

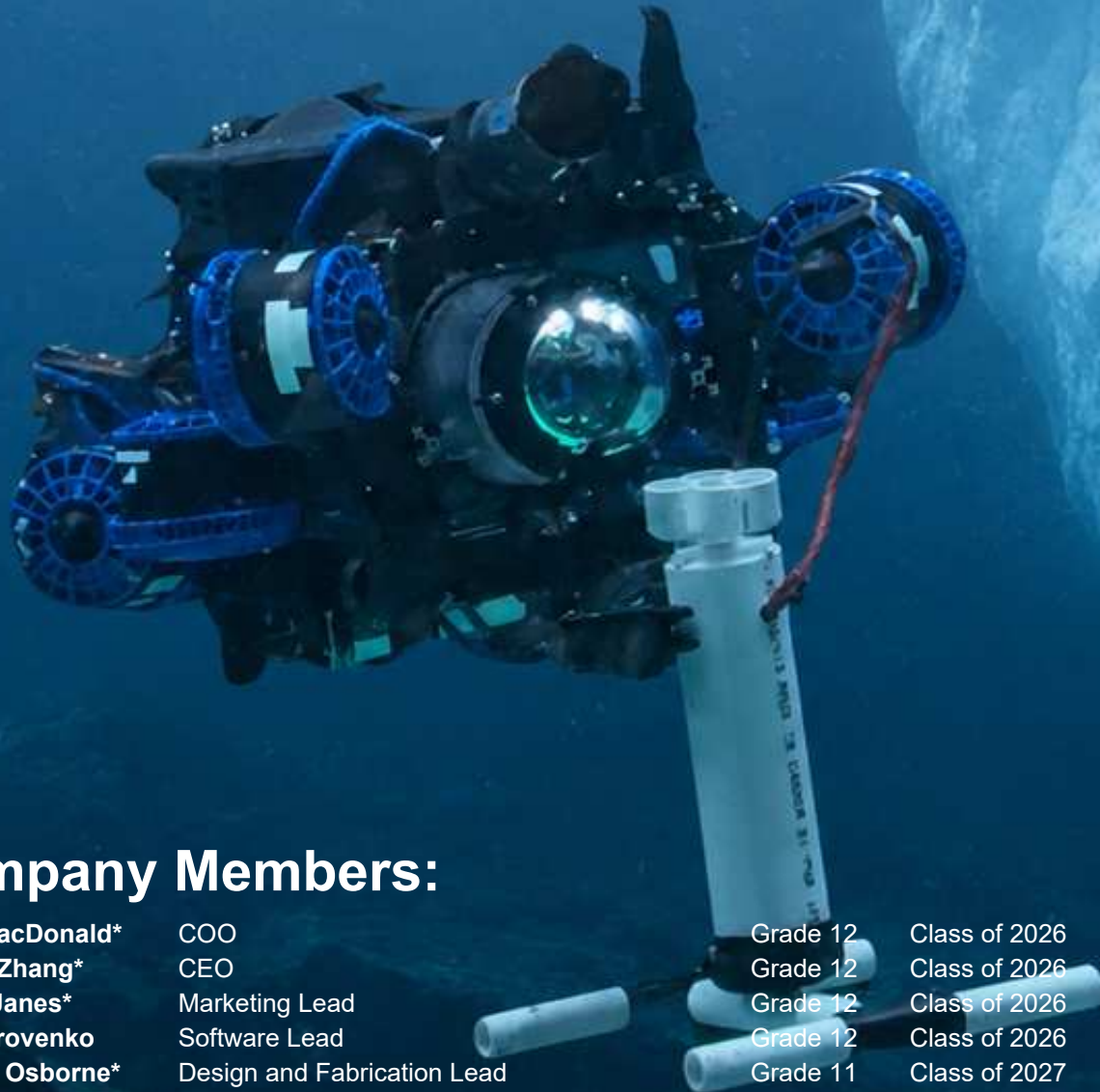


HEART Innovators

Holy Heart of Mary High School

St. John's, Newfoundland and Labrador, Canada

Technical Report



Company Members:

Noah MacDonald*	COO	Grade 12	Class of 2026
Sophia Zhang*	CEO	Grade 12	Class of 2026
Abbey Janes*	Marketing Lead	Grade 12	Class of 2026
Vlad Yarovenko	Software Lead	Grade 12	Class of 2026
Michael Osborne*	Design and Fabrication Lead	Grade 11	Class of 2027
Nathan Stanley	Design and Fabrication Assist (Safety Officer)	Grade 10	Class of 2028
Nolan Ash	Software Assist	Grade 12	Class of 2026
Joseph Ye	Software Assist	Grade 11	Class of 2027
Nash Billard	Design and Fabrication Assist	Grade 12	Class of 2026
Zac Mallet	Design and Fabrication Assist	Grade 10	Class of 2028
Musab Ahmed	Design and Fabrication Assist	Grade 10	Class of 2028
Noura Elfeki	Design and Fabrication Assist	Grade 10	Class of 2028
Vidya Chedella*	Marketing Assist	Grade 11	Class of 2027
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* - Returning Members

Mentor:

Mr. Cole Murphy



TABLE OF CONTENTS

1. Abstract	3
2. Project Management	4
A. Company Overview	4
B. Company Organization	4
C. Operational Challenges	5
3. Design Rationale	7
A. Planning and Design Process	7
B. Systems Approach	8
C. Vehicle Structure	8
4. Vehicle Systems	9
A. Electrical System	9
B. Topside Control System	9
C. Pneumatic	10
D. Tether and Tether Management	10
E. ROV Software Design	11
F. Propulsion	12
G. Buoyancy and Ballast	12
5. Mission Payload, Tools, & Build Logic	13
A. Optical Network	13
B. Specialized Tooling	13
C. Vertical Profiling Float	15
D. Build vs Buy, New vs Used	16
6. Safety	18
A. Safety Rationale	18
B. Personnel Safety	18
C. Equipment Safety	18
D. Operational Safety	18
7. Critical Analysis	19
A. Vehicle Testing Methodology	19
B. Propulsion Testing	19
C. Pneumatics Testing	20
D. Vertical Profiler Testing	20
E. Troubleshooting	20
8. Budget and Accounting	21
A. Budget	21
B. Project Cost	21
9. Acknowledgements	22
10. References	22
11. Appendices	23



1. ABSTRACT

HEART Innovator's is based in St. John's, Newfoundland and Labrador, Canada, and is a leading innovator of underwater Remotely Operated Vehicles (ROVs). For the 2026 MATE ROV Competition, HEART Innovators designed and built *The Great Eastern*, an ROV engineered for durability and maneuverability across diverse aquatic environments, from iceberg-filled waters to rugged coastlines and the deep sea.

To meet the competition's mission requirements, *The Great Eastern* is equipped with a pneumatic rotating claw for precise manipulation tasks, a vertical profiler, and a recovery line to pick up seafloor structures. These components were meticulously designed using Onshape and fabricated through 3D printing, ensuring functionality.

