned their own meetings and workdays during the week in addition to those shared by the whole team in order to accomplish goals more quickly.

Since building an ROV takes extensive time and effort, the team decided to schedule out the overall progress of the ROV. The overall schedule is shown in Table 2 below.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Initial Design Phase: Frame, claw, connectors, housing, vertical profiler, and controls. Design, Test, Review, Redesign			**Secondary Design Phase:** Start testing in pool, redesign to make functionality better. Build props. Design, Test, Review, Redesign			**Practice Phase:** Practice at pool to gain experience using the props and make decisions on what task should take focus.			Compete
Oregon Space Grant: Dec 1			Start Tech Docs Start volunteering program at Boys and Girls Club			**Regionals:** Apr 20 **Registration:** April 26 **Fluid Power Quiz:** April 26 **Qualification:** May 15 **Tech Docs:** May 22			June 18-22

Table 2. Build schedule by month

Design Rationale

Design Philosophy

At the very heart of our design philosophy is the idea of iterative design. We believe that one of the best ways to learn is by doing, and along those lines we have placed emphasis on high modularity and affordability for our design.

As a practical ramification of this design philosophy, our build features a large quantity of 3D printed polyethylene terephthalate glycol (PET-G). This medium lends itself to our overall design philosophy by allowing a piece to be tested, edited, and the next version printed all within a day or two. While 3D printed parts are not as strong as aluminum or other metals, they are much cheaper to make, do not need to be outsourced, have a much lower barrier to entry, and have plenty of strength for our applications.

PET-G also lends to durability and longevity, providing superior strength, flexibility, impact resistance, and moisture resistance.

The first step for any solution is understanding the question itself. As such, the first step of our design process is always an examination of the objectives. After breaking down the question into smaller pieces, we start with a loose prototype, test it, and then review the results. After looking at what went well and what could use improvement, we incorporate our findings into a new design. Then we continue to test, review, and redesign until we arrive at a satisfactory product. This practice of iterative design can be seen in the creation of every component of Spike (Figure 4).

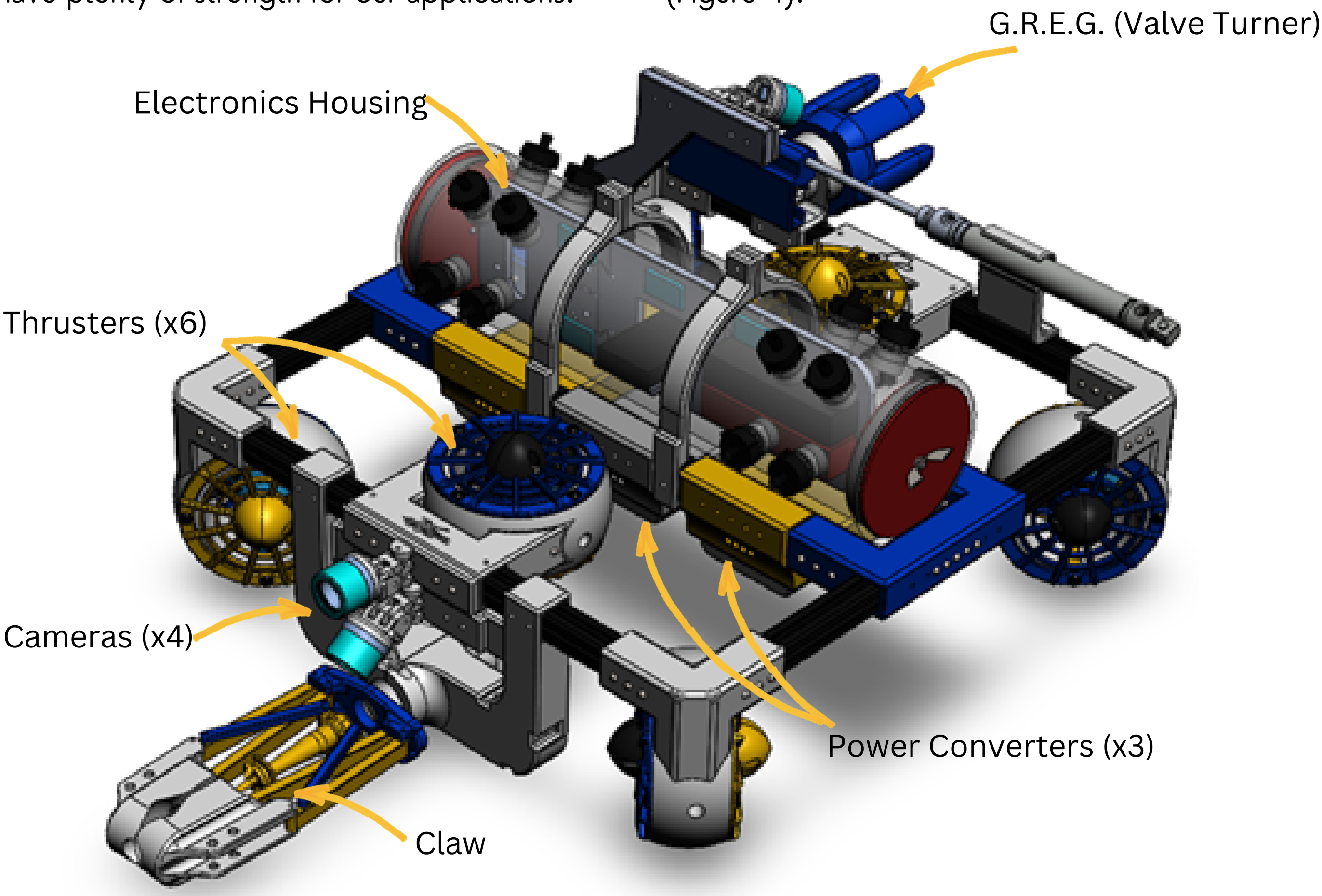

Figure 4. Spike

Hardware

Frame and Structure

Spike features an anodized extruded aluminum frame (Figure 5), measuring 0.48 m × 0.48 m × 0.15 m. The frame incorporates 3D-printed corner brackets that serve as thruster mounts and cover all sharp edges, while the anodization of the aluminum prevents oxidation. This robust yet lightweight aluminum structure ensures ample strength and allows for modular expansion with additional components as needed.

The frame is designed to accommodate three power converters and a cylindrical electronics housing, all centrally mounted along the vehicle's axis. This arrangement provides a low and centralized center of mass, maximizing stability during operation. Likewise, R-3312 polyurethane foam from BlueRobotics is arranged on the corners and below the electronics housing to achieve neutral buoyancy (Figure 6).

While the bulk of the frame is aluminum, true to the company design philosophy, 3D printed brackets hold the aluminum frame together. These brackets were iteratively designed to provide the necessary strength without hindering the function or design intentions of the frame itself. In contrast to previous frame designs by the ROVRunners, Spike's "single layer" flat frame uses significantly less aluminum, creating a lighter, more affordable, and hydrodynamic basis upon which the rest of the vehicle can be built.

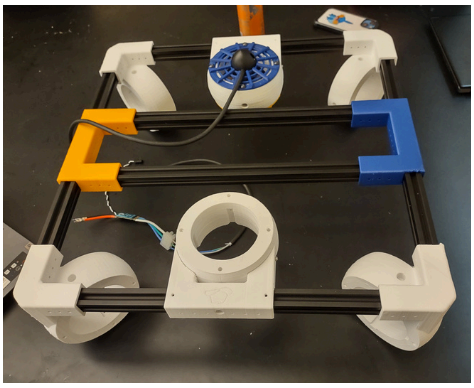

Figure 5. Spike's frame

Figure 6. Spikes' buoyancy foam on the frame

Propulsion System

Spike uses six BlueRobotics T200 thrusters for navigation. These thrusters, an upgrade from previous ROVRunner builds, were selected for their enhanced thrust capabilities and the brand's proven reliability. Four thrusters are mounted at a 90° offset from one another at each corner, providing primary directional movement. The remaining two thrusters are mounted on top of the ROV, enabling vertical and tilt movements (Figure 7).

