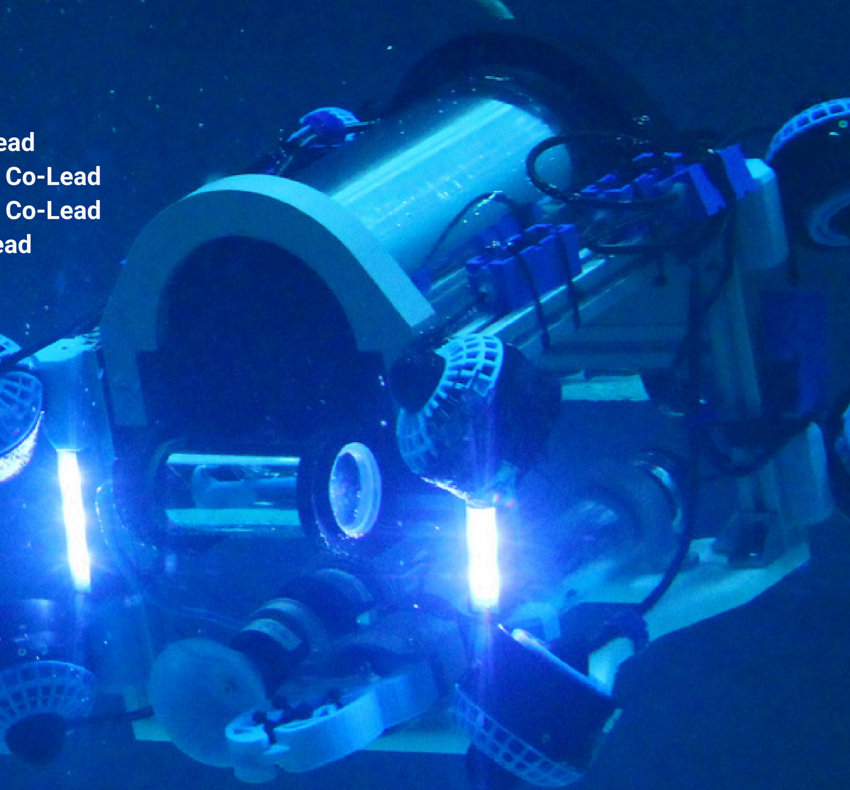
Memorial University of Newfoundland and Labrador
St. John's, Newfoundland and Labrador, Canada

Employees:

Martha Snelgrove	CEO
Russell Corbett	COO
Jadzia Penney	CMO
Evan Vokey	CIO
Zach Bennett	Electrical Team Lead
Mark Johnson	Mechanical Team Co-Lead
Eric Goulding	Mechanical Team Co-Lead
Zaid Duraid	Software Team Lead
Alex Kennedy	CSO
Shane Tetford	Electrical
Logan Smith	Electrical
Abdulmujeeb Abdulwaheed	Electrical
Kaitlin Healey	Mechanical
Ty Freda	Mechanical/Pilot
Bedir Acar	Mechanical
Sarthak Srivastava	Mechanical
Oluwademilade James	Mechanical
Kristin Lahey	Mechanical
Evan Whelan	Software
Agustin Eguiguren	Software
Ridwan Abdulwaheed	Software
Jacob Critch	Software
Zaeem Mazed	Software
Logan Janes	Software
Aaron Oates	Software
Cameron Shea	Software
Inusha De Silva	Software
Mohammad Kibria	Software



Mentors:

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Michaela Barnes, B.Tech
Anthony Randell, P.Eng
David Drover, B.Eng

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Abstract

Eastern Edge Robotics (EER) is a multidisciplinary company based out of the Marine Institute in St. John's, Newfoundland and Labrador, Canada. EER has designed and constructed a new Remotely Operated Vehicle (ROV) for the MATE 2024 Request For Proposal (RFP). EER is proud to present Beaumont, an ROV engineered to aid in preserving the environment and observing marine life. Beaumont has an eight-thruster omnidirectional system that allows for six degrees of freedom, granting the pilot increased mobility. Two custom tools have been designed for the 2024 RFP. A newly designed manipulator based on the design from the 2023 RFP but with a new and improved mounting and gripper design. There is also a valve-turning tool specifically designed to deploy probiotic irrigation systems that heal diseased coral and promote healthy coral ecosystems. Beaumont includes four cameras: one to see the tooling skid for ease of use of tools, one to see in front of the ROV for pilot navigation, one to see above Beaumont for ease of maneuvering in and out of the moon pool and to view tether in case of snares, and a bottom camera to aid in navigating for autonomous movements of the ROV. Beaumont has been built from the ground up by EER using durable materials to create a long-lasting yet lightweight product. EER has spent over 2000 hours brainstorming, designing, constructing, and testing Beaumont to create a highly optimized system with the user in mind.

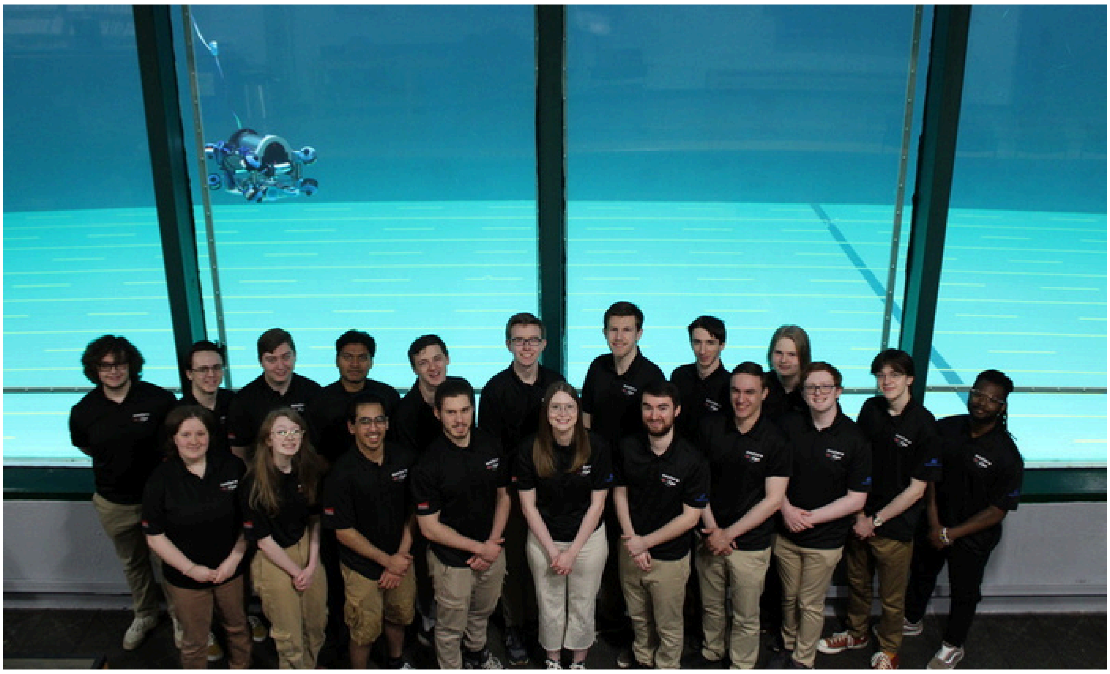

Figure 1: Eastern Edge Company Photo, Anthony Randell 2024

From left to right
Back: *Cameron Shea, Mark Johnson, Zach Bennett, Mohammad Kibria, Alexander Kennedy, Eric Goulding, Russell Corbett, Kristin Lahey, Evan Whelan,*
Front: *Martha Snelgrove, Kaitlin Healey, Sarthak Srivastava, Zaid Duraid, Jadzia Penney, Shane Tetford, Evan Vokey, Logan Smith, Ty Freda, Omari De'Pluzer*
Not Pictured:
Bedir Acar, Aaron Oates, Oluwademilade James, Agustin Eguiguren, Ridwan Abdulwaheed, Jacob Critch, Zaeem Mazed, Logan Janes, Abdulwaheed Abdulmujeeb, Inusha De Silva

Team Work

Project Management

For the 2024 RFP, EER has improved the existing corporate structure used to complete previous RFPs (*Figure 2)*. Everyone involved has the opportunity to aid in the construction of Beaumont. The Chief Executive Officer (CEO) and the Chief Operations Officer (COO) oversee the company's day-to-day procedures, scheduling, and finances. The Chief Marketing Officer (CMO) manages all social media, outreach events, and sponsorship opportunities. The Chief Safety Officer (CSO) supervises safe operations in the workshop and safety training of all employees. EER employees are divided into software, mechanical, and electrical subteams. The Chief Integration Officer (CIO) is a new role added for the 2024 RFP to oversee the team leads of the three engineering subteams. The CIO ensures clear communication among subteams, allowing the company to take a holistic approach to design.