Safety is a fundamental aspect of HEART Innovator's operations. A Safety Officer oversees adherence to strict safety protocols. While the CEO and COO meticulously plan and schedule tasks, ensuring all team members coordinate and work efficiently.

The Great Eastern is designed to perform a wide variety of tasks in harsh aquatic environments, iceberg-riddled Arctic waters, rugged coastlines, and delicate ecosystems. These tasks encompass servicing a subsea observatory, recovering a buoy anchor, mitigating invasive species, and collecting coral samples. Additionally, *The Great Eastern* is equipped to monitor fragile underwater ecosystems and assess iceberg risk levels, aligning with the competition's focus on exploration in harsh marine environments.



Back row (left to right): Joseph Ye, Vidya Chedella, Nolan Ash, Nash Billard, Vlad Yarovenko, Amina Kydykova, Michael Osborne

Front row (left to right): Musab Ahmed, Nathan Stanley, Sophia Zhang, Noah MacDonald, Abbey Janes, Zac Mallet



2. PROJECT MANAGEMENT

A. Company Overview

HEART Innovators is a fourth year, student-run company that is “Driven by Passion, Building with the Heart.” This year, our company is made up of 14 members, all dedicated to engineering, underwater exploration, and conservation.

As the Company’s needs evolved, returning employees remained in their previous roles, while new members were assigned positions that aligned with their skills and interests. Each meeting starts with a full-team briefing to review objectives, responsibilities, and upcoming tasks. Progress is tracked through shared Google Documents, whilst communication is maintained through Google Classroom and Discord, allowing quick and effective communication between different departments. This system creates an organized and supportive environment that encourages collaboration and innovation.

B. Company Organization

We assign roles based on individual strengths, with leadership from our CEO, Sophia Zhang, and COO, Noah MacDonald, who are in their third and second year with the team, respectively. To maximize efficiency within the company, we have split all members into three groups according to their roles:

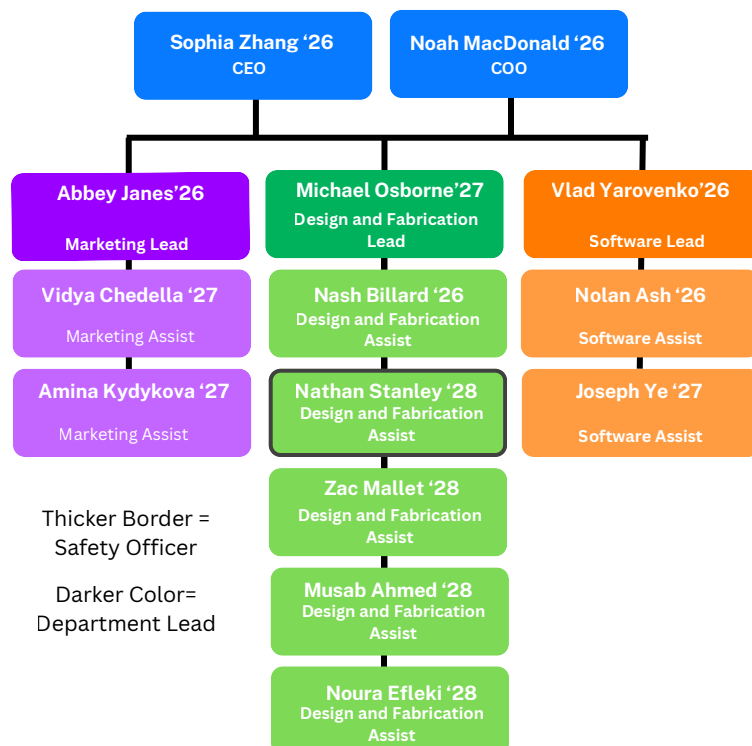


Figure 2: HEART Innovators Company Organization

The Software department is led by Vlad Yarovenko. This department's primary role is to code our ROV and the Float. They are responsible for ensuring the “brain” of our ROV can perform data collection, subsea exploration, and other underwater tasks appropriately.

The Design and Fabrication department is led by Michael Osborne. This department is responsible for constructing and testing the ROV’s tools and parts. They ensure designs are both functional and visually appealing.

The marketing department is led by Abbey Janes. This department manages all HEART Innovators documentation, marketing display, and social media activities to promote MATE and our company to the public and local community.



C. Operational Challenges

The HEART Innovators team **prioritizes organization and time management** throughout the competition season. The team meticulously established deadlines and prioritized tasks to effectively balance various components of the MATE ROV competition, encompassing vehicle construction, mission preparation, technical documentation, presentation development, and outreach initiatives, as shown in Figure 3. By addressing key tasks, the team was able to allocate additional time for testing, redesigns, troubleshooting, and practice runs. Regular team meetings and interdepartmental communication through Discord and Google Classroom facilitated progress tracking and efficient problem-solving.

One of the **primary operational challenges** faced by HEART Innovator was a notable knowledge gap within the team, as only 5 out of 14 members had returned from the previous season. This situation necessitated a considerable investment of time to train new members on design processes, fabrication techniques, and competition expectations, which initially impeded early development and decision-making. Another significant limitation was the restricted access to appropriate testing facilities.

It was difficult for us to book local underwater tanks to test our ROV. To solve this problem, we were incredibly grateful that one of the Design and Fabrication members, Nathan Stanley, generously enabled us to test our ROV in his backyard pool. Additionally, we were able to roughly test our float's functionalities in a large garbage bin filled with water.

Despite these constraints, HEART Innovators used structured training sessions, mentorship between returning and new members, and iterative prototyping to ensure steady progress and the successful completion of the ROV within competition timelines.