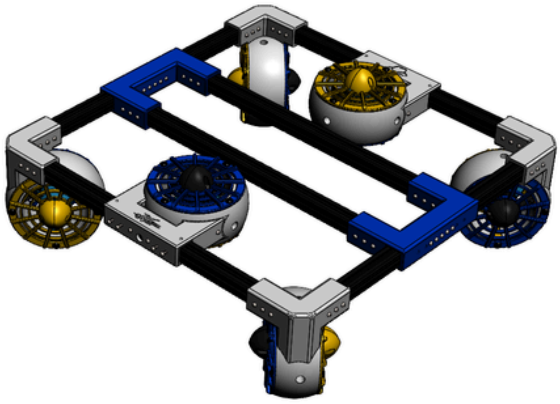

Figure 7. Spike's Thruster Layout

The main directional movement is achieved using vector geometry. This arrangement reduces movement power because half of each thruster's output is countered by another when moving linearly. However, this approach allows for precise yaw movements to change the ROV's direction without sacrificing stability or requiring additional thrusters.

The T200 thrusters are housed in custom-made 3D printed cases, with IP-20-compliant shrouds protecting the propellers for safety (Figure 8).

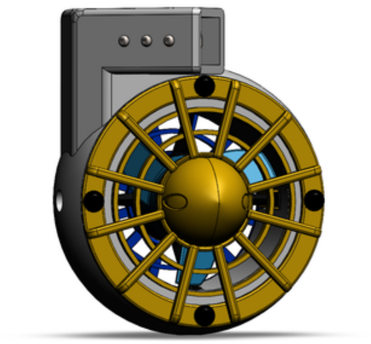

Figure 8. Spike's Thruster Shrouds

Electronics Housing

At the center of Spike lies our custom waterproof housing. Born out of the need to waterproof a control component that didn't end up getting used, the team broke away from their long held tradition and designed a completely custom waterproof container. The housing cuts costs that you would find for a prefab housing, using a length of clear PVC that we already had and inexpensive 1/2 inch poly barb male adapter as ports designed to be connected to 1/2 inch swivel adapters.

The first iteration (Figure 9) of this design had fifteen ports for electronics and was set using heat cure epoxy, which was found to be difficult to work with due to heating of the plastic. It was also found to be too short and the wires were difficult to plug when the extended down the length of the tube.

Figure 9. Initial housing design

The second iteration (Figure 10) has sixteen ports for electronics, pushing them to the ends for easier access. These ports were set using air cure epoxy, so while it took longer to cure, it didn't warp or shrink any components. This design is also double the length of the first iteration at 40cm, reaching across the entire ROV, leaving plenty of room for components and wiring. Oatey mechanical test plugs were used for sealing the ends, with a pressure rating of 17 PSI.

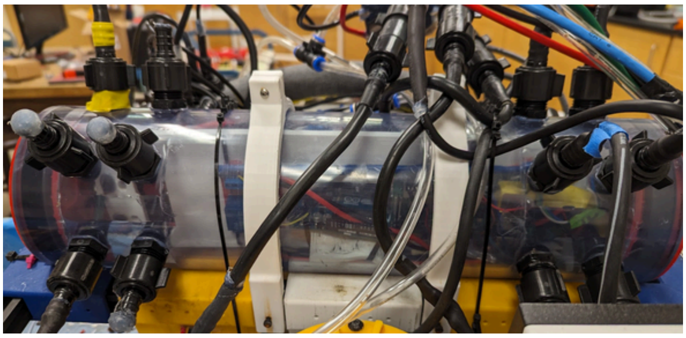

Figure 10. Final housing design with electronics components inside.

Manipulators

Spike is equipped with a pneumatic claw (Figure 11) designed specifically for the 2024 competition challenges. The 3D printed claw is engineered with high precision and is built to be very durable, making it ideal for underwater operations. It features two concave fingers that automatically center objects, ensuring a secure hold on various shapes, especially round ones like PVC pipes. Each finger is powered by three couplings and a single pneumatic piston, allowing for smooth opening and closing with a simple switch. The pneumatic system is affordable and easy to install. Additionally, the fingers are 3D-printed in clear, flexible resin, which offers excellent visibility and a stronger grip, which is crucial for underwater tasks.

The claw plays a vital role in several tasks for the 2024 competition. In the Coastal Pioneer Array task, it can accurately pull the acoustic release pin, triggering the recovery float of the multi-function node and ensuring it rises to the surface for retrieval. For the SMART Cables for Ocean

Observing task, the claw is used to deploy the cable through specific waypoints and place the repeater accurately, which is essential for obtaining temperature sensor readings and installing a power connector from the AUV docking station. This design improves efficiency and ensures precision in complex underwater tasks, making it a key component of Spike's capabilities.

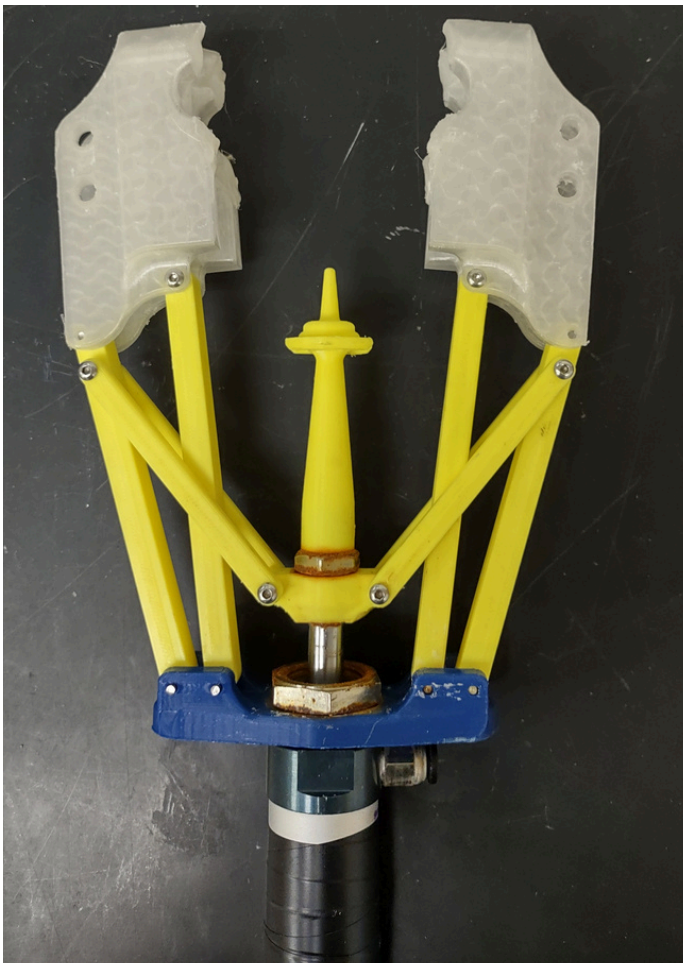

Figure 11. Spike's Manipulator

In tackling the challenge of rotating the irrigation valve, we developed the Great Rotary Exceptional Grabber (G.R.E.G.). The core mechanism of G.R.E.G is a linear actuator, activated alongside the pneumatic claw. A cogged rack attached to the actuator interfaces with a pinion to convert linear motion into rotational force. The pinion's axle features a robust base with a hexagonal axle for stability, and five contoured fingers designed to ensure effective engagement and self-alignment with the valve.