A schedule was developed in September 2023 to prepare for the 2024 RFP, as seen in Appendix C. Multiple organizational and communicative programs were used for project management to keep the company on schedule. Trello was used to plan EER's long-term goals and create day-to-day tasks to work towards them. The company uses Google Drive to track documentation and finances. Cloud-based software like GitHub and OnShape allow employees to work together on projects that contribute to a holistic design approach. Discord is used for company communication to ensure all employees can convey information and collaborate to meet company goals. Appendix A shows multiple procedures have been created to ensure safe work practices, handling the ROV during day-to-day operations, and purchasing through the appropriate channels.

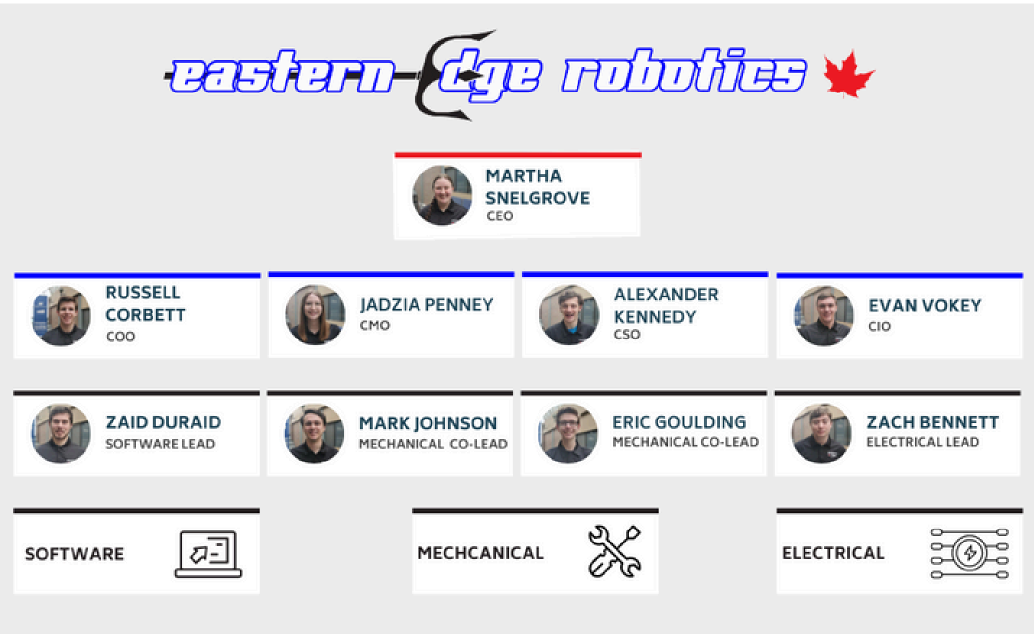

Figure 2: Eastern Edge Robotics Organizational Chart, Jadzia Penney 2024

Design Rationale

The company followed a user-centric design philosophy when designing and manufacturing Beaumont. User-centric design is a philosophy that concentrates on streamlining the user experience. EER has created an effective yet easy-to-use product by concentrating on the end user. For the pilot's benefit, Beaumont is stable and maneuverable while in motion, has intuitive controls, and has a reliable and effective payload of tools. Downtime on deck is minimized as Beaumont is field serviceable. Beaumont is light and compact enough to be carried easily, allowing for easier handling by the deck crew. By keeping the user-centred design philosophy in mind, EER has developed a product that is both easy to use and capable of completing the 2024 RFP.

Systems Approach

Beaumont's vehicle systems were designed, tested, and assembled to create a maneuverable, precise, and modular ROV that kept the end user in mind. Beaumont (*Figure 3*) was engineered to efficiently perform various tasks, including moving objects, visual inspection, transmitting data, and more. During the design process, the company participated in weekly "design standups" to discuss, update, and analyze the evolution of each subsystem. From the start, the electrical system was designed to accommodate a variety of potential tooling equipment, such as extra cameras, a variety of motors, and more. This made improving system components like changing a stepper motor to a bilge pump motor for the valve turning tool easy. The software subteam created a simulator for Beaumont to configure the camera layout and control system. This helped make Beaumont's transition to a physical operation smoother and improved its observational capabilities. This holistic design approach taken by the company, where each subsystem can function together and allow room for innovation, has allowed Beaumont to become a highly capable ROV.

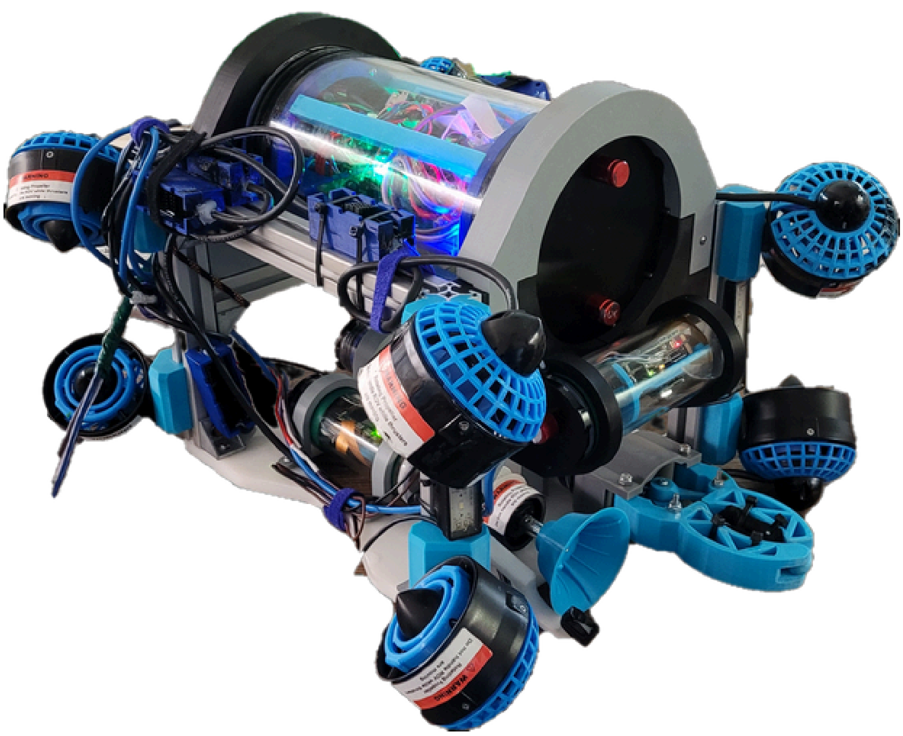

Figure 3: Beaumont ROV, Zach Bennett 2024

Vehicle Structure

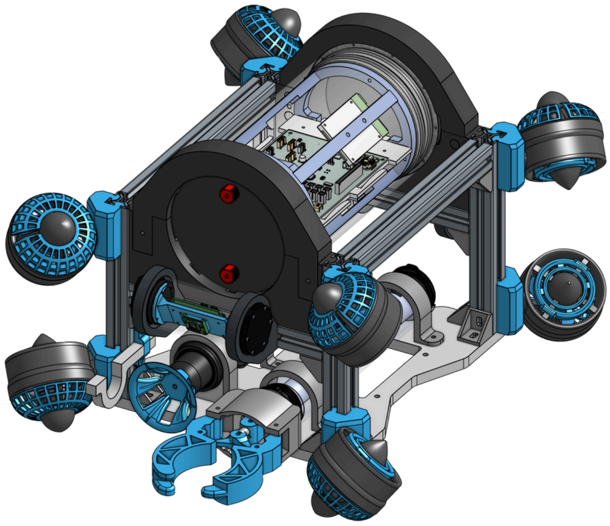

Figure 4: Beaumont ROV Render, Mark Johnson 2024

For this RFP, a 6-inch watertight enclosure and four separate 2-inch enclosures were reused to limit the cost of the vehicle structure. These enclosures create a lot of positive buoyancy, but reusing them allowed EER to purchase new materials to optimize underwater performance. One major purchase was new 30 x 30 mm aluminum t-slot as the main structural pieces for Beaumont. This allowed the company to offset the enclosures' buoyancy more effectively while keeping the ROV's size down, as the aluminum t-slot is extremely light, strong, modular, and dense. However, the aluminum t-slot is unsuitable for tooling and small mounts because of its set shape and size. Instead, ABS+ and PLA+ 3D-printing plastics were used to manufacture complex components. The final portion of the structure utilizes a sheet of donated HDPE plastic for a flat landing platform and an area for mounting tools. There is great flexibility in designing a tooling skid that perfectly fits the pilot's needs, as the company had the resources to mill the HDPE on an in-house CNC machine. While this flat sheet reduces vertical hydrodynamics, the cost savings using donated materials and the flexibility this material provides in machining offset this downside.