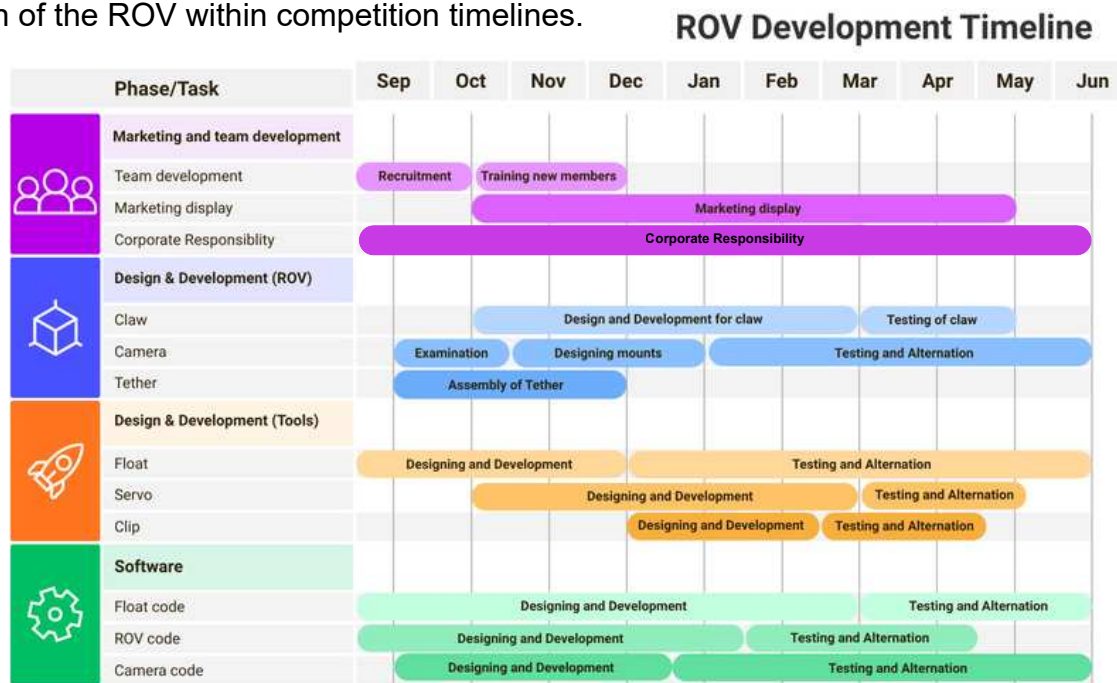


Figure 3: HEART Innovators Company Timeline

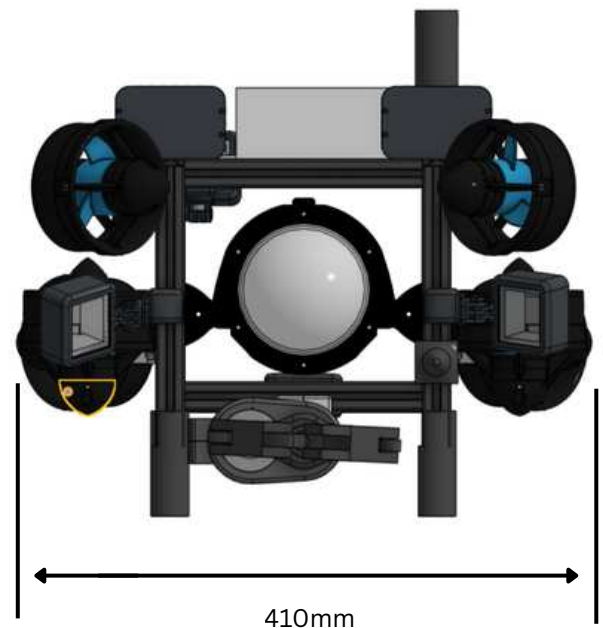
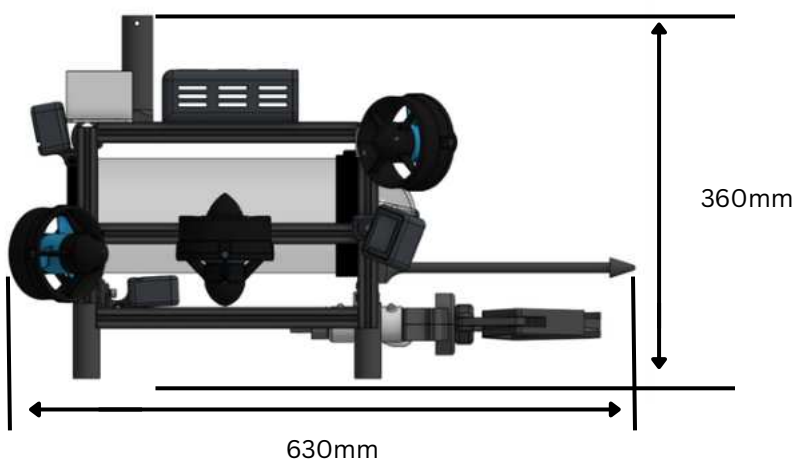
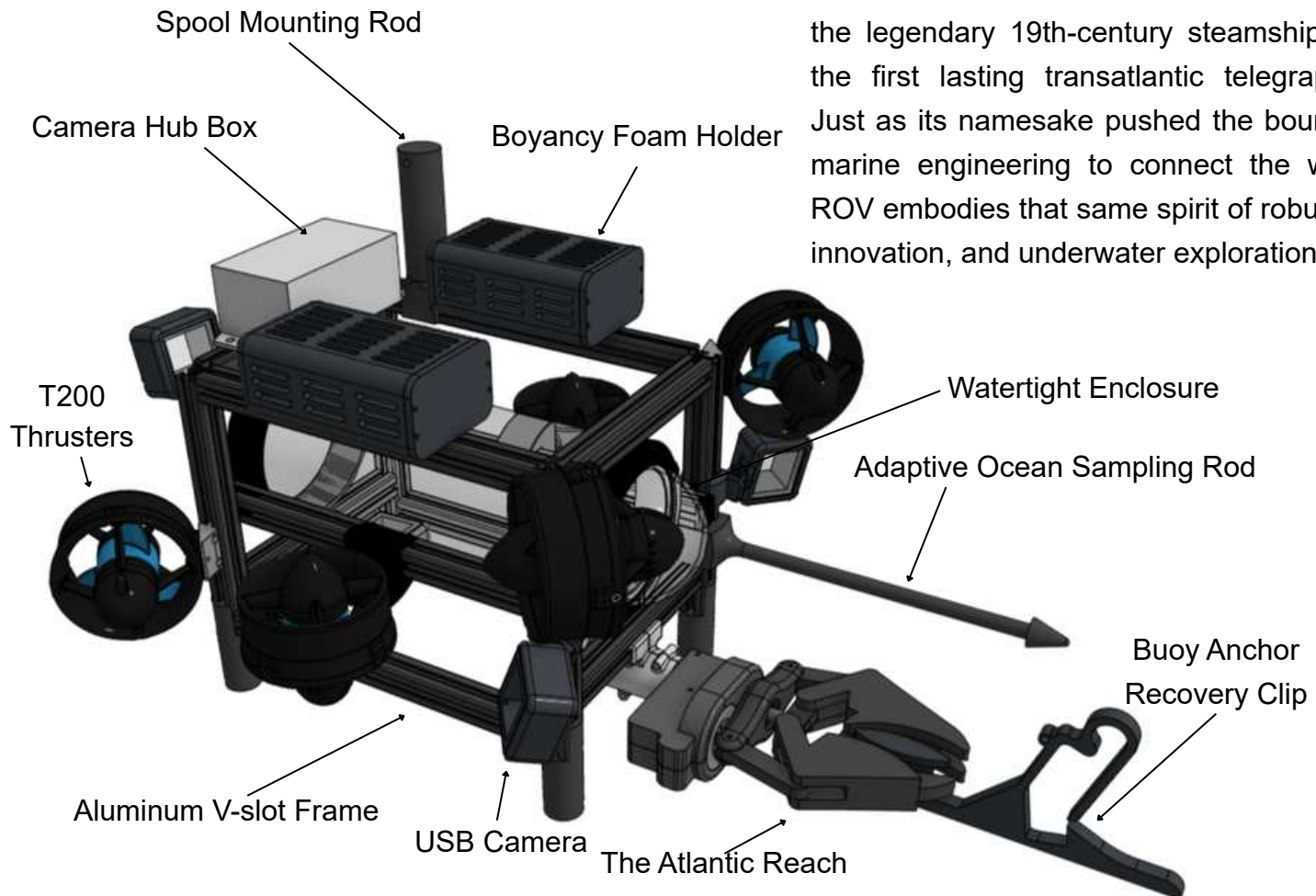