Initially, we considered a friction-based approach using a cylinder lined with steel comb brushes, but it was abandoned in favor of a hollow cylinder with five internal bars. This design, however, required a viable rotational force application, leading us to experiment with a pneumatic drill. Despite multiple iterations, the drill lacked the necessary torque, prompting a shift to a rack and pinion system toggled by a solenoid. After several adjustments, this configuration proved successful, culminating in a functional G.R.E.G. (Figure 12). Subsequent underwater tests indicated minor improvements were needed, but the overall system remains effective and largely unchanged.

Figure 12. The G.R.E.G.

Analog Cameras

The cameras use 22AWG UL2464 Power Cable with red, black, and yellow tinned copper conductors, ensuring reliable power delivery and signal transmission. Each camera connection features a SharkBite 1/2 Inch Poly Crimp Swivel Adapter, making the cables waterproof and durable for underwater conditions. The central hub (Figure 13) has six connections in total—four for the cameras, one for the 12V power input, and one for the video feed output. This setup enables efficient power distribution to the cameras and seamless video feed transmission to the topside DVR. This year, a smaller DVR, the Eversecu 4ch Mini CCTV Video Recorder, was selected to save space, resulting in a cleaner setup and more efficient data management.

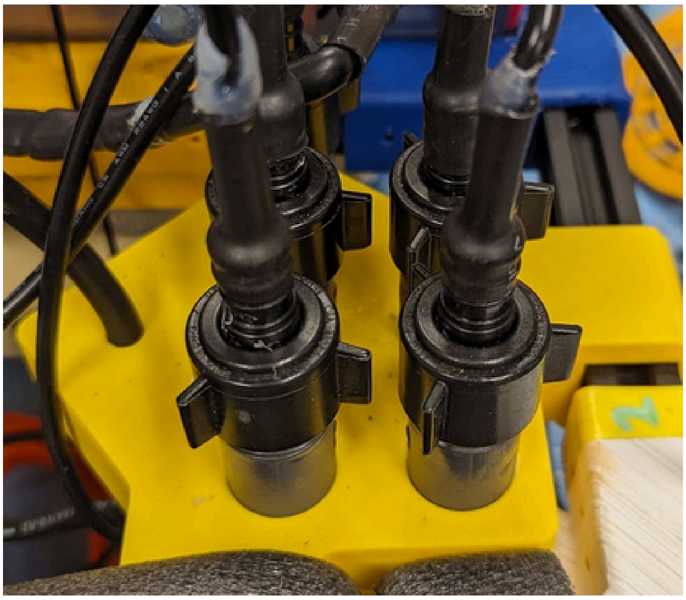

Figure 13. Analog Camera Hub

The 2024 ROV analog camera system has made a lot of progress. The focus has been on making the system modular and as small as possible to improve the ROV's functionality and maintenance. The system uses four SoloGood Caddx Ant FPV Cameras, each in custom resin casings for the best protection and performance. These cameras were picked because they are small and perform well (1200TVL, Global WDR, OSD, 1.8mm Nano FPV). Their small size means they can be placed in more spots without getting in the way, making maintenance and troubleshooting easier. A faulty camera can be swapped out in under five minutes, ensuring minimal downtime and maximum efficiency. The custom resin housing (Figure 14) protects the cameras from water damage and other risks while keeping a clear view, making the camera system very robust.

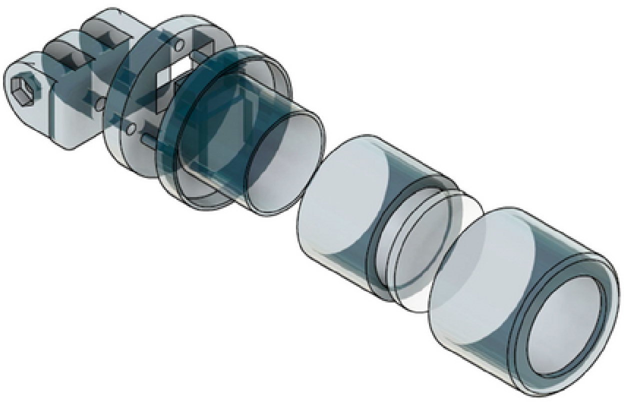

Figure 14. Exploded View of Camera Housing

Electric/Controls System

Tether

The ROVrunner team designed Spike’s tether (Figure 15) to be flexible and detachable. The tether measures 15 meters and is composed of four wire cords and two air hoses, all of which are contained in a wire sheathing.

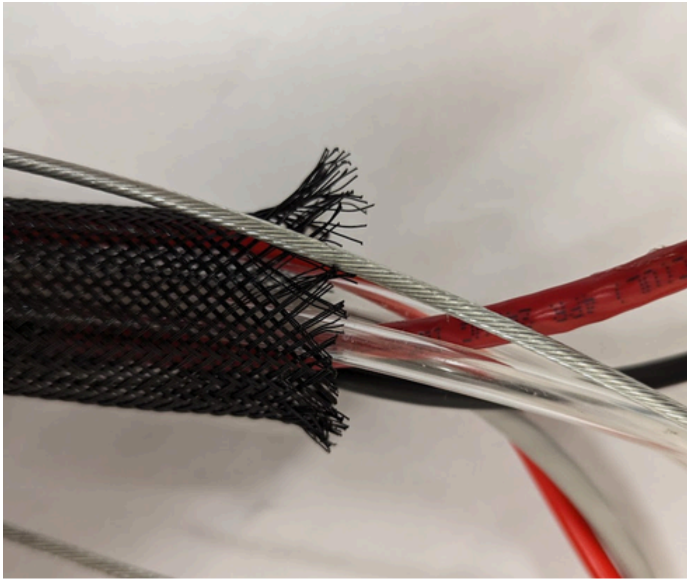

Figure 15. Tether

Wires contained in the sheathing are:

- Ethernet for the analog camera signal
- Ethernet for the control signal
- Two 10-gauge power wires for 48 VDC power
- Two pneumatic air hoses with a 148-psi (1.02 x 10^6 pascal) rating for the claw and valve spinner

At the topside of the tether, there is a closed-mesh, single-eye strain relief that connects to a plastic clamp on the control station. Coming from the strain relief, we have a red Ethernet which connects to the control station computer, a white Ethernet which connects to the analog video control system, and two power wires entering an Anderson SBS50, which connects to our fused power supply box. There are also two air hoses coming from the strain relief, which connect to the pneumatic outputs of the control station.

On the ROV-side of the tether, there is a closed-mesh, single-eye strain relief that connects to a cable that wraps around the ROV frame, rated for 100 kg. The connections from the tether wires come from the strain and connect to their specified places. The two 10-gauge wires are divided into three 48 VDC power connections, which connect to the onboard power converters through custom waterproof connector couplings. The white Ethernet connects to the analog camera system, and the red Ethernet enters the electronics housing to connect to the onboard Raspberry Pi. The two air hoses connect to the pneumatic claw and valve spinner, such that both tools will actuate in tandem.

Connectors

The waterproof connectors this year were designed to be affordable, allow for modularity, and simple to make. All connectors (Figure 16) are custom made using plumbing components, which keeps cost down, costing only six dollars per connector, which is substantially less than the SubConn connectors that we were previously using.