This optimization of components and materials helped an innovative vehicle structure that met budget, sizing, and weight constraints. Beaumont weighs approximately 16.25 kg, which is 1.75 kg under the ideal weight per the RFP and approximately 25% lighter than EER's previous ROV. This was accomplished by using less HDPE and investing in aluminum t-slot instead. This allowed the company to use less material while still creating a sound structure, reducing weight.. Also, compared to last year's RFP, the total size was reduced from an end-to-end volume of 535 x 564 x 418 mm to 522 x 501 x 359 mm, an approximately 26% decrease. While these changes reduce mounting space on Beaumont, thanks to the versatility of the claw design, less space is needed for extra tooling. This allowed the company to design with a smaller deck crew in mind by making this year's vehicle easier to lift and take up less space when aboard a ship, where space is extremely valuable.

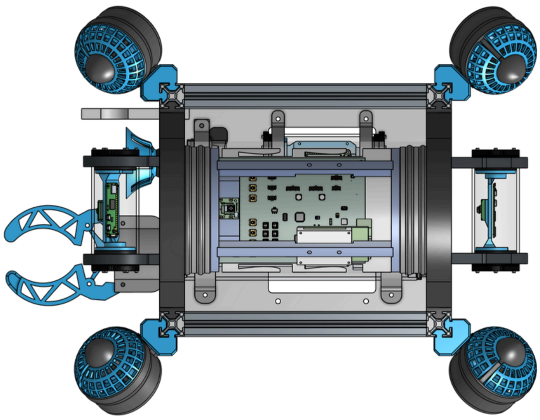

Figure 5: Beaumont ROV Top Render, Mark Johnson 2024

Electrical Control System

Overall System

In previous years, a complex electrical architecture spread over many Printed Circuit Boards (PCBs) made assembly, disassembly, debugging, and manufacturing a time-consuming process. This increased downtime for servicing and made operations less convenient for the user. This year, EER's electrical architecture consists of a custom-made tether and two PCBs, one for Beaumont's controls and the other for the conversion of power from the surface. These PCBs were designed by employees and assembled in-house. This lower number of PCBs allowed Beaumont to be assembled and disassembled in less time than previous designs. It also streamlined the process of finding faults, as each type of error could be traced to one of two PCBs instead of searching through multiple connected PCBs.

ROV Control Board

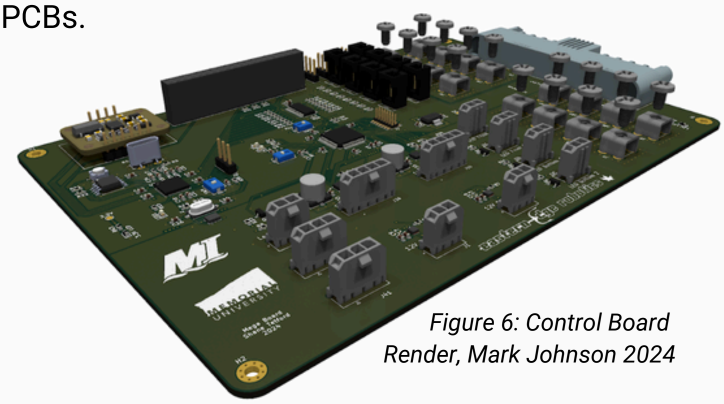

Figure 6: Control Board Render, Mark Johnson 2024

The ROV Control Board (*Figure 6*) powers and communicates with all other systems on the vehicle, including the onboard computer, Electronic Speed Controllers (ESCs), motors, and lights.

In last year's RFP, this subsystem consisted of six independently developed PCBs. While the multiple PCB design was intended to increase the modularity and serviceability of the vehicle, mounting the boards inside the electronics enclosure required three plastic trays stacked on top of each other. Wiring between the trays effectively "stitched" them together, making identifying problems on and servicing PCBs in the middle of the stack difficult.

This year, Beaumont's entire ROV Control Subsystem is housed on a single PCB to reduce downtime and improve the user experience of the deck crew and pilot in case of electronic failure. This eliminates wiring between devices inside the enclosure, allowing for easier access to all components during repair and eliminating potential points of failure. The board is mounted to a tray in the middle of the electronics enclosure for easy accessibility, greatly improving the user's ability to visually inspect and troubleshoot the vehicle's electrical system without mechanical disassembly.

The development of this new single PCB architecture required careful planning by EER's electrical team, as the board must be able to power high-current devices such as the thrusters. The board's layout reflects this consideration; the screw terminals that power Beaumont's ESCs are located as close as possible to the board's power connector, where it receives power from the power conversion subsystem. The screw terminals are connected to large copper pours on multiple layers, creating a large area to dissipate heat from the board.

Power Conversion Board

Figure 7: Power Conversion Board, Mark Johnson 2024

The Power Conversion Board (*Figure 7*) is responsible for converting the 48V supplied from the surface to 12V for use by Beaumont's thrusters and tools and 5V for use by all onboard communications. In previous RFPs, EER utilized 12V for some communications devices, which resulted in the shutdown of these devices in the event the vehicle's thrusters used all available power for the board's DC/DC converters.

For this year's RFP, EER ensured all communications devices were powered from 5V instead of 12V. Isolating the communications systems from thrusters in this means the vehicle's control systems can recover from an "over-current" or "brown-out" in a matter of seconds rather than minutes. This decreases downtime and allows the pilot a better experience while operating. The new 48V-to-5V converters can handle a much lower input voltage than the original 48V-to-12V converters. That means that if the input voltage drops due to the thrusters pulling too much power, the 48V-to-5V converters can still accommodate and keep the communication lines powered.

The conversion of 48V down to 12V and 5V generates significant heat, which could result in damage to components if not properly dissipated. To remedy this, the Power Conversion Board is specially designed and sized to mount perfectly on one of Beaumont's aluminum end caps. This allows the heat produced by the board to be dissipated into the surrounding water.

Diagnostics

Sensors providing diagnostic data are useful for live debugging during runs. For this reason, Beaumont includes the following sensors:

- Three Analog Digital Converters (ADCs) for voltage readings on the 48V, 12V, and 5V buses
- Six temperature sensors throughout the Power Conversion and ROV control board
- An onboard Inertial Measurement Unit (IMU) for measuring Beaumont's orientation and acceleration.

Each of these sensors is wired to the same communication line as Beaumont's onboard Raspberry Pi 4, where they are regularly sampled and displayed in the topsides Graphical User Interface (GUI) *(Figure 8)*.

Items	Values
ADC	{"adc_48v_bus":46.2,"adc_12v_bus":11.6,"adc_5v_bus":4.9}
TEMPERATURE	{"power_board_u8":30.125,"power_board_u9":31.375,"power_board_u10":30.25,"mega_board_ic2":29.875,"power_board_u11":29.75,"mega_board_ic1":30.125}
ORIENTATION	{"Acceleration_x":0.12,"Acceleration_y":-0.05,"Acceleration_z":0.02,"yaw":36,"pitch":6,"roll":8}

Figure 8: Sensor GUI Display, Zaid Duraid 2024

Tether

In the past the company used a fiber-optic tether for communications with the ROV. Due to its delicacy and safety risks, fiber-optics are difficult to repair in the field making it a poor choice for the tether. In finding a replacement, EER brainstormed solutions considering repairability, low cost, durability, and flexibility as the most important factors in meeting the RFP specifications (*Table 1*). The company assessed various options, including solid-core Ethernet, stranded Ethernet, and fiber, and determined that stranded Ethernet best fit EER's specifications for transmitting data.

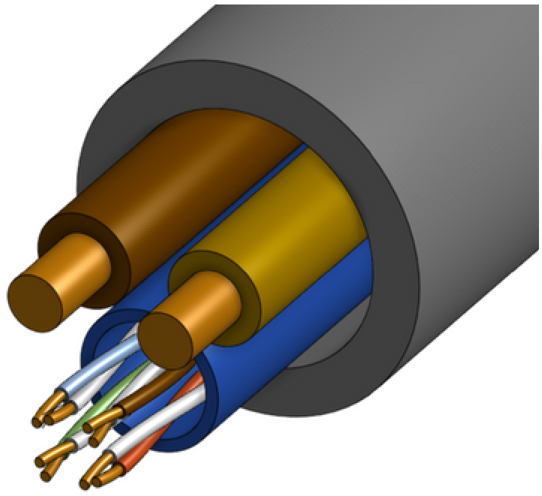

Figure 9: Beaumont Tether, Mark Johnson 2024

	Repairability	Cost	Durability	Flexibility
Ethernet (Solid-Core)	High	Low	Medium	Low
Ethernet (Stranded)	High	Low	High	High
Fiber	Low	Free	Low	High

Table 1: Table used in making choices for tether make-up, Martha Snelgrove 2024

In previous years, the tether also contributed to the ROV losing power due to the voltage drop over the length of the tether. Due to the 16.8 m of tether, that drop can be extreme. This year, the company aimed to correct this through changing the power conductors of the tether; it is now composed of two 12 AWG wires to carry 48V to the vehicle this is an increase in gauge from previous tethers that housed 14 AWG wires, reducing the voltage drop from 8.31V to 5.22V.