THE GREAT EASTERN

Design Overview

Our ROV is named after the *SS Great Eastern*, the legendary 19th-century steamship that laid the first lasting transatlantic telegraph cable. Just as its namesake pushed the boundaries of marine engineering to connect the world, our ROV embodies that same spirit of robust design, innovation, and underwater exploration.



3. DESIGN RATIONALE

A. Planning and Design Process

The Great Eastern is a modular, customizable, and compact ROV designed to meet the needs of MATE's Request for Proposals (RFP) and support the United Nations Sustainable Development Goals. Our vehicle was designed to focus our efforts on the most important parts, ensuring efficient task execution and meeting mission standards in the MATE competition.

A major consideration during the development process was reusing components from our previous vehicle to maximize our efficiency, and making improvements or developing new parts. With limited resources due to the high costs of advanced tools on the market, we maximized high-performance output throughout the design process without financial burden.

Our design process for **problem solving** followed a structured **step by step** design process conducted through iterative brainstorming, prototyping, testing, and evaluation:

1. Identify the Problem: We ensured to address the ongoing issues that arise in completing MATE's mission tasks.

2. Collaborate and Brainstorm Solutions: Once problems were found, team members prioritized collaboration within and between departments. Issues were first discussed within the department most directly involved, where members brainstormed possible solutions and shared different perspectives. Ideas were evaluated based on functionality, reliability, and affordability. To ensure each solution supported the overall advancement of the ROV and the smooth integration of subsystems, department leads facilitated consultations with other departments to gather additional feedback and insight. The department leads could additionally discuss with other leads to make final decisions on whether a design should move forward.

3. Innovate and Design: Members began the prototyping process based on the solution that was determined. During the design process, the team considered factors such as efficiency, reliability, affordability, and ease of integration with other subsystems. Other members could provide constructive feedback throughout this process to refine prototypes before they are tested.

4. Assemble and Test: The finalized design was physically constructed and tested. Areas for improvements are discussed among members who designed the prototype, and iterative design is continued until the best performance is achieved.

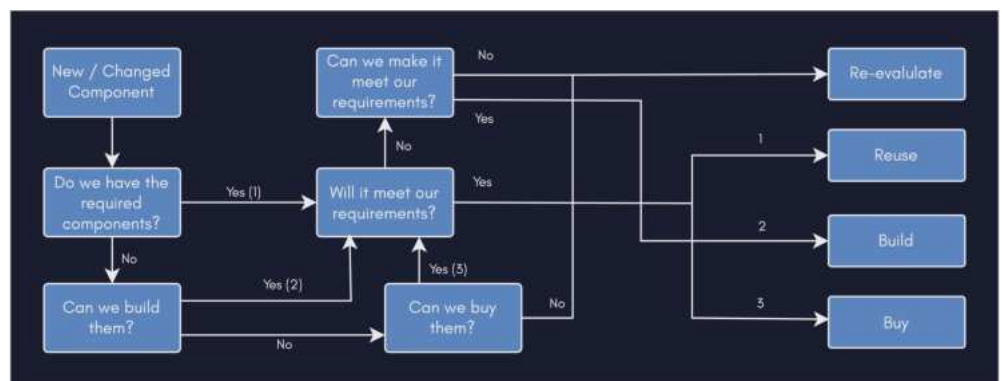


Figure 4: Decision Matrix for Build vs. Reuse vs. Buy



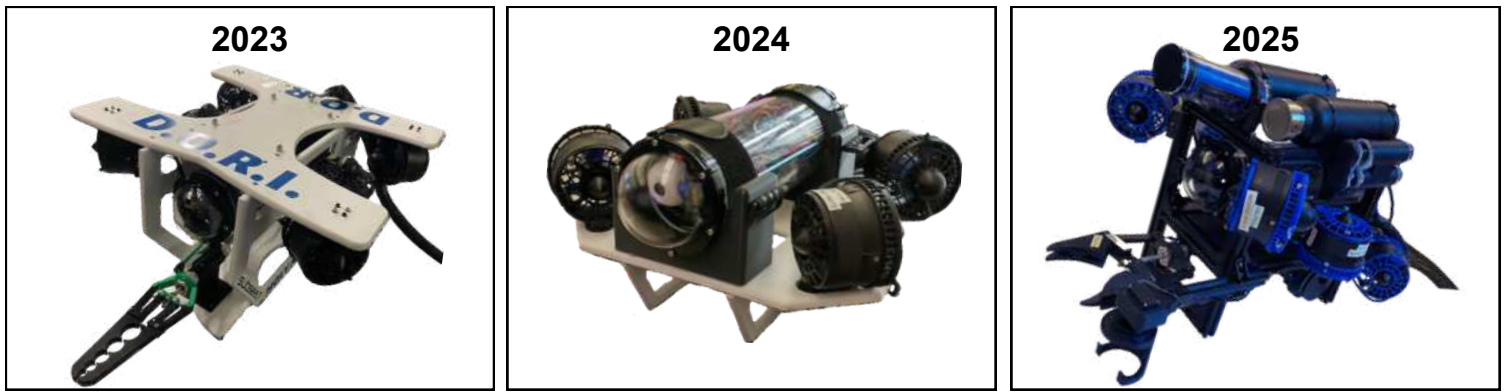


Figure 5: Design Evolution of The Great Eastern

B. Systems Approach

HEART Innovators approaches every design decision with functionality and simplicity in mind, ensuring customers receive the best product possible. The HEART Innovators design team has dedicated hundreds of hours to developing the final design of *The Great Eastern*, balancing the trade-offs between the various onboard systems and tools on the ROV. The team identified **three essential systems** crucial to the ROV's success: propulsion, vision, and pneumatics. Each system was fully integrated into the ROV's frame to ensure *The Great Eastern* could successfully meet the requirements of the 2026 MATE ROV RFP.

C. Vehicle Structure

As mentioned in the design evolution, HEART Innovators has constructed *The Great Eastern's* frame out of V-slot aluminum. **This decision was based on several factors**, including cost, availability, density, practicality, and past success. These considerations are outlined in the decision matrix in Table 1.