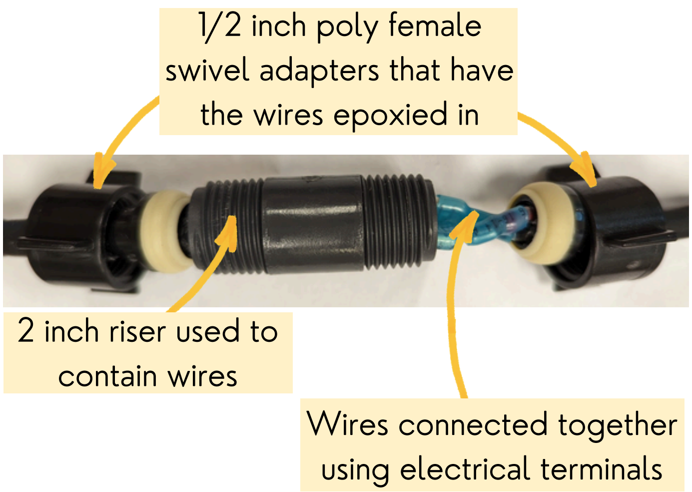

Figure 16. Custom connectors

These connectors are used to attach the tether to the 48 to 12 VDC converters. Single connectors are also used to connect to the electronics in the waterproof housing and used for the analog cameras.

Converters

Spike hosts three onboard power converters (Figure 17) which convert the provided 48 VDC to the more commonly used 12 VDC. Almost all powered components of Spike connect to one of these power converters. As with all of Spike's components, the power converters were designed with modularity in mind – each converter is an independent unit that can be removed or replaced as needed to accommodate different functions.

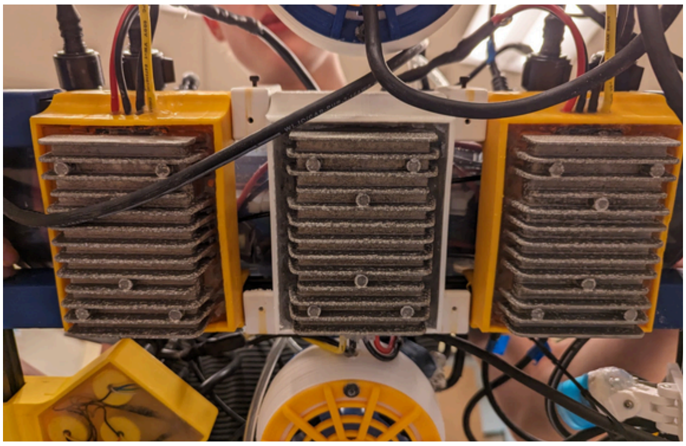

Figure 17. Spike's 48 to 12 Volt Converters

Inside the custom waterproof housing, there are two 12 VDC to 5 VDC converters running in parallel to supply power to the Raspberry Pi.

Controls

Spike is controlled via an Xbox controller (Figure 18) connected to a surface Intel NUC via USB.

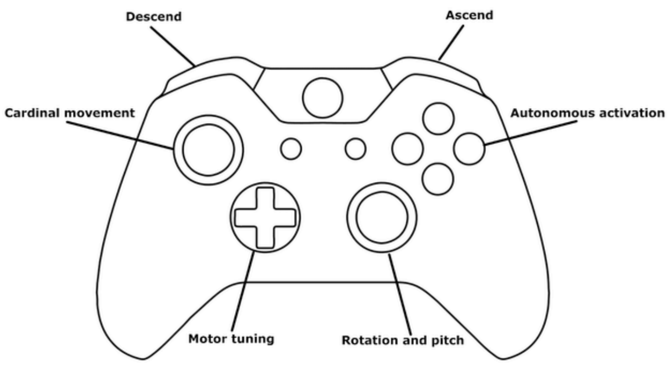

Figure 18. Spike's Controller Layout

The NUC, located in our topside control box (Figure 19), converts controller inputs into PWM frequencies for the electronic speed controllers (ESCs), packages them into an Ethernet packet, and sends it to the onboard Raspberry Pi, which is located in the electronics housing on the ROV (Figure 20). The Pi translates this data into binary, which the onboard Arduino UNO uses to control the motors. Digital cameras will be connected to the Pi via USB; the Pi will compress frames as JPEGs and send them to the PC through Ethernet.

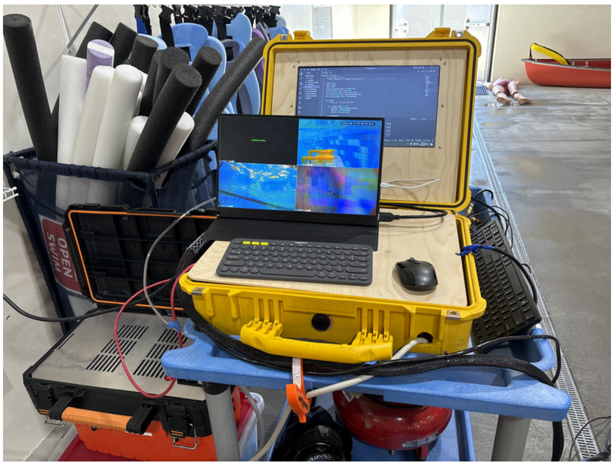

Figure 19. Spike's Topside Control Box

Initially, the control system used a Pixhawk 6C and Raspberry Pi 4B, housed in a custom electronics casing. Despite early success, issues arose post-repair, including inconsistent motor thrust and full-power motor startup, leading to uncontrolled barrel rolls. These problems prompted a switch to the Arduino and Pi system, deferring Pixhawk development to the following year.

The motion programming aims to make the ROV move like a video game character. Inputs from the joystick axes are combined and adjusted according to thruster positions and desired motion. An integrated accelerometer and gyroscope ensure precise pitch and angular velocity control. The code allows fine-tuning of thruster output to account for asymmetrical drag, optimizing vehicle stability and movement.

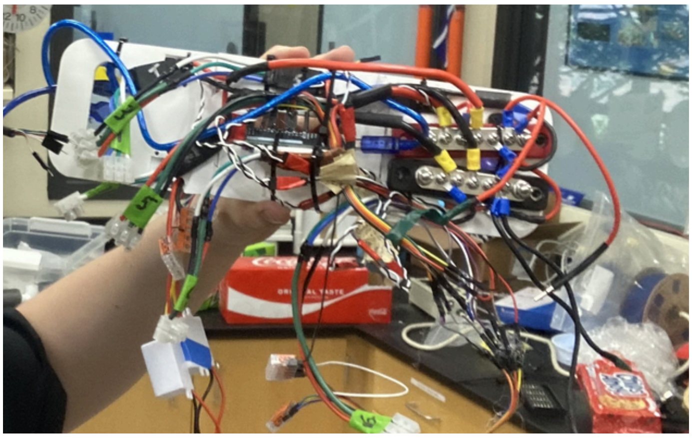

Figure 20. Electronics components on tray before placed in waterproof housing

Spike's secondary control system is for its pneumatic tools. The pneumatics are controlled through the use of a bi-directional switch to open and close the claw and a ball valve for engaging our variable buoyancy tool (currently not in use). The switch is connected to a series of electric pneumatic valves allowing us to control the flow of air. From the control interface (Figure 21) pneumatic tubing is ran through the tether directly to the tools on Spike.

Figure 21. Pneumatics Control Interface

Vertical Profiler

The Vertical Profiler (Figure 22) prototype is designed for a larger production run aimed at deploying a 50-capsule swarm to collect data in the Red Sea during a solar eclipse. We prioritized easily sourced and economical components, with aesthetic elements like the clear PVC housing being easily modified post-prototype.

The device includes a 25 cm clear PVC tube, a flexible silicone diaphragm secured with a hose clamp, and a modified test plug. Key electrical components are a BlueRobotics Bar02 pressure sensor, a 2-channel relay, a linear actuator, a buck converter, and an Adafruit BlueFruit BTLE chip.

The Bar02 sensor was selected for its I2C connection and dual temperature and pressure data collection, though its delicacy suggests future replacement. The 2-channel relay allows the linear actuator to be powered by a higher current than the Adafruit board can provide, necessitating a buck converter to step down the 9V battery voltage to 3.3V for the Arduino board.