Beaumont's tether is protected on both ends using a mesh cable sleeve for strain relief. This mesh sleeve mechanically connects to the vehicle frame, preventing strain on the tether from damaging the water-proof seals to the electronics enclosure. The mesh sleeve also connects to the tether termination box on the surface, which is clamped to the control station table. This prevents damage to topside equipment, such as the power supply and control laptop, should strain develop on the tether.

The company's tether manager's protocol is the result of years of development. The tether is kept in a neat figure 8 position and managed by two on-deck members. One member watches the ROV and feeds and takes back slack as the vehicle moves. The other member takes that slack and recoils it neatly in the company's figure 8 position to keep the tether free of tangles and contained to prevent tripping hazards.

Lessons Learned

For this year's RFP, EER took a radically different approach to the design and manufacturing of Beaumont's electrical system. The new architecture of the ROV Control Board deviated significantly from previous EER designs, necessitating the development of new internal guidelines and review processes for PCB design. These processes were informed by several industry contacts and provided the basis for EER's design processes in future projects.

In the development of vehicles for previous RFPs, EER hand-soldered all components onto the PCBs, one at a time. This year, EER took advantage of equipment made available at Memorial University of Newfoundland's Student Design Hub (SDH) to use a different approach to the assembly of components onto its PCBs: reflow soldering. Reflow soldering uses solder paste applied to a PCB using a stencil; components are placed on their respective pads, and the board is placed in a reflow oven.

The reflow oven provides greater consistency in the soldering process and is significantly quicker than hand-soldering components. EER was able to complete the assembly of this year's ROV Control Board in a single day, while the hand-soldering of the equivalent number of components in the previous year's vehicle took five days.

Software

ROV Controls

Beaumont's software package was written with modularity and ease of use in mind. Most notably, the pilot may use any computer with an Ethernet port to connect to the tether, with no need to install any software or have an internet connection. The GUI can be reached through a web browser, which accesses a server running on a Raspberry Pi onboard Beaumont or a computer running the EER proprietary simulation environment. Furthermore, the pilot may choose to control Beaumont with a keyboard or most popular controllers, creating and saving control profiles via the GUI. The GUI is shown in Figure 10.

The GUI features a camera stream viewing tab, a control and diagnostics tab, and a settings/controller profiles tab. The camera tab opens motion JPEG (MJPEG) streams, displaying up to 4 streams at once. On the other hand, the controls/diagnostics tab allows the copilot to adjust thruster power in certain directions. It also indicates if Beaumont is powered on, the controller profile in use, and various other diagnostics (temperature, voltage, orientation, brain coral task progress). Finally, the settings tab allows the pilot to modify the controls database and specify camera stream URLs. Figure 10 shows screenshots of the controls/diagnostics tab.

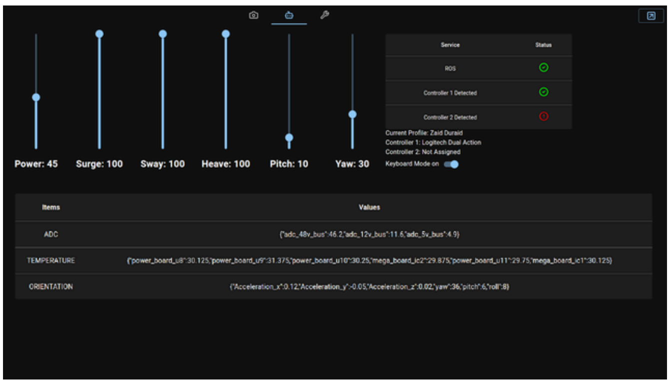

Figure 10: Controls GUI, Zaid Duraid 2024

The GUI not only controls Beaumont, but it can also be used to control an innovative ROV simulation developed by EER in Gazebo Classic [2]. Thanks to the node-based architecture of the Robotics Operating System 2 (ROS2) [3], which the software package relies on, the majority of the code is identical between the simulation environment and real Beaumont. The simulation also features a four-camera MJPEG streamer, a claw akin to Beaumont's, and a recreation of the mission tasks. This makes it an effective tool for pilot practice, strategizing, and software feature development. Figures 11-14 shows a comparison between Beaumont and the simulation environment.

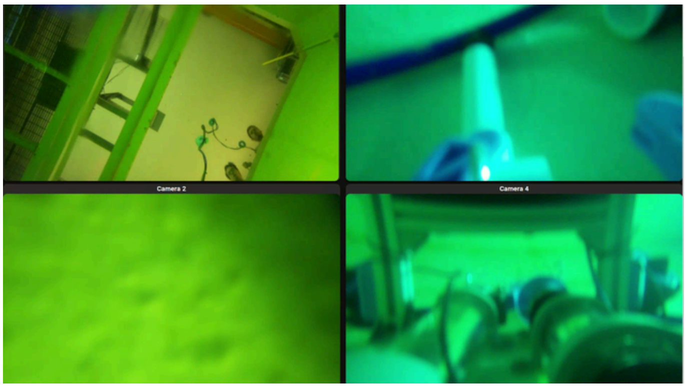

Figure 11: Camera View Screenshot, Zaid Duraid 2024

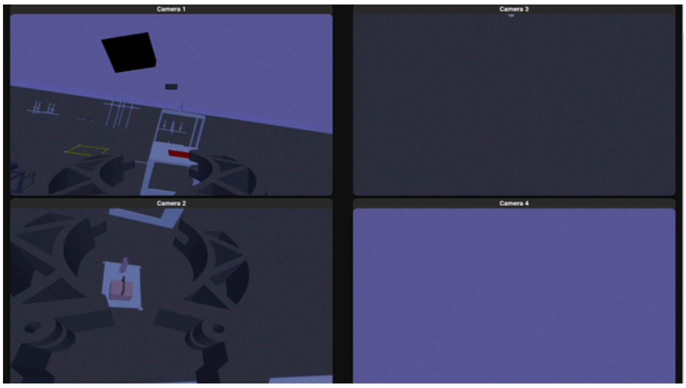

Figure 12: Simulator Camera View, Zaid Duraid 2024

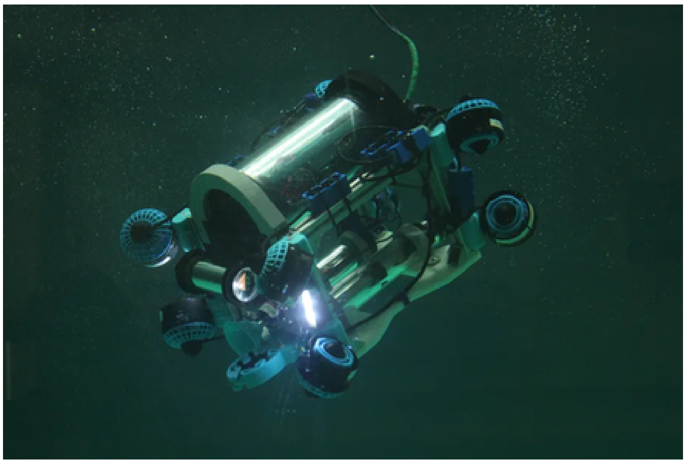

Figure 13: Beaumont ROV in Water, Anthony Randell 2024

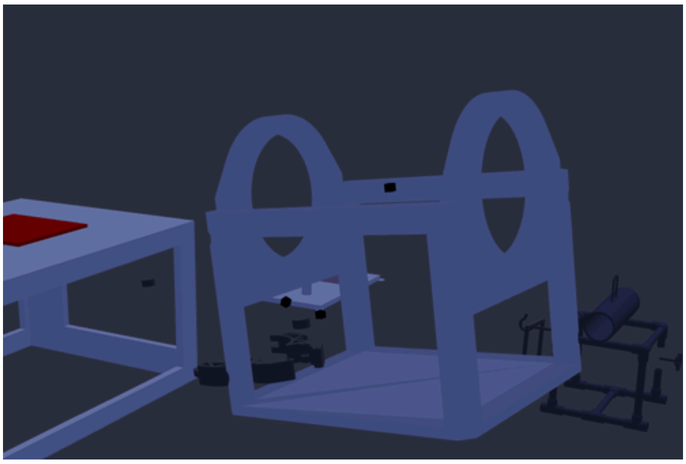

Figure 14: Beaumont ROV in Simulator, Zaid Duraid 2024

Propulsion

The ROV uses eight Blue Robotics T200 Thrusters. They were reused from a previous RFP, significantly reducing costs, as new thrusters cost $200 each. The orientation of the thrusters allows for movement in all six degrees of freedom (*Figure 15*). As opposed to having dedicated thrusters for horizontal and vertical movement, Beaumont's thrusters are angled such that they exert force in both directions. This allows all eight thrusters to be used together, resulting in a 41% increase in horizontal and vertical thrust.