V-slot aluminum, despite being denser than plastic, was chosen for its structural and modular applications. It allows the ROV to remain durable in situations where high pressure may be applied to the frame and facilitates the attachment of modular components and tools.

The frame's dimensions - 25 cm in length, 12 cm in width, and 16 cm in height - were meticulously chosen to enhance maneuverability in confined underwater environments, such as coral reefs. This compact design facilitates agile navigation and precise control. Additionally, the lightweight construction ensures the ROV weighs under 10 kg, aligning with MATE's mission proposal preference for lighter vehicles. Moreover, V-slot aluminum imparts a professional, polished appearance to *The Great Eastern*.

Material	Availability	Density g/cm ³	Cost per Meter(USD)
V-slot aluminum	Order	1.25g/cm ³	\$20.95
½ PVC Pipe	Local	0.80g/cm ³	\$10.00
½ Foamalux	Order	0.65g/cm ³	\$14.54

Table 1: Decision Matrix for Frame Materials



4. VEHICLE SYSTEMS

A. Electrical System

The Great Eastern’s electronic system was engineered with functionality, modularity, expandability, and ease of maintenance as primary design considerations. At the centre of the system is a Raspberry Pi 4B, which controls communication between the ROV and the topside control station while managing the transmission of sensor data. To support the vehicle’s electrical architecture, the team designed a custom printed circuit board (PCB) **tailored specifically to the ROV’s operational requirements**. The PCB features I²C ports for sensor integration, eight PWM outputs for thrusters and servos, dedicated power distribution ports, and a GPIO breakout section to accommodate future expansion. To improve usability and servicing, a printed reference table and team branding were incorporated directly onto the PCB.

All onboard electronics are housed within a Blue Robotics 4-inch watertight enclosure, with cable penetrations sealed using epoxy-potted penetrators to ensure reliable waterproofing and a clean, professional internal arrangement. The primary enclosure contains the core electronic components, including the Raspberry Pi 4B, six Electronic Speed Controllers (ESCs), a network switch, the primary camera system, the power distribution system, and the custom PCB.

A secondary 4" × 3" aluminum electronics enclosure contains the USB extension hub, which interfaces with four task-specific USB cameras to provide enhanced visual coverage during mission operations. This auxiliary enclosure allows the camera system to be easily expanded or reduced while transmitting all video feeds to the topside computing system through the primary tether Ethernet connection via the onboard Gigabit Ethernet switch. The switch manages the three required Ethernet connections while also providing additional network capacity, enabling future system expansion without increasing the number of cables within the tether.

B. Topside Control System

The Great Eastern’s topside control system is **engineered to permit fast and reliable setup**, minimizing delays before operation. Contained within a protective Pelican case, the control box includes a simple separation of the main control laptop and other electrical components using a custom CNC cut piece of PVC sheeting. The main Ethernet line from *The Great Eastern* is connected to our topside control system via Ethercon connectors, ensuring reliable, secure data connections.



Figure 6: 3D Render of The Great Eastern’s Custom PCB

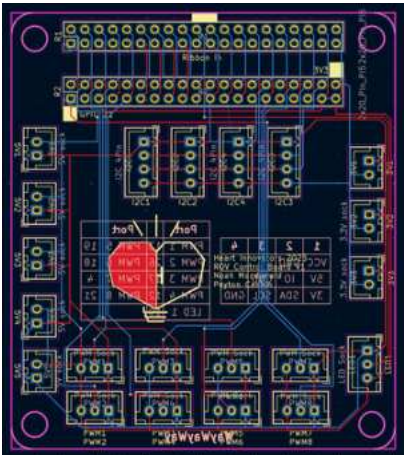


Figure 7: Custom PCB Layer View

	Max Speed	Required Twisted Pairs	Extra Hardware
Gigabit Ethernet	1000 Mbps	4	None
Fast Ethernet	100 Mbps	2	None
BR Fathom-X	60-80 Mbps	1	Media Converters
Automotive Ethernet	1000 Mbps	1	Media Converters

Figure 8: Networking Specification Comparison



Control Interface: The ROV’s six thrusters are controlled by a standard console-style game controller. This provides a large number of programmable buttons and permits precise movement control.

Integrated Triple Monitors: The top of our control box houses a triple-monitor setup that can be connected to any laptop. These monitors, in addition to the laptop's original screen, offer the viewing area required to effectively monitor the ROV and its surroundings.

Pneumatic Claw Control: The control valve for our pneumatic claw is located outside of the protective casing. This valve enables precise psi regulation and straightforward control of the claw.



Figure 9: Control Valve



Figure 10: Controller



Figure 11: Control Box

C. Pneumatic System

The *Great Eastern’s* pneumatic systems integrate two 15m-long polyethylene pneumatic lines rated at 125 PSI, a pneumatic piston, a pressure control valve, and an air compressor. The compressor is connected to the control valve, which is set to MATE standard 40 PSI. The control valve then drives the claw piston through the pneumatic lines running through the tether. These lines are locked in place and can be easily detached through push-connectors on the control valve. This system enables easy assembly and clean-up and allows the Pilot to open and close the claw as needed.

D. Tether and Tether Management

The tether connects the topside control systems to the ROV. *The Great Eastern* has a 15m neutrally buoyant tether consisting of one Cat6 Ethernet cable for data transfer, two pneumatic airways for control of our manipulator, and 14 AWG wire for power transmission with minimal voltage drop. A protective mesh covering keeps wires and tubing from being damaged or tangled. To maintain neutral buoyancy, small pieces of PE foam are wrapped in half-meter increments on the outside of the tether to prevent it’s weight from affecting the ROV’s maneuverability while operating.

The HEART Innovators deck team understands the importance of good tether management during mission operations. Our team’s Pilot and Deck Manager has developed an efficient system for managing the tether during product demonstrations. This system assigns two designated Tether Managers, who are interchangeable in completing tasks and controlling the amount of tether on the deck, while maintaining communication with the Pilot. This minimizes tripping hazards, entanglements, and potential damage to both the ROV and tether.

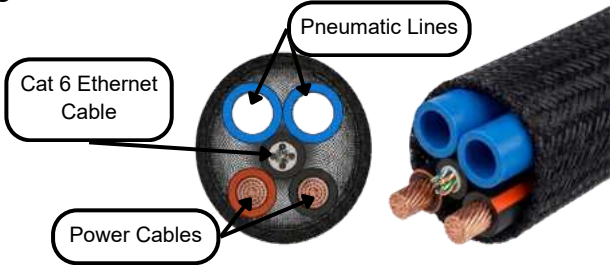


Figure 12: Tether Diagram

	Voltage Drop
I = 25A	V = IRL
R = 0.008286Ω/m	V = (25)(0.008286) (15)
L = 15m	V = 3.12V Drop

Figure 13: Voltage Drop Calculations



E. ROV Software Design

The Great Eastern’s **software architecture** utilizes a custom built graphical user interface within the topside terminal to enable comprehensive remote control of the ROV and its payload peripherals. Within this network framework, low-level communication protocols establish the command link between the subsea Raspberry Pi 4B and the surface control station, while specialized hardware pin mapping libraries manage internal components wired to the microprocessor.