The Adafruit BlueFruit BTLE board, chosen for its built-in Bluetooth and cell phone app, simplifies control during proof of concept but has several shortcomings. It will likely be replaced by swarm control technology similar to aerial drones. As BTLE loses connection when submerged, the dive cycle must be fully automated. While simple, our code needs refinement. Future iterations may rely on SD cards for data logging or other transmission methods.

Specialty components include rare earth magnets to manage the silicone diaphragm's expansion and contraction, initially designed to maintain positive pressure. However, the magnets couldn't withstand this pressure, leading to design adjustments. The VP is tuned for neutral buoyancy at the actuator's mid-stroke, enabling it to ascend and descend to collect data.

Integration with the PVC housing was efficient using test plugs. Modifications included a bracket for the actuator mount and adjustments to maintain a seal after adding the Bar02 sensor. After iterations, a flange-headed bolt and leather washer were used to create an adequate seal.

Future iterations will likely feature printed circuit boards, SD card data logging, improved wireless communication, and added functionality like temperature logging or video capture.

Figure 22. Vertical Profiler

System Integration Diagrams (SIDs)

Electrical SID

Component	Quantity	Nominal Voltage	Max Current Each (A)	Total Power Draw (W)	Current @ 12 V (A)
Thrusters	6	12.0	17.000	1224.000	102.0000
Cameras	4	12.0	0.220	10.56	0.8800
Raspberry Pi	1	5.0	2.5	12.500	2.5000
Arduino	1	5.0	0.200	1.000	0.2000
				Total Current Draw @48 V:	**26.4 A**
				150%	**39.6 A**
				ROV uses 30 A fuse.	