Figure 15: Diagram of the thruster direction (left) and thruster placement on Beaumont (right), Mark Johnson, 2024

In previous RFPs, EER's ROVs lacked vertical power, making them slower and unable to pick up heavy objects. To fix this, Beaumont's thrusters are angled slightly more upward so they produce more thrust vertically than horizontally. Extra vertical power makes it easier to lift heavy objects, such as coral reef irrigation systems. Since the thruster orientation prioritizes vertical power, Beaumont has less power when moving horizontally. However, large amounts of horizontal thrust are unnecessary to complete the 2024 RFP, so this trade-off is well worth it. The pilot can also control how much power is allocated to the thrusters, allowing for faster and more powerful movements as well as slower and more careful movements.

Buoyancy and Ballast

Beaumont, while fully assembled, weighs approximately 159 N. This is counteracted by an upward buoyancy force of 95 N, so foam was required to achieve neutral buoyancy underwater. The largest buoyancy point is caused by air inside the 6-inch watertight enclosure located on the top of Beaumont's structure. It is strategically placed at the top to create distance between the center of buoyancy and the center of gravity. This separation distance helps stabilize Beaumont by creating moments to rotate it back to an upright position, as shown in Figure 16.

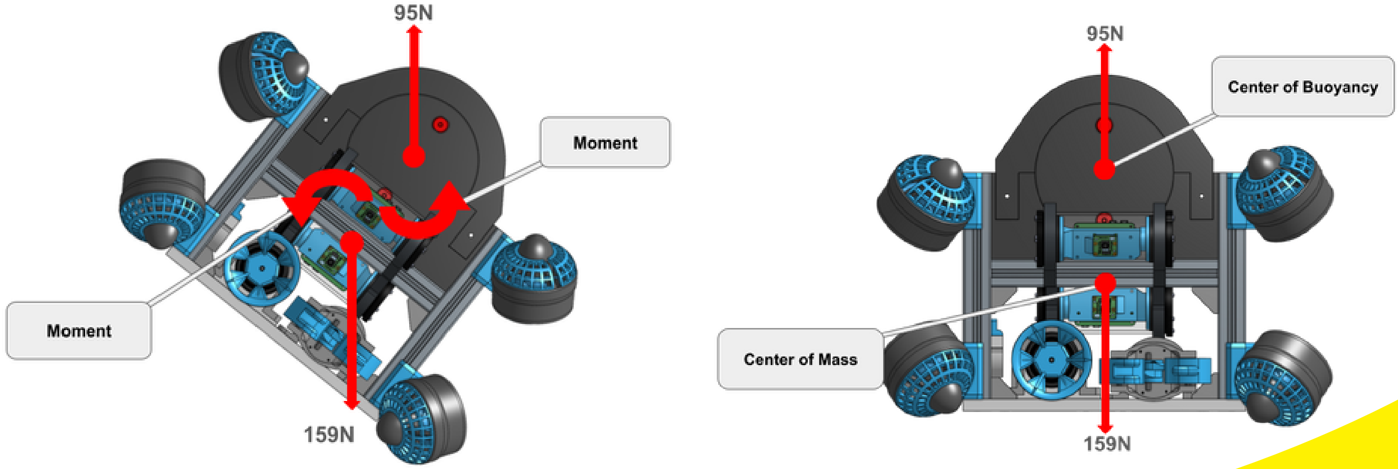

Figure 16: Beaumont Moment (left) and Center of Mass/Buoyancy (right), Mark Johnson, 2024

Payload and Tools

Cameras

In previous years, the company's choice of cameras had a narrow view, negatively affecting the pilot's ability to complete their mission effectively. Following EER's focus on user-centric design, the company brainstormed solutions and conducted market research to decide that the Raspberry Pi Camera Module 3 Wide would fix this problem. These cameras feature a new 120-degree wide-angle lens (*Figure 17*), greatly improving the pilot's field of view.

Beaumont features four cameras, which provide the pilot with all the views necessary to meet the RFP specifications. One camera is located inside the main enclosure and looks directly upwards. This camera makes it much easier to see targeted locations on the water's surface, such as the vertical profiler deployment region, recoverable floats, and moonpools. It additionally aids with not tangling the tether with any obstacles.

The rest of the cameras are located in individual waterproof tubes. One faces directly toward the tools, and another faces forward through the chassis to see what is in front of the vehicle. Two front-facing cameras give the pilot better depth perception, making it easy to perform precise tasks such as releasing recovery floats and deploying SMART repeaters. The final camera looks straight down and is used to scan and model coral restoration areas for autonomous modeling. It can also be rotated 90 degrees by the deck crew and used as a side-view camera.

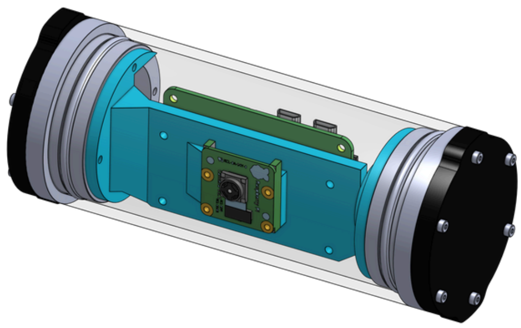

Figure 17: Beaumont Camera Tube, Mark Johnson, 2024

Sensors

Beaumont is equipped with a temperature probe to measure ocean temperatures to assess the accuracy of a newly placed SMART repeater. There is also an IMU used for the vehicle's positioning data used for autonomously transplanting brain coral.

Claw

Last year, EER designed a claw for the 2023 RFP. This claw used a 2” linear actuator and was waterproofed by enclosing it in an acrylic tube. The grippers of the claw were 3D printed from PLA plastic and curved so they could easily grab the cylindrical vertical profiler. The deck crew could manually rotate the claw to grab objects at different angles. It was mounted to the tooling skid, where the most mounting space was available.

The claw designed for the 2023 RFP was an effective tool, except for a design flaw that jammed the actuator. This caused the actuator to strip the screws that held the claw enclosure together, compromising the waterproof seal. The jamming problem damaged some parts of the acrylic tube enclosure, but the tube itself was reusable. For the 2024 RFP, the company’s goal was to innovate on the old claw’s design by fixing this problem. The new claw, Hamel, is a better-functioning tool that resourcefully reuses old design components (*Figure 18*).

Initially, the plan was to outsource the creation of flexible grippers that the actuator could stretch without causing permanent damage. Instead, it was decided that a small spring would be added to the mechanism. The spring design was inspired by the suspension systems of remote-controlled race cars, which use small springs to absorb forces and protect delicate parts. It was chosen as it could be manufactured in-house, unlike the flexible grippers.

The spring can stretch out when the actuator retracts to close the grippers (*Figure 19*). This allows the actuator to continue moving after it has grabbed an object, preventing it from jamming. The new claw design can once again be rotated manually by the deck crew, making it an innovative and versatile tool capable of completing multiple tasks, such as deploying SMART cables or transplanting coral samples.

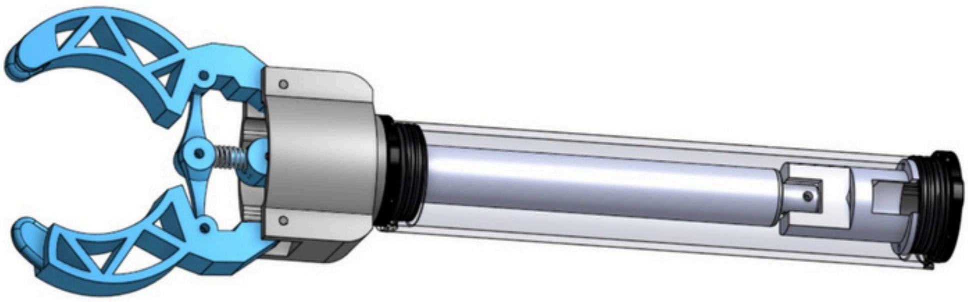

Figure 18: Beaumont Claw Render, Mark Johnson, 2024

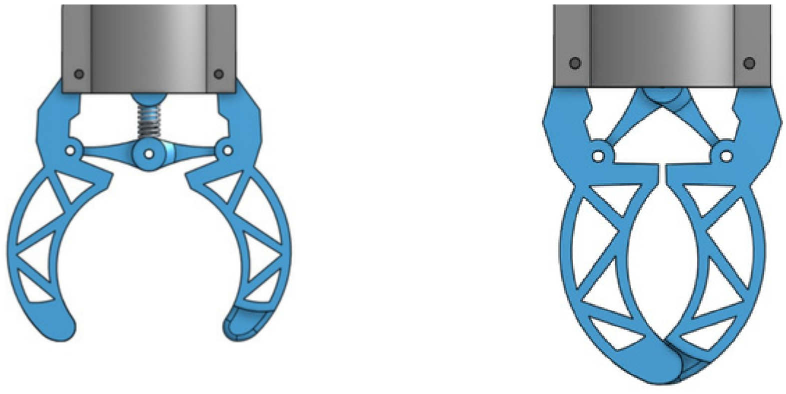

Figure 19: Claw Open (left) and Closed (right), Mark Johnson, 2024

Valve-Turning Tool

To complete the probiotic irrigation system deployment portion of the 2024 RFP, EER created a custom tool to turn the valve to activate the system. This tool rotates a custom 3D-printed socket featuring ridges that allow it to grip the edges of the valve for easier turning. Originally the tool was designed to be turned by a stepper motor. However, waterproofing the stepper motor in-house using epoxy was attempted, but determined to be unviable. More specifically, it was not possible to sufficiently seal the coils without getting epoxy on the motor's moving parts. For this reason, a waterproof bilge pump, which EER had in stock, was used instead.