To maximize thrust within strict amperage limits, the team used T200 current-draw and performance charts to calibrate precise motor PWM values. The **main advantage** of this architecture is that it enables operators to adjust thruster PWM limits, change mission-specific servo velocities, and modify real-time camera settings directly via the topside GUI, eliminating the need to access the subsea Raspberry Pi 4. However, the **primary limitation** is that this setup depends entirely on a stable network link; any sudden drop in connection stability can introduce latency into pilot drive commands and video streams.



Figure 14: ROV Graphical User Interface

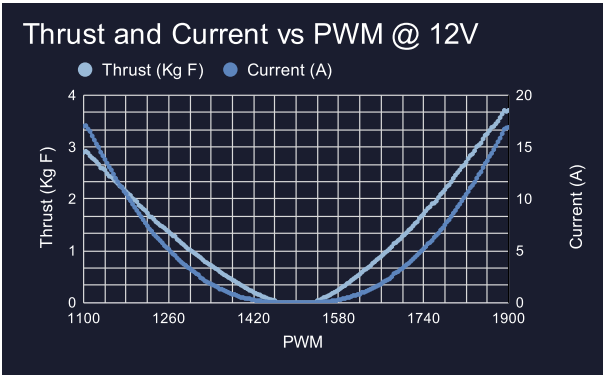


Figure 15: Thruster Thrust vs Current

To ensure software integrity, the team used a **GitLab repository for version control** to track changes, enabling rapid fault isolation by pinpointing the revisions that caused system instability. **Our testing methodology** combined dynamic and static analysis to evaluate real-time behavior alongside manual code reviews to optimize execution.

To enhance **system performance**, a linear interpolation algorithm was integrated into the flight loop, guaranteeing smooth velocity transitions and mitigating transient mechanical stresses on the thruster assemblies during rapid acceleration. Finally, to optimize **operator performance**, the topside interface features native joystick integration, translating intuitive analog inputs into precise directional drive vectors, simplifying vehicle control.

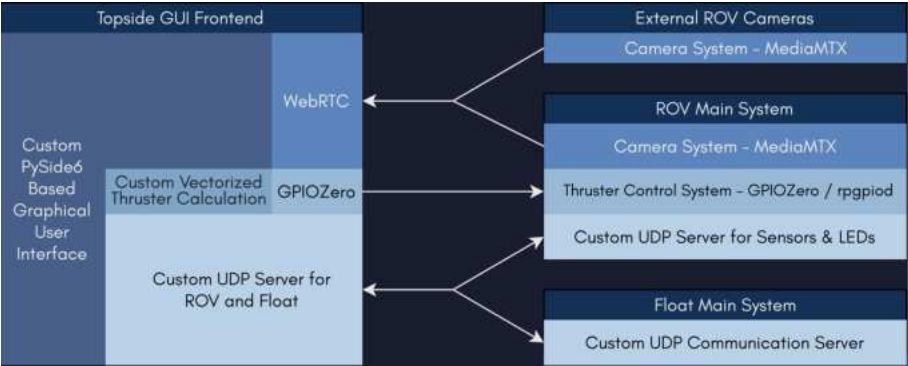
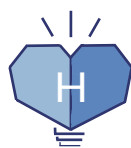


Figure 16: Software Flowchart



F. Propulsion

The *Great Eastern's* propulsion system uses **six Blue Robotics T200 12V thrusters**, each producing approximately 3.71 kg of thrust. The thrusters were strategically positioned to maximize stability, maneuverability, and control while enabling the ROV to achieve full **six-degree-of-freedom (6DoF)** motion with 6 motors. This allows the vehicle to perform surge, sway, heave, roll, pitch, and yaw movements for precise underwater operation in an efficient manner. Each thruster is shrouded to IP2X motor safety standards to ensure safety during operation.



Figure 17: Thruster Placement

An initial four-thruster configuration was tested; however, it limited the ROV's maneuverability and rotational control. To overcome this, two additional thrusters were added. Two thrusters are mounted vertically to control upward and downward movement, while the remaining four are mounted at 45° angles on each corner of the frame, as shown in Figure 17. This configuration enables efficient omnidirectional movement and stable rotational control.

Several propulsion options were evaluated by comparing thrust output, current draw, and cost, as shown in Table 3. Bilge pump motors were rejected due to their low thrust output, while the T500 thruster was considered too expensive for the performance gained. The T60 thruster also drew more current than the T200. After comparing all options, the T200 provided the best balance of performance, efficiency, and cost, making it the optimal choice for *The Great Eastern*.

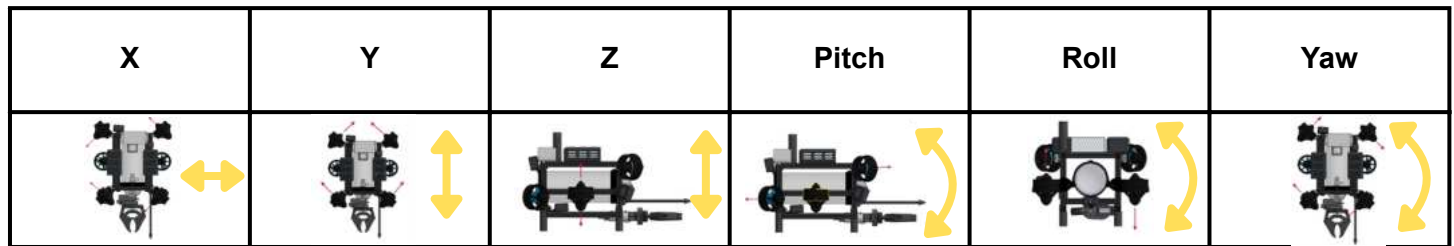


Figure 18: Thrust Directions, Pink - Thruster Direction, Yellow - Net Movement

Thruster Model	Current Draw at 12V	Force	Cost (USD)
T200	17 Amps	36.4N	\$230.00
12V Bilge Pump	5.2 Amps	3.1N	\$90.78
T500	16.9 Amps	58.8N	\$790.00
T60	23 Amps	49.0N	\$116.00

Table 3: Thruster Comparison

G. Buoyancy and Ballast

The *Great Eastern* was designed to achieve near-neutral buoyancy, reducing the force required for vertical movement while improving maneuverability and efficiency underwater. During testing, a slightly negatively buoyant configuration was preferred because it provided greater stability and smoother handling. To achieve this balance, HEART Innovators applied **buoyancy principles** based on density and water displacement, selecting materials with densities lower than water to generate upward force. Low-density foam sourced from a life jacket was used because it is designed to provide sufficient buoyancy to support a human's weight. The foam is mounted in three custom 3D-printed holders positioned atop the ROV to maintain stability and proper buoyancy distribution.