Table 3. ROV Fuse Calculations

Wire legend

48VDC	**7-12VDC**
12VDC	**Signal**
5VDC	**Ethernet**
USB	**120VAC**

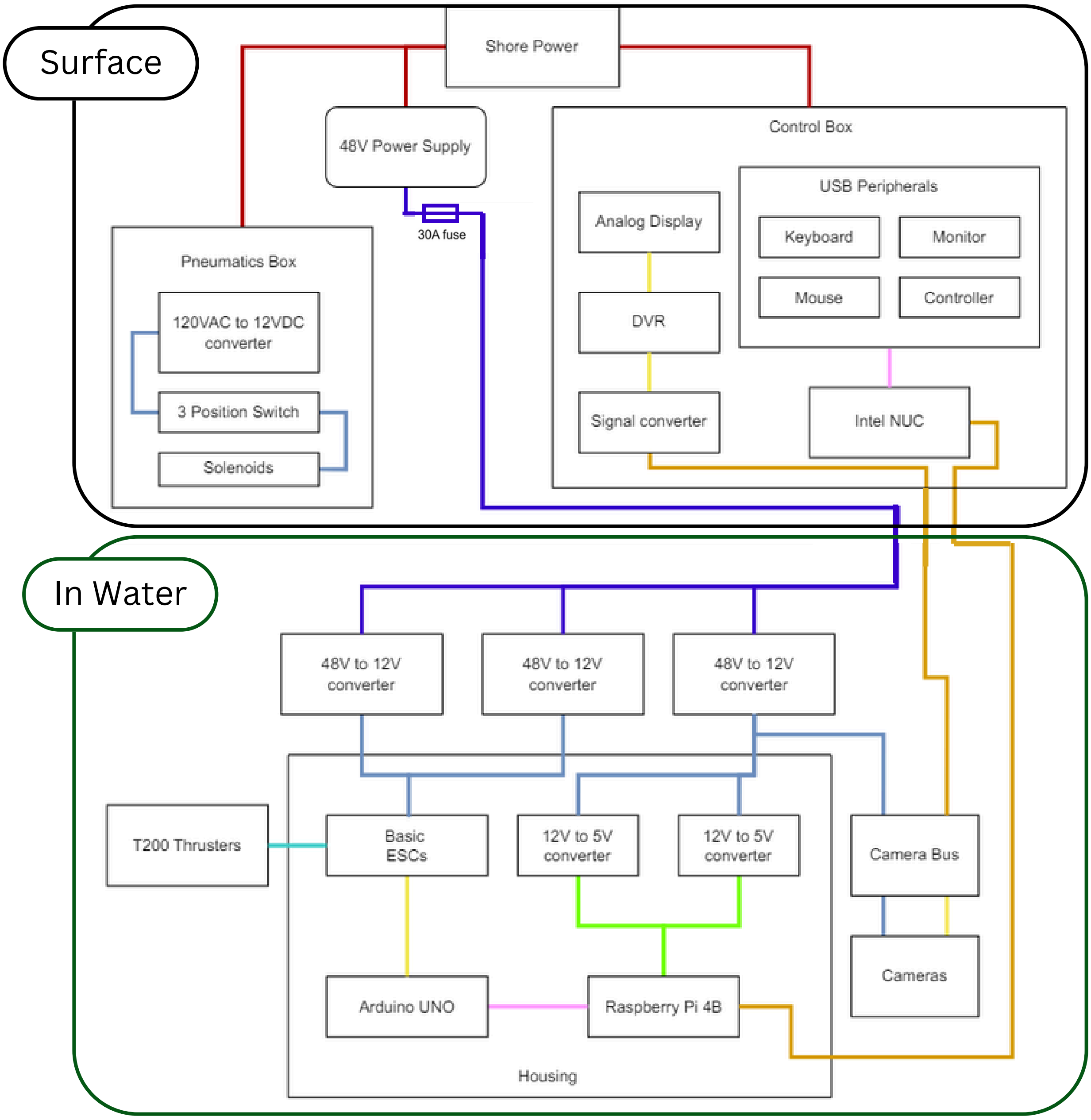

Figure 23. Electrical SID for Spike

Pneumatic SID

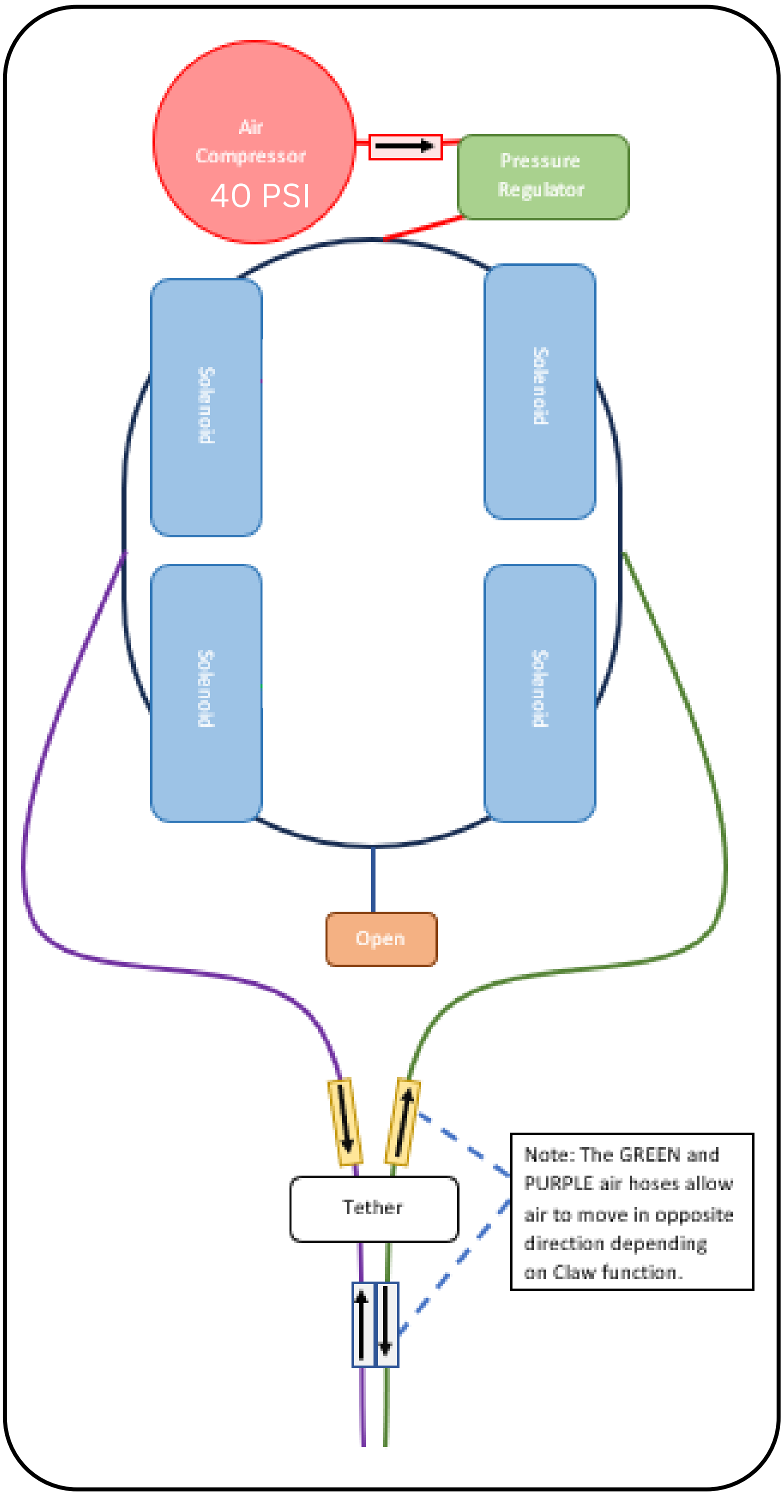

Figure 24. Pneumatic System Integration Diagram

Vertical Profiler SID

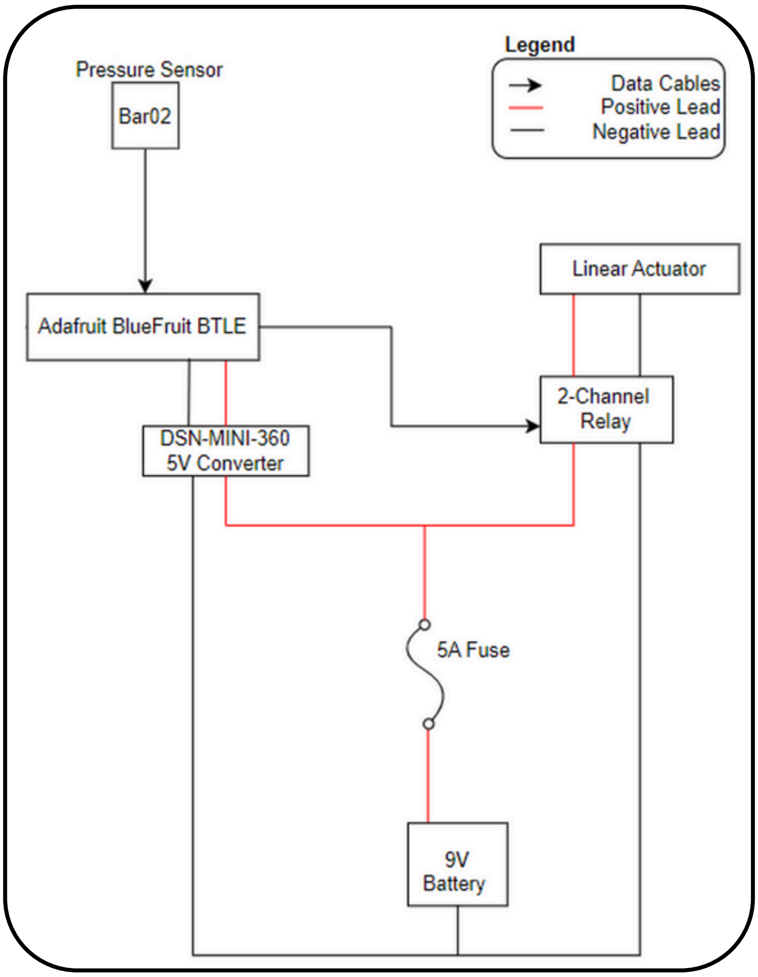

Figure 25. Vertical Profiler Diagram

	Voltage (V)	Current (A)	Wattage (W)
DSN-MINI-360	9	0.05	0.45
BlueFruit BLTE	3.3	0.15	0.495
2 Channel Relay	9	0.14	1.26
Linear Actuator	9	3	27
Bar02 Sensor	3.3	0.00125	0.004125
		Total Power	29.209125
		Total current @ 9v	3.245458333
		Safety Factor 1.5	4.8681875
		Installed Fuse	5A

Table 4. Vertical Profiler Fuse Calculations

Safety

Safety Philosophy

Employee safety is the company’s top priority. All team members are dedicated to strictly following and exceeding the safety guidelines and procedures established by MATE.

Before participating in any poolside operations, ROVrunner members are required to complete a comprehensive training course focused on safety protocols and potential hazards. During all relevant activities, proper PPE is required to prevent injuries.

Company Safety Protocols

Safety protocols are strictly enforced, with all members having a designated job to ensure the safety of the group and machinery. For example:

- Sara and Aren are designated to perform vehicle safety checks during setup for operation. The vehicle may not enter or be near water prior to completing the safety checks. In performing this inspection while keeping the vehicle away from the water, we reduce the risk of electrocution and harm to personnel, in addition to reducing the risk of shortages and damage to both the control station and the ROV.
- Samantha is responsible for control station checks, including assuring that all wires are properly connected and protected. This procedure is performed prior to events as well as during setup.

Additionally, the ROVrunners enforce the following lab protocols:

- Two people are required in lab when using tools.
- Safety glasses must be worn if using power tools.
- Closed toe shoes must be worn.
- While using knives or razors maintain arms length from teammates.
- During hot-work team members are encouraged to remove synthetic materials.
- If unsure of a task, ask for assistance.
- An organized workspace is the best way to prevent accidents. Clean often.

The setup and operational plans can be seen in the Appendix.

Vehicle Safety Features

Just as the company's personnel are held to strict safety standards, the company's vehicle's are designed and built with safety as the ultimate goal.

When building Spike, the company paid special attention to the following safety features:

- smooth edges
- shrouded propellers
- securely waterproofed components
- highly rated waterproof connections between components
- fused power converters
- tether is fused at point of connection to power

Additionally, the vehicle's power supply features a single switch for quick disconnect of power in case of emergency.

Critical Analysis

Testing & Troubleshooting

Iterative design has been the keystone of Spike's development. When designing a complex system, iteration is an absolute necessity. Clever new ideas and innovations are rarely implemented without hiccups. Iterative design allows for reflection, collaboration, and overall enhancement of the final product. A core company focus is on the value of diverse perspectives.

As a company, we implemented many ambitious new designs. We successfully introduced an entirely new frame design, modified our pneumatic claw, and created an electronics housing for our important, electrical components to be stored on the vehicle. To foster collaboration, we held debriefs after each pool test where all members were encouraged to highlight a positive outcome and a negative outcome along with a suggestion for improvement in that area.

The manipulator design has particularly benefited from our highly iterative approach. To meet specific task demands, such as turning valves for the coral fertilizer sprinkler system, we went through four iterations of the G.R.E.G. (Figure 26). Each iteration was guided by feedback from pool tests, demonstrating the power of iterative design in refining and perfecting complex systems.

This approach has enabled the team to navigate challenges, implement ambitious innovations, and continuously improve the ROV. Through collaboration and structured feedback sessions, we have refined key components, such as the frame design and manipulator, ensuring Spike's effectiveness in meeting its operational goals.

Figure 26. G.R.E.G. iterations 1-4. First iteration at the top, current iteration at the bottom.