The socket and bilge pump were attached to the tooling skid and tested on a model version of a real irrigation system. This version of the tool was able to complete the task successfully. However, it was found that because the socket covered the entirety of the valve, it was difficult for the pilot to see whether the valve had been turned. To fix this, the socket was redesigned with holes so that the pilot could see the valve turning when using the tool, making it much easier to complete the task. Additionally, the new socket uses less plastic, making it more economical to produce (*Figure 20*).

Figure 20: Valve Turning Tool Iterations, Mark Johnson, 2024

Vertical Profiler

The vertical profiler, Jonesy, is an ROV deployable observational device capable of tracking data while moving up and down in a water column (*Figure 21*). This year, a custom PCB was designed to allow the use of either a DC or stepper motor to operate a syringe-based variable buoyancy engine. 4 AA batteries power the device remotely with an operational time of up to 48 minutes before they must be replaced. During the operational time, Jonesy wirelessly communicates time elapsed, pressure, and depth data to the topside control station for analysis.

The cylindrical watertight enclosure was made by assembling a 3-inch acrylic tube with custom CNC-milled HDPE end caps. The decision to build this enclosure was better than buying commercially available options, as enclosures available from distributors such as Blue Robotics would have cost an additional $240 [2]. Also, a custom enclosure made it easier to create mounting points for the sensors, battery pack, and DC motor-syringe buoyancy system. This observational tool supports the United Nations Sustainability Goal #13, climate action, and Ocean Decade Challenge for collective impact #5, unlock ocean-based solutions to climate change.

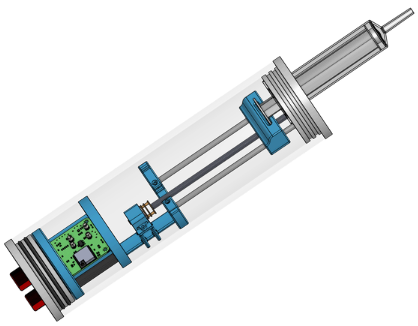

Figure 21: Vertical Profiler (Jonesy), Mark Johnson, 2024

Testing and Troubleshooting

EER recognizes the crucial value of testing and troubleshooting to create a quality product. These values lead to strict testing and troubleshooting protocols with all components and systems before integration. Independent testing of systems allows the company to find and resolve issues before they are integrated to streamline the troubleshooting process later.

Initial water testing was completed prior to the implementation of the electronics system to validate the viability of the vehicle structure. This tested Beaumont's leak resistance and avoided any potential safety risks or damage from exposing the electrical system to water. The initial test showed that the main electronics enclosure had a leak present, which would need to be fixed before the final assembly. Some techniques that helped to find this leak included visual and physical inspection of all penetrators and spraying the enclosure with soapy water to create bubbles from leaking air. This resulted in a loose penetrator being found and retightened to remove the leaking problem entirely.

All PCBs, motors, cameras, and other electrical components onboard Beaumont were tested individually to ensure all faults were properly addressed before final assembly. The assembled system was also tested prior to implementing the system in the ROV enclosure, as shown in Figure 22. This way, any potential damage to other components was limited to what was being tested, and problems could be addressed one at a time. While testing the first version of the Power Conversion Board, it was found that the DC-DC output was reversed, meaning it would need to be rewired for the electrical system to function properly. This error was found by testing individual sections on the board and comparing them to the design in KiCad, with the schematic shown in Figure 23. Thanks to the testing protocol, no major damages occurred to the ROV Control Board as the Power Conversion Board was fixed. The following revision of the Power Conversion Board addressed this issue.

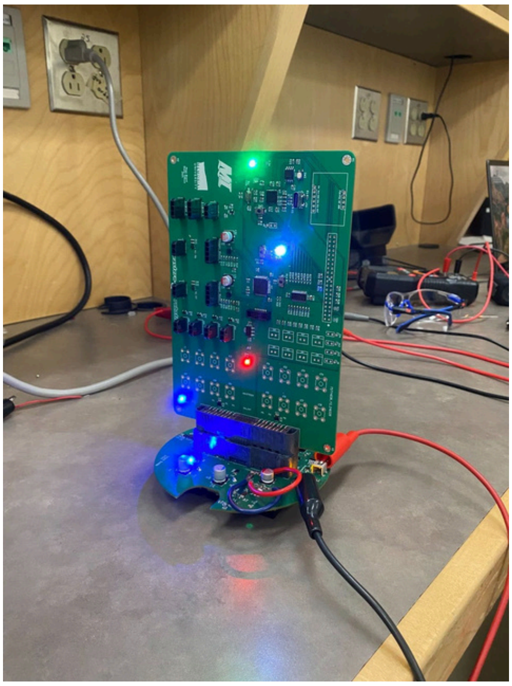

Figure 22: Testing Control Board, Evan Vokey, 2024

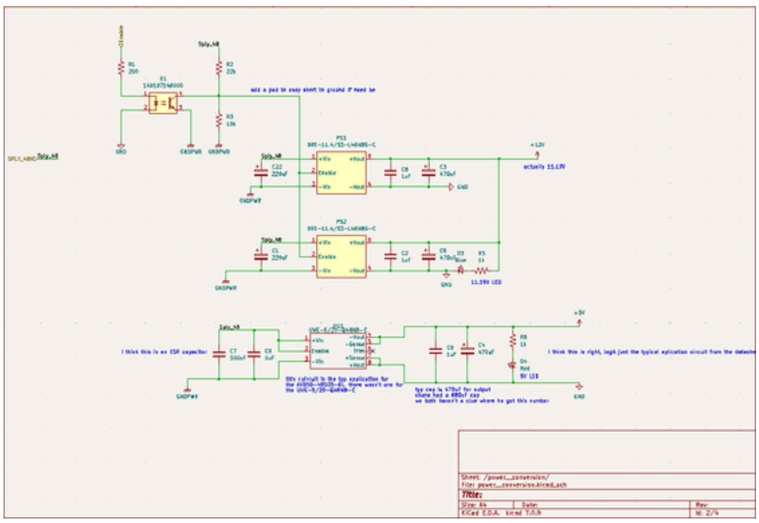

Figure 23: Control Board Schematic, Zach Bennett, 2024

An element that greatly reduced the required time for testing and troubleshooting for this year's RFP is the ROV simulation (*Figure 24*). The simulation was critical in developing software features for this year's RFP ahead of schedule, without the need to access Beaumont or an electrical system for testing. Some of the features include the development of the GUI, implementing an algorithm to compute thruster values with user input, and much more. This ability to both build the vehicle and test code in parallel cut hours of debugging once Beaumont was ready to be piloted.

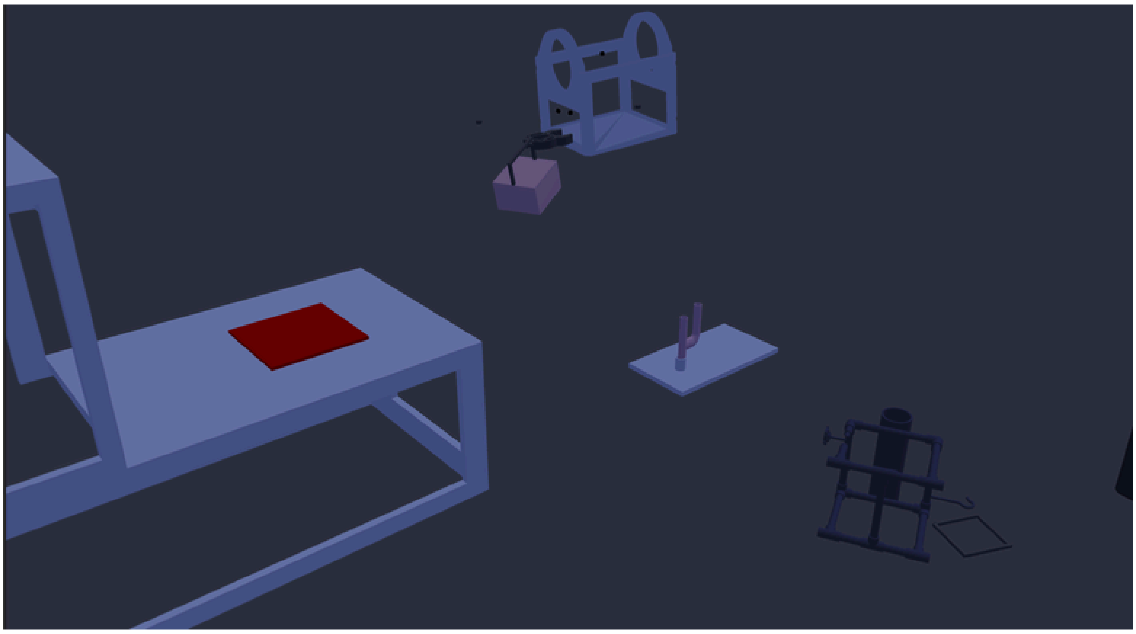

Figure 24: Beaumont in Simulator for Testing, Zaid Duraid, 2024

Safety

Safety is EER's top priority. To foster a culture that takes safety seriously and holds up the safety motto: "Nobody gets hurt," the Company has numerous policies in place that cover all situations employees may encounter. These procedures are implemented in a variety of mediums.