Figure 19: Buoyancy Foam Holders



5. MISSION PAYLOAD, TOOLS, & BUILD LOGIC

A. Optical Network

The Great Eastern uses **five cameras** to ensure sufficient subsea visualization.

A primary camera is located inside our main electronics tube. Its orientation faces forward, and it can pivot vertically through 180 degrees using a small servo motor to maximize visibility. This camera is essential for piloting *The Great Eastern*, being used in almost every task to varying degrees. This camera interfaces through the onboard Raspberry Pi, and the high-speed video feed is streamed through the Raspberry Pi's Ethernet port.

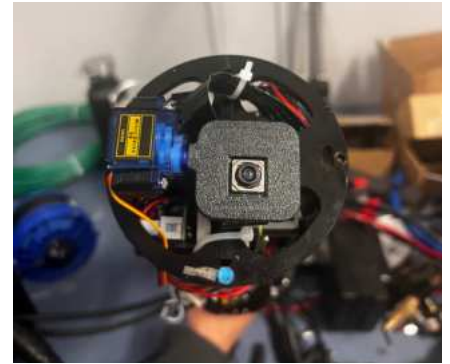


Figure 20: *The Great Eastern's* Primary Camera

Four additional USB cameras are mounted in task-specific locations around the frame of *The Great Eastern*. These cameras are contained in custom 3D-printed housings, sealed with epoxy, and mounted using custom hardware designed to the **universal mounting standard**. These additional cameras connect via a USB extender hub, allowing us to send four separate video streams over our tethered Ethernet cable. **This system reduces CPU strain** on the Raspberry Pi by operating independently, thereby increasing performance.



Figure 21: One of *The Great Eastern's* USB Cameras

B. Specialized Tooling:

i) *The Atlantic Reach Manipulator*

To align with the 2026 MATE RFP focused on specialized ocean observation, HEART Innovators engineered an upgraded manipulation system for *The Great Eastern*. While the legacy claw executed basic functions successfully, it lacked the precision needed for this season's complex structural interactions. Rather than re-engineering the entire design, our team used modular design principles, preserving the structural framework while implementing an upgraded subsystem tailored to current mission requirements. The resulting innovation, *the Atlantic Reach Manipulator*, was fully prototyped and 3D-printed in-house to achieve high-precision accuracy and modular flexibility. This custom swivel configuration dramatically increases vehicle dexterity, reducing operator cognitive workload and simplifying maneuvering for less experienced pilots.

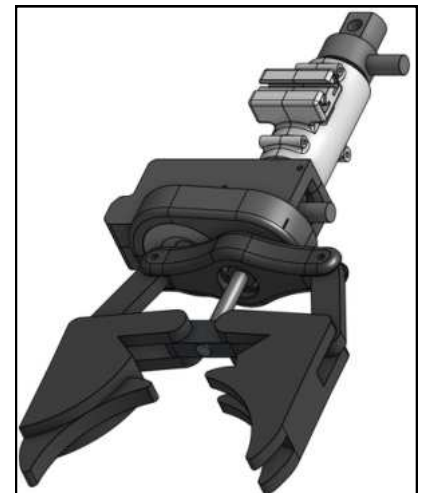


Figure 22: CAD Photo of The Atlantic Reach Manipulator

The manipulator features dual interlocking talons actuated by a pneumatic piston to securely grip underwater objects. A rotating base powered by a 70 kg/cm subsea servo drives a custom helical gear system, improving positioning accuracy while eliminating mechanical slippage. An adapter plate maintains compatibility with the previous chassis design, allowing rapid replacement if required. For safety and durability, a custom shroud encloses the gear assembly to prevent debris from entangling and to strengthen the claw structure.

ii) Buoy Recovery Line

The HEART Innovators recovery line consists of a specialized 3D-printed hook and spool, allowing it to be efficiently attached to buoy anchors from the seafloor. The spool features a custom made attachment point that fits our claw, and a rod that allows us to line up to the anchor, ensuring efficiency in the deployment process. the spool utilizes a thick paracord rope preventing it from getting stuck in the thrusters, ensuring safety throughout the recovery process.



Figure 23: CAD Model of Buoy Recovery Line and Clip

We experimented with many different designs for the clip before eventually deciding on the version shown in Figure 23. Originally the clip was underneath the claw which made it hard to see and take time to line up. The new design has the clip in front of the claw making it easy to see and the protruding rod allows us to line up quickly and efficiently. As for the spool it was originally mounted to the side of the ROV but we found that it threw off our weight and led to drifting in the water. Instead we mounted it facing upwards, minimizing the impact on our maneuverability.

iii) Up She Rises Lift Bag and Attachment Clip

To fulfill Task 2.3: Reclaiming whale safe fishing gear, the company engineered an integrated subsea recovery device combining an adapted mechanical retention clip with an air lift bag. Operating within the high-velocity currents of the Marine Institute Flume Tank was a critical constraint on minimizing pilot cognitive workload. Consequently, our pot attachment clip replicates the spring-assisted latching logic of our Task 4 buoy coupler, scaled to match the 2.54 cm outer diameter of the lobster pot's PVC handle and weight. Rather than forcing our two vertical T200 thrusters to sustain high current draws to lift the pot's weight, which risks exceeding our 23.4 A Full Load Amperage (FLA) safety envelope and tripping the 25A fuse, the operator triggers surface-pneumatic inflation of our lift bag using a dedicated pneumatic line. The expanding lift bag generates immediate vertical lift, bringing the whale safe fishing gear to the surface while saving valuable mission time. *The Great Eastern* can direct the gear to the deck side for easy recovery.



Figure 24: CAD Model of Up She Rises Lift Bag and Attachment Clip

iv) Adaptive Ocean Sampling Rod (AOSR)

The AOSR is a specialized tool engineered for the secure collection and safe transportation of a variety of task-specific objects. First of all, it can collect and safely transport two basket star samples to the surface from Task 1.1 simultaneously, increasing overall time efficiency. The AOSR is also designed to collect and secure old environmental DNA (eDNA) sensors that require replacement as part of Task 2.1. Finally, the AOSR can collect and remove the power cover from Task 3.1 to eliminate any risk of leaving debris on the ocean floor. Overall, our Adaptive Ocean Sampling Rod serves as a premier example of modular tool design and operational efficiency featured on *The Great Eastern*.