Accounting

Budget

The budget for the 2023 - 2024 competition year was structured around a $10,000 grant awarded by the Oregon NASA Space Grant Consortium. Initial estimates were for $2,000 to be allocated to the project build. The remaining $8,000 would be allotted to competition travel expenses. The completion of a travel expense projection revealed an approximate budget deficit of $7,000. This deficit was ultimately covered by the generous contribution of Linn-Benton's student government. Further partitioning of build expenses was achieved through team estimates. A contingency fund was established for budget overages. Multiple checks and balances were implemented to ensure appropriate spending. Expenses would be submitted by teams to a shared Google Sheets document. These requests were to be approved by faculty advisor Greg Mulder. For Cost Accounting see Appendix C.

School: Linn Benton Community College			
Mentor: Greg Mulder			
Income			
Source			**Amount**
Oregon Space Grant Consortium			$10,000.00
Oregon Section of Marine Technology Society			$500.00
minirROV Physics			$1,200.00
Sexton Co.			$500.00
Expenses			
Category	**Description/Examples**	**Projected Cost**	**Budgeted Value**
Hardware	PVC, pneumatic tubing, wire, aluminum frame, etc.	$1,500.00	$1,500.00
Electronics	cameras, arduino, rasberrypi, etc.	$500.00	$500.00
Travel	airplane tickets, hotel costs, etc.	$16,584.00	$15,000.00
		Total Funds:	$12,200.00
		Total Expenses	$17,000.00
		Fundraising Needed:	$4,800.00

Table 5. ROVrunners 2024 budget

Conclusion

Acknowledgements

The ROVrunners would like to acknowledge the countless contributors that allowed the company to thrive in the MATE competition.

Members of the ROV team would like to personally thank our mentors, including Greg Mulder, Kathy Austin, and Heather Hill, for their immense efforts towards leading and guiding the efforts of the team for the greater success of our ROV.

We would also like to thank Oregon Space Grant, miniROV Physics, LBCC Sutdent Life and Leadership, the Oregon Marine Technology Society, and Sexton Co. for providing the funds to allow the team to come together and participate in a truly amazing learning and professional experience. From their contributions, we were able to design, build, and operate an ROV of our own.

We must also thank the Willamette-Valley Family YMCA for graciously allowing our team to use their pools each week for crucial testing of ROV piloting and tasks. Through their help, we have been able to greatly improve nearly all aspects of the ROV, allowing us to achieve many more of our company goals.

References

- “Bar02 Ultra High Resolution 10m Depth/Pressure Sensor.” BlueRobotics, https://bluerobotics.com/store/sensors-cameras/sensors/bar02-sensor-r1-rp/
- Beddows, Patricia, and Edward Mallon. “A Simple DIY Underwater Connector System Made from Plumbing Parts | Underwater Arduino Data Loggers.” Underwater Arduino Data Loggers, https://www.facebook.com/WordPressco m, 29 Jan. 2015, https://thecavepearlproject.org/2015/01/2 9/a-simple-diy-underwater-connector-system/. (Used for waterproof connectors)
- “Polyurethane Subsea Buoyancy Foam.” General Plastics, https://www.generalplastics.com/products /r-3300
- “T200 Thruster.” BlueRobotics, https://bluerobotics.com/learn/t100-thrusterusage/

Appendix A

Setup Plan

<u>ROV Setup</u>

Topside:

- ❏ Ensure the air compressor drain valve is closed.
- ❏ Charge air compressor.
- ❏ Ensure tether is securely mounted to the control station.
- ❏ Set up ROV power supply:
    - ❏ Ensure power supply is switched *OFF*.
    - ❏ Ensure ROV power supply is switched *OFF*.
    - ❏ Connect White Power Cord to power supply input.
    - ❏ Connect White Power Cord to shore power (extension cord may be needed).
    - ❏ Connect blue Anderson Connector from tether to power supply.
- ❏ Set up yellow monitor box:
    - ❏ Connect Orange Ethernet from tether to Topside Arduino (blue/yellow box).
    - ❏ Connect PS2 Controller to Yellow Ethernet from Topside Arduino.
    - ❏ Connect the Topside Arduino to power using the 12 V power supply.
    - ❏ Connect Gray Ethernet from tether to Orange Ethernet in the monitor box.
        - ❏ Ensure orange camera ethernet connects to DVR through baluns.
    - ❏ Ensure the power strip is switched *OFF*.
    - ❏ Ensure DVR, Monitor, Pneumatic Control Box and Arduino are connected to the power strip.
    - ❏ Plug the power strip into shore power (extension cord may be needed).
    - ❏ Switch on the power strip. Ensure the monitor, DVR, and Arduino are receiving power. Ensure the red *analog* light on the PS2 Controller is on.
- ❏ Set up pneumatic control box:
    - ❏ Ensure the toggle switch is in the *middle* position.
    - ❏ Ensure the ball valve is in the *closed* position.
    - ❏ Connect the red pressure regulator hose to the red IN fitting in the pneumatic control box.
    - ❏ Connect the air compressor to the red pressure regulator hose.
    - ❏ Connect the purple air hose from tether to the purple fitting.
    - ❏ Connect the blue air hose from tether to the blue fitting.

Wait for ROV Side setup to complete before continuing.

ROV Side:

- ❏ Ensure tether is securely attached to ROV with both strain relief hooks.
- ❏ Connect the 2-pin square connectors (4 total) to the power converters. Ensure any unused 2-pin connectors are securely covered with a dummy plug.
- ❏ Connect the orange 8-pin circular connector to the ROV Side Arduino (8-pin) and fasten the screw casing.
- ❏ Connect the purple 8-pin circular connector to the analog camera connector (8-pin) and fasten the screw casing.
- ❏ Connect the purple air hose to the purple claw fitting.
- ❏ Connect the blue air hose to the blue claw fitting.
- ❏ Ensure all connections are secure.
- ❏ Ensure all unused connections are covered with dummy plugs.

    Commonly unused connections:
    - ❏ Arduino FTDI
    - ❏ 48 V Power from tether
    - ❏ 12 V output from PCBs (*2*)
    - ❏ Digital Camera CAT5 from tether
- ❏ Have a second person check all connections before proceeding.

Figure 27. Set Up Plan

Appendix B

Operations Plan

ROV Pre-Operation Power-On Test (Pilot & Co-Pilot):

- ❏ Verify with those who set up the ROV that all connections are plugged and secure.
- ❏ Verify that the Red LED on the PS2 Controller is glowing red.
- ❏ Turn the main power on to the power supply and following this, turn on power to the ROV.
- ❏ Ensure no controls on the controller are engaged and verifies that no thrusters are moving when the controller is not receiving input.
- ❏ Verify cameras are operational and communicate the camera view adjustments to the tether team.
- ❏ Verify thrusters do respond to input by slightly bumping controls.
- ❏ Disengage power from the ROV, keeping the power supplies main power engaged.

ROV Operation Plan:

- ❏ The tether team lowers the ROV into the water.
- ❏ Co-Pilot engages power to the ROV as it is lowered into the water.
- ❏ Pilot communicates with the tether team necessary adjustments to all cameras.
- ❏ Pilot then completes mission tasks communicating with the tether team as needed to interact with mission components and adjustments in tether tension.
- ❏ At the end of the mission Pilot returns ROV to the poolside it entered on and requests the tether team to remove the ROV from the pool.
- ❏ Co-Pilot Disengages power once they confirm the tether team has control over the ROV.