Safety Training

At the beginning of the year, the company's CSO reviews and demonstrates the company's custom safety forms and goes over general safety rules in the workshop (*Appendix B)*. Time is set aside for safety presentations throughout the year to teach the team about more specific safety situations, such as fire safety.

Junior employees are trained in using tools by their team leads or other senior employees as needed, allowing for supervised hands-on experience and immediate applications of safety lessons.

A safety training course must be completed to work out of the Student Design Hub (SDH) at Memorial University. EER encourages all employees to complete this, as many safety lessons still apply even when not working in the SDH.

Operational Safety

Before any hazardous work can begin, a Job Safety Analysis (JSA) form must be completed and submitted. They allow employees to determine a task's danger and encourage them to obtain proper safety equipment before the job begins. Each JSA is sent to the CSO directly so that they can review the data in case of a safety incident.

If a safety incident resulting in an injury or a “near-miss” were to occur, the Incident Report Form (IRF) would be used to track this incident. This would allow the team to review safety procedures and make necessary changes.

The unsafe work refusal form is a confidential form that employees can fill out if they have been asked to complete a task they feel unsafe. This form allows the CSO to investigate the job and determine if further action must be taken. This ensures a safe working environment for EER and a private way for employees to seek help if unsafe working conditions exist.

EER cares greatly about its employees' safety, so protocols have been developed to ensure that employees are safe when the ROV is being used, as seen in Figure 25. We have protocols for the assembly and disassembly of Beaumont. To ensure on-deck safety, there are pre and mid-operations checklists. To ensure compliance with the pre-operations checklist, users of Beaumont must complete it before accessing the GUI and taking control of the ROV.

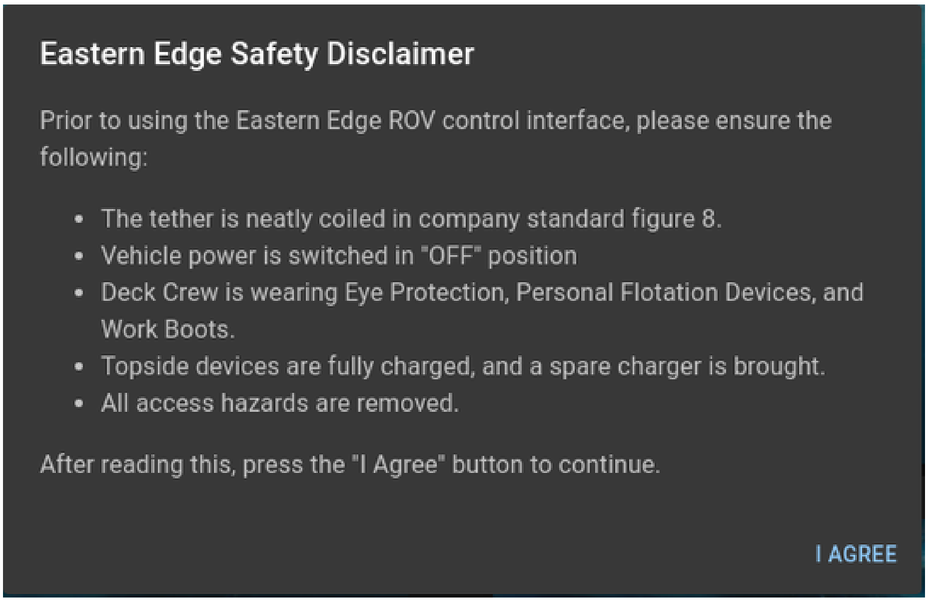

Figure 25: Safety Disclaimer, Zaid Duraid, 2024

Vehicle Safety

To ensure both the safety of employees and the safety of the environment, Beaumont is equipped with many safety features. Amongst all the safety features required for the 2024 RFP, some key features include hardware and software kill switches, thruster guards, no sharp edges, and warning labels on all power connections and moving parts.

Accounting

Budget

After the release of the RFP, a preliminary budget was developed by the CEO, COO, CIO, and team leads for the components and materials necessary to complete the contract. The initial proposed cost for the construction of Beaumont with added contingency was estimated at $2,555.99 USD. The cost breakdown in Appendix D includes the budgeted and expensed amounts for planned items. Administrative costs for registration, printing, uniforms, and long-term non-ROV equipment were estimated at $2,097.77 USD. The initial cost for travel to Kingsport was estimated at $28,146.45 USD (*Appendix D*).

Cost Accounting

After determining the budget for the 2024 RFP, Eastern Edge pursued an iterative design for Beaumont while utilizing available spare components to minimize costs for the project. EER remained within the allocated budget to produce Beaumont at a fair market value of $3,991.96 USD, as shown in Table 2.

ROV Fair Market Value			
		Price	Description
Electronics	Power Conversion System	$268.84	New
	ROV Control System	$123.17	New
	Networking Components	$88.15	New
	Onboard Computers	$113.09	New
	Visuals Subsystem	$212.74	New
	Tether	$42.56	New
	Electronics Total	**$848.55**	
Mechanical	Mech Hardware	$55.00	Reused
	Enclosure	$625.00	Reused
	80/20	$45.54	New
	HDPE	$49.87	In-Stock
	Mounting and Integrations	$50.00	New
	T-200	$1,600.00	Reused
	ESC's	$304.00	In-Stock
	Mechanical Total	**$2,729.41**	
Payload	Active Tooling Manupulators	$218.00	New
	Vertical Profiler	$186.00	New
	Other Required Tools	$10.00	Reused
	Payload Total	**$414.00**	
	Total	**$3,991.96**	

Table 2: Fair Market Value Table, Russell Corbett 2024

Acknowledgments

Eastern Edge would like to thank the following organizations for their monetary support in the development of Beaumont, travel expenditures to Kingsport, Tennessee, and; the MATE ROV Competition both regionally in Newfoundland and Labrador and internationally. ExxonMobil; Atlantic Canada Opportunities Agency; Department of Tourism, Culture, Industry and Innovation; Fugro GeoSurveys Inc; Hibernia Company Ltd; Crosbie Group Ltd; Husky Energy; Equinor; Marine Institute of Memorial University; Memorial University Faculties of Engineering, Humanities and Social Sciences and Science; Memorial University Technical Services; Memorial University of Newfoundland and Labrador Student Union; City of St. John's; RobotShop; Blue Robotics; CoLab Software; SubC Imaging; Subsea 7; InspectAR; Angler Solutions; Energy and Research Newfoundland and Labrador;

Eastern Edge would also like to thank the following organizations for donating software or material resources: GitHub and OnShape.

The Company extends a heartfelt thank you to our mentors Paul Brett, Joe Singleton, Anthony Randell, Shawn Pendergast, Chris Batten, David Drover, and Michaela Barnes for their time, administrative support, and unwavering encouragement, as well as to the MATE Center for making this all possible.

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[2] Osrf Why gazebo?- gazebo, https://classic.gazebosim.org/.

[3] Ros 2 documentation ROS 2 Documentation - ROS 2 Documentation: Humble documentation. https://docs.ros.org/en/humble/index.html.

[4] Watertight enclosures for underwater rovs, cameras, and sensors, https://bluerobotics.com/store/watertight-enclosures/wte-vp/.