ROV Post-Operation Plan:

- ❏ Remove all items brought from the pool.
- ❏ Remove all connections from the control system interfaces (Arduino, DVR, Pneumatic Control Box, Power Supply).
- ❏ Return all tools and wiring to the location it arrived in.
- ❏ Move control system interface containers to the bottom of the ROV cart.
- ❏ Leave all connections that directly attach to the ROV attached. It is quicker and allows more water to be removed before exposing the electrical connections.
- ❏ Wrap the ROV tether up on top of the ROV .
- ❏ Move the ROV to the top of the cart.
- ❏ Release the pressure drain valve on the air compressor.
- ❏ Pack all Props and ROV components.
- ❏ Double check we have gathered everything we brought.

Figure 28. Operations Plan

Appendix C

Cost Accounting

Cost Accounting for MATE 2023 - 2024		
Income		
tegory	Item Description	Amount
Money	Oregon Section of Marine Technology Society	$ 500.00
Sponsorship	miniROV Physics	$ 1,200.00
Sponsorship	Sexton Co.	$ 500.00
Grant	Oregon Space Grant Consortium	$ 10,000.00
	TOTAL INCOME	$ 12,200.00

Expenses						
Cameras						
te	Item Description	Type	Cost for All	Shipping	Cost	Running Budget
3/6/2024	30ct. 3mm 12v white LEDs	Purchased	$ 94.50	$ -	$ 94.50	$ 12,105.50
3/18/2024	LEDs, Brass Nut Fittings	Purchased	$ 56.37	$ -	$ 56.37	$ 12,049.13
				Total Cameras Cost	$ 150.87	
Frame						
9/1/2023	Buoyancy Foam	Re-used	$ 15.00	$ -	$ 15.00	$ 12,049.13
2/26/2024	Extruded Aluminum	Purchased	$ 30.99	$ -	$ 30.99	$ 12,018.14
3/4/2024	PETG Filament , M3 Nuts	Purchased	$ 42.97	$ -	$ 42.97	$ 11,975.17
3/8/2024	Subsea Buoyancy Foam	Purchased	$ 35.00	$ 6.50	$ 41.50	$ 11,933.67
3/18/2024	Spring Loaded T Nut M3, 100-pk	Purchased	$ 16.68	$ -	$ 16.68	$ 11,916.99
				Total Frame Cost	$ 147.14	
Claws						
2/26/2024	Display Driver	Purchased	$ 23.99	$ -	$ 23.99	$ 11,893.00
3/18/2024	Display Driver	Purchased	$ 26.99	$ -	$ 26.99	$ 11,866.01
3/22/2024	Pnuematic Drill	Purchased	$ 14.99	$ 6.99	$ 21.98	$ 11,844.03
3/28/2024	PNEUMATIC 1/4" NPT 5-Way Solenoid Valve	Purchased	$ 16.99	$ -	$ 16.99	$ 11,827.04
4/18/2024	Pneumatic Fittings, Pneumatic Tubing, Channel Relay	Purchased	$ 58.96	$ -	$ 58.96	$ 11,768.08
4/26/2024	PNEUMATIC 1/4" NPT 5-Way Solenoid Valve	Purchased	$ 16.99	$ -	$ 16.99	$ 11,751.09
				Total Claw Cost	$ 165.90	
Electronics						
9/1/2023	6 T200 Thruster + Basic ESC BlueRobotics	Re-used	$ 1,400.00	$ -	$ 1,400.00	$ 11,751.09
10/23/2023	Plumbing Adapters, USB-C, Display Drivers	Purchased	$ 89.18	$ -	$ 89.18	$ 11,661.91
2/27/2024	Raspberry Pi 3b	Purchased	$ 35.00	$ 5.01	$ 40.01	$ 11,621.90
3/4/2024	Tether Strains, Tether Sheathing	Purchased	$ 70.63	$ -	$ 70.63	$ 11,551.27
3/7/2024	Assorted Wires, 48-12V Converters, Plumbing Adapters	Purchased	$ 277.14	$ -	$ 277.14	$ 11,274.13
3/18/2024	Display Driver, Distribution Module, MicroSD	Purchased	$ 107.34	$ -	$ 107.34	$ 11,166.79
4/24/2024	12-5V Converter, Mini DVR, Busbars	Purchased	$ 129.63	$ -	$ 129.63	$ 11,037.16
				Total Electronics Cost	$ 2,113.93	
Tools						
2/26/2024	Heat Gun	Purchased	$ 28.99	$ -	$ 28.99	$ 11,008.17
4/24/2024	Variable Power Supply	Purchased	$ 62.99	$ -	$ 62.99	$ 10,945.18
				Total Tools Cost	$91.98	
Vertical Profiler						
9/1/2023	Clear PVC	Reused	$ 20.00	$ -	$ 20.00	$ 10,945.18
11/16/2023	Adafruit Feather, Gear Motor, Battery Holder, Batteries	Purchased	$ 53.60	$ 13.08	$ 66.68	$ 10,878.50
1/12/2024	Silicone Air Bladder, Magnets	Purchased	$ 22.24	$ -	$ 22.24	$ 10,856.26
1/18/2024	Linear Actuator 2in Stroke	Purchased	$ 25.19	$ -	$ 25.19	$ 10,831.07
3/18/2024	Silicone Diaphram, Bread Boards	Purchased	$ 20.97	$ -	$ 20.97	$ 10,810.10
				Total Vertical Profiler Cost	$ 155.08	
Props						
1/12/2024	PVC	Reused	$ 40.00	$ -	$ 40.00	$ 10,810.10
1/12/2024	Vinyl Tubing, Stop Valve, Velcro, Bowl, U-Bolt, PVC, Tent Pegs	Purchased	$ 105.56	$ -	$ 105.56	$ 10,704.54
3/4/2024	Rope, Screw Hook, PVC Fittings	Purchased	$ 35.50	$ -	$ 35.50	$ 10,669.04
3/18/2024	PVC Fittings, 16 Gauge Wire	Purchased	$ 16.32	$ -	$ 16.32	$ 10,652.72
				Total Props Cost	$ 197.38	
Research and Development						
10/24/2023	Adhesive Guru Mold Release Spray	Purchased	$ 14.99	$ -	$ 14.99	$ 10,637.73
2/27/2024	Pixhawk Controller	Purchased	$ 233.99	$ 29.16	$ 263.15	$ 10,374.58
4/26/2024	PNEUMATIC 1/4" NPT 5-Way Solenoid Valve	Purchased	$ 16.99	$ -	$ 16.99	$ 10,357.59
				Total R&D Cost	$ 295.13	
Travel						
5/19/2023	Flights	Purchased	$ 3,800.00	$ -	$ 3,800.00	$ 6,557.59
5/19/2023	Lodging (5 rooms w/ 2 per room)	Purchased	$ 5,565.00	$ -	$ 5,565.00	$ 992.59
5/19/2023	Meals	Purchased	$ 1,920.00	$ -	$ 1,920.00	$ (927.41)
19/2023	12 Passenger Van Rental	Purchased	$ 1,184.00	$ -	$ 1,184.00	$ (2,111.41)
19/2023	OSU Motorpool for Newport Trip	Purchased	$ 159.96	$ -	$ 159.96	$ (2,271.37)
				Total Travel Expense	$12,628.96	
					TOTAL EXPENSES	$ 14,471.37
					TOTAL COST OF ROV	$ 2,577.84
					TOTAL COST OF VERTICAL PROFILER	$ 155.08
					TOTAL COST OF PROPS, R&D, TOOLS	$ 584.49
					TOTAL COST FOR TRAVEL AND LODGING	$ 12,628.96
					TOTAL VALUE OF RESUSED PARTS	$ 1,475.00
					FINAL BUDGET	$ (2,271.37)

Table 6. Cost Accounting

ROVrunners

For the ROVs who say "Beep Beep!"

6500 Pacific Blvd SW
Albany, OR 97321

Follow us on Instagram!
@lbcc.rov

OREGON NASA SPACE GRANT CONSORTIUM

Linn-Benton Community College

MATE ROV COMPETITION 2024