Appendix A - Safety Checklist for Operations

ROV Operation:

Pre-Deployment:

- There is no damage to ROV
- All attachments and ballast is secured
- Enclosure is properly sealed with vent plugs inserted
- That the tether is neatly coiled in the figure eight pattern for easy use
- Those interacting with the ROV must ensure that the power switch starts in the OFF position.
- Deck crew must wear eye protection, a personal flotation device (PFD) and steel toe boots to use the ROV.
- There is no water or risk of shorts in control area
- Employees must check to ensure that the topside laptop is fully charged, and a charger is available.
- All topside electronics are properly setup and powered
- Employees shall identify any hazards that must be removed from the workspace and address these issues before work can begin.
- If an air compressor is being used, it must be checked to ensure that everything is connected correctly.
- ROV is placed in water
- Power on is called, bot is powered on with controls disabled
- Hands off is called by deck crew and deck crew remove hands, and piloting may begin

Mid-Run ROV Handling:

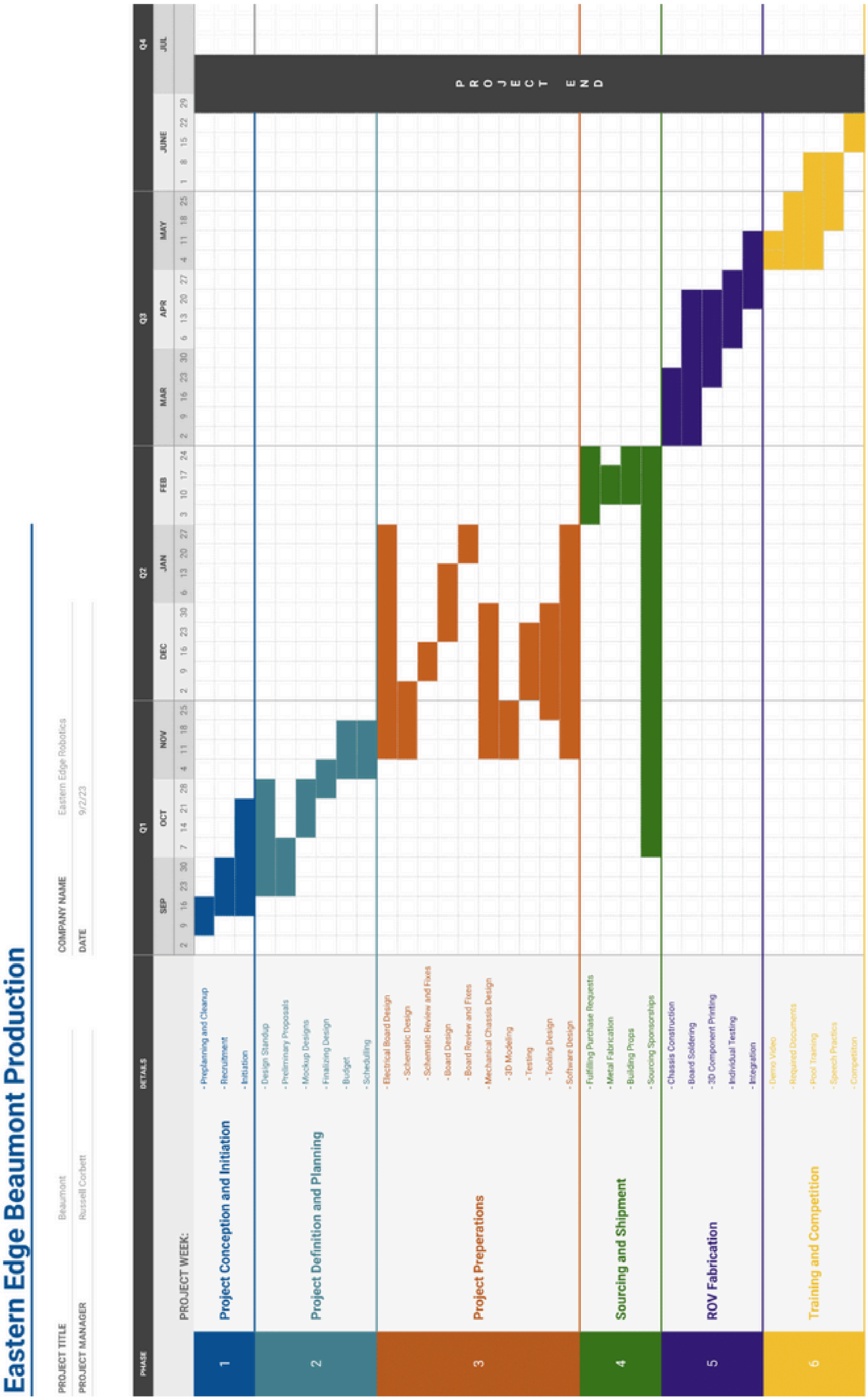
- Surface is called by Deck crew once ROV is visible in moonpool
- Safe is called by pilot once controls are disabled
- Hands on is called by deck crew once contact is made with ROV

Appendix B - Safety Checklist for Construction

Lab Safety Regulations

- Safety Gear Requirement: All individuals entering the shop must wear appropriate safety gear, including but not limited to safety glasses, closed-toe shoes, and hearing protection where necessary.
- Job safety analysis (JSA): Before any hazardous work can begin employees must complete a JSA to log the work and make sure they are prepared to begin.
- Tool and Equipment Training: Before using any equipment or tools, students must undergo proper training on their usage, safety procedures, and maintenance.
- No Unauthorized Modifications: Employees are not allowed to modify or tamper with any equipment, tools, or safety features without authorization from the instructor.
- Cleanliness and Organization: Employees are responsible for maintaining a clean and organized workspace. Tools must be returned to their designated places after use, and work surfaces should be kept clear of clutter.
- No Horseplay or Running: Horseplay, running, or any behavior that could endanger oneself or others is strictly prohibited in the shop area.
- No Food or Drink: Eating, drinking, or chewing gum is not permitted in the shop area to prevent contamination of tools, equipment, or work surfaces.
- Emergency Procedures: Employees must familiarize themselves with the location of emergency exits, fire extinguishers, first aid kits, and other safety equipment. They should also know the procedures to follow in case of an emergency.
- Report Accidents or Hazards: Any accidents, injuries, or hazards must be reported immediately to the CSO through IRF.
- Respect for Equipment and Others: Employees must treat all equipment, tools, and fellow students with respect. Rough handling of equipment or disrespectful behavior towards others will not be tolerated.
- Personal Protective Equipment (PPE): PPE such as gloves, aprons, or respirators must be worn when working with hazardous materials or processes, as specified by the instructor.
- Restricted Areas: Certain areas of the shop may be restricted to authorized personnel only. Employees should adhere to these restrictions and seek permission before entering such areas.
- Prohibited Activities: Certain activities such as welding, grinding, or machining may have specific safety requirements and usage guidelines. Employees must adhere to these guidelines and obtain proper authorization before engaging in such activities.

Appendix C - Project Schedule



Appendix D - Budget Table

Eastern Edge Robotics Budget 2024				
Description		Procurement Method	Budgeted USD	Expenses USD
Electrical Expenses	Power Conversion Subsystem	New	$400.00	$399.22
	ROV Control Subsystem	New	$200.00	$191.28
	Networking Components	New	$90.00	$88.15
	Onboard Computers	New	$113.09	$113.09
	Visuals Subsystem	New	$190.32	$212.74
	Electrical Budget+Contingecy & Expenses Total :		**$1,092.75**	**$1,004.48**
Mechanical Expenses	Mech Hardware	New	$440.88	$442.06
	Enclosure	Reused	$164.47	$164.47
	80/20	New (Sponsored)	$50.00	$45.54
	HDPE	In-Stock	$49.87	$0.00
	Mounting and Integrations	New	$225.00	$207.14
	T-200	Reused	$0.00	$0.00
	ESC's	In-Stock	$0.00	$0.00
	Non-Bugeted Items	N/A	$0.00	$0.00
	Mechanical Budget+Contingecy & Expenses Total :		**$1,023.24**	**$859.21**
Payload Expenses	Active Tooling Manupulators	New	$250.00	$234.99
	Vertical Profiler	New	$150.00	$145.78
	Props for Testing	In-Stock	$0.00	$0.00
	Other Required Tools	In-Stock	$0.00	$0.00
	Payload Budget+Contingecy & Expenses Total :		**$440.00**	**$380.77**
Administration Expenses	Competition Registration	New	$450.00	$450.00
	Printing	New	$300.00	$176.35
	Website Fees	New	$40.00	$23.51
	Open House	New	$88.18	$85.56
	Poster Printing	New	$46.85	$40.74
	Fluid Power Quiz	New	$25.00	$25.00
	Shirts/Polos	New	$734.81	$703.95
	Non-Budgeted Items	New	$222.22	$0.00
	Administrative Budget+Contingecy & Expenses Total :		**$2,097.77**	**$1,505.11**
Travel Expenses	Flights (15 people)		$8,817.69	$8,745.24
	Accommodations (8 rooms, 8 nights)		$11,756.93	$9,311.08
	Vehicle Transports		$2,571.83	$2,863.33
	Misc Travel		$5,000.00	$0.00
	Travel Budget & Expenses Total:		**$28,146.45**	**$20,919.65**
Taxes and Shipping Expenses	**Shipping Costs Budgeted & Expensed**		**$444.44**	**$405.30**
	Taxes Budgeted & Expensed		**$691.59**	**$579.98**
Total Budgeted & Expensed:			**$33,936.24**	**$25,654.50**
Total ROV Budgeted+Contigency & Expenses (Not including props for testing):			**$2,555.99**	**$2,244.46**

Appendix E - System Integration Document