Figure 25: CAD Model of AOSR



C. Vertical Profiling Float

HEART Innovators designed a vertical profiling float named *Heart's Content*, proudly inspired by a local Newfoundland community. The float was engineered for simplicity and reliability, incorporating as few moving parts as possible to complete Task 4: MATE Floats Under the Ice. *Heart's Content* is powered by a Raspberry Pi Zero 2W, selected for its proven performance, efficiency, and widespread support. The Pi's processing capabilities ensure the efficient operation of all onboard programs and control systems. The **buoyancy engine** aboard *Heart's Content* utilizes a linear actuator, chosen for its high stroke speed, strength, and precise control. This improved responsiveness enables the float to execute precise vertical movements with greater speed and stability. A Blu-Sub Subsea Depth Sensor was selected for its reliability and integration of the MS-5837 30BA digital pressure sensor. To integrate the hardware systems, *Heart's Content* was programmed in Python for its versatility, accessibility, and low barrier to entry.

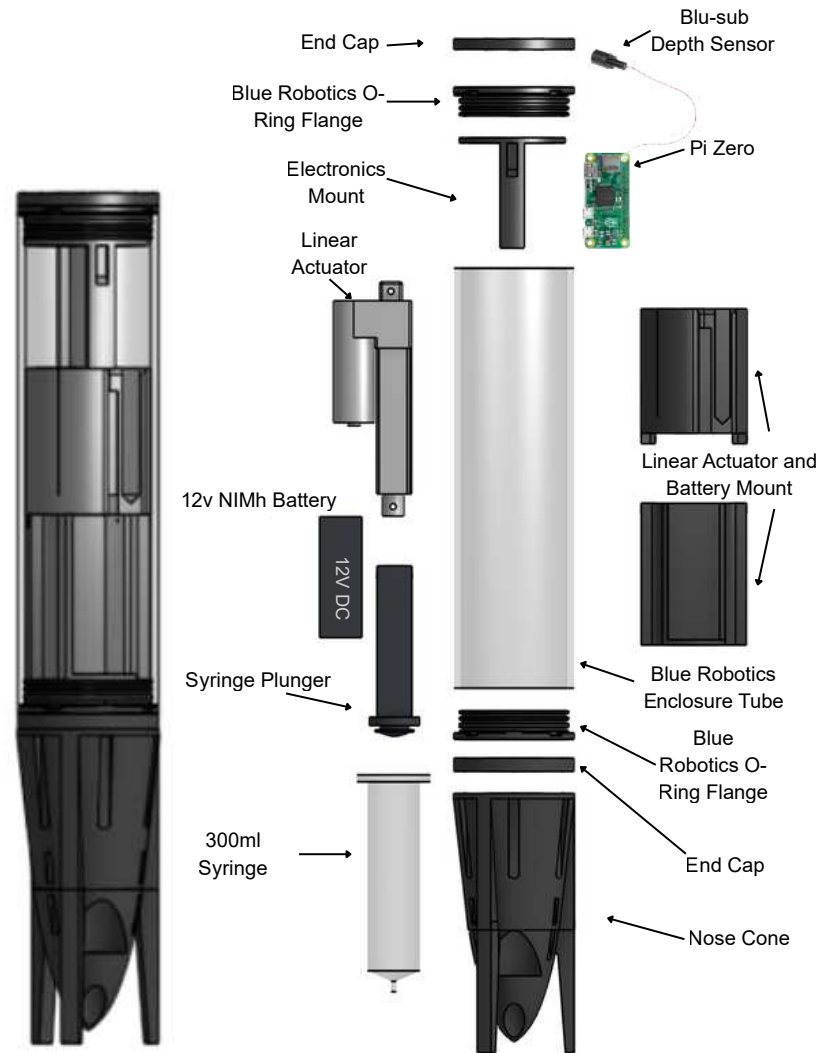


Figure 26: Float Assembled CAD View

Figure 27: Float Exploded CAD View

The software architecture aboard *Heart's Content* utilizes a streamlined, reliable state machine to execute autonomous profiling, data logging, and recovery routines. Communication is handled via lightweight JSON-formatted API calls, including commands to extend or retract the buoyancy engine and a "startRun" sequence, ensuring seamless integration with the Python control loop. The float's modular libraries include standard *time* and *JSON* modules alongside a specialized *ms5837* module from Blue Robotics' to interface with the onboard depth sensor. This integrated software stack ensures reliable, low-latency execution of automated underwater tasks while minimizing processing overhead on the embedded processor.

Upon completing two vertical profiles, *Heart's Content* connects via Wi-Fi to stream mission data directly to the topside terminal.

- Data Management: Telemetry is sorted by profiling run (including time and depth profiles) and mapped onto a custom GUI for efficient pilot monitoring.
- Power & Protection: Internal systems are powered by a 12V NiMH battery loop safeguarded by a master switch and a 3A inline safety fuse.
- Structural Enclosure: All electronic components are isolated within a watertight 4-inch Blue Robotics housing, ensuring a reliable, well-insulated, and professional internal framework.



D. Build vs Buy, New vs Used

HEART Innovators optimizes operational efficiency through a strict build, buy, or reuse evaluation pipeline, **prioritizing in-house** production over outsourcing. A critical element of this process involves balancing the advantages of component reuse against sourcing new materials. Integrating reclaimed parts drastically minimizes financial overhead and material waste. This approach aligns directly with our core sustainability and upcycling philosophy, which extends the operational life cycle of legacy components by repurposing them into new, mission-specific roles.

System	Justification
Raspberry Pi 4B	Meets Requirements: computing performance, electrical demand, vehicle control, camera, and data transmission
Main Electronics Tube	Meets Requirements: space, ease of access, water-tight, and additional buoyancy
Blue Robotics T200 Thrusters	Meets Requirements: ensures precise maneuverability and adequate thrust for MATE operations
Main ROV Laptop	Meets Requirements: delivers dependable system performance without additional costs
Cameras	Meets Requirements: sufficient visibility for mission tasks efficiency
Gaming Controller	Meets Requirements: piloting ability, familiarity, reliability, and programmability
Frame Material	Meets Requirements: strong, durable, and mounting point ability

Table 4: Reused Purchased *The Great Eastern* Systems

System	Justification
Tether	Meets Requirements: long, neutrally buoyant, low voltage drop, organized, and secure
Thruster Guards	Meets Requirements: improved safety and low impact on thrust force
Claw	Meets Requirements: strong gripping force, reliable, and able to handle a variety of objects

Table 5: Reused In-House Designed *The Great Eastern* Systems

System	Justification
Control Station Screens	Provides clear and reliable visual feedback for necessary for piloting and completing mission tasks
Float Hardware	New float design with better cost efficiency, reliability and overall performance

Table 6: Newly Purchased *The Great Eastern* Systems

System	Justification
Surface Control Station	Meets Requirements: durable and organized control hub with reliable system integration.
Buoyancy Foam Holders	Meets Requirements: modular, custom fitting, and adjustable
Claw Rotation Gears	Meets Requirements: provides precise and controllable rotational movement at a custom size
Tether Thimble	Meets Requirements: strong, simple, and reliable tether strain relief.

Table 7: New In-House Designed *The Great Eastern* Systems



System Integration Diagrams (SID's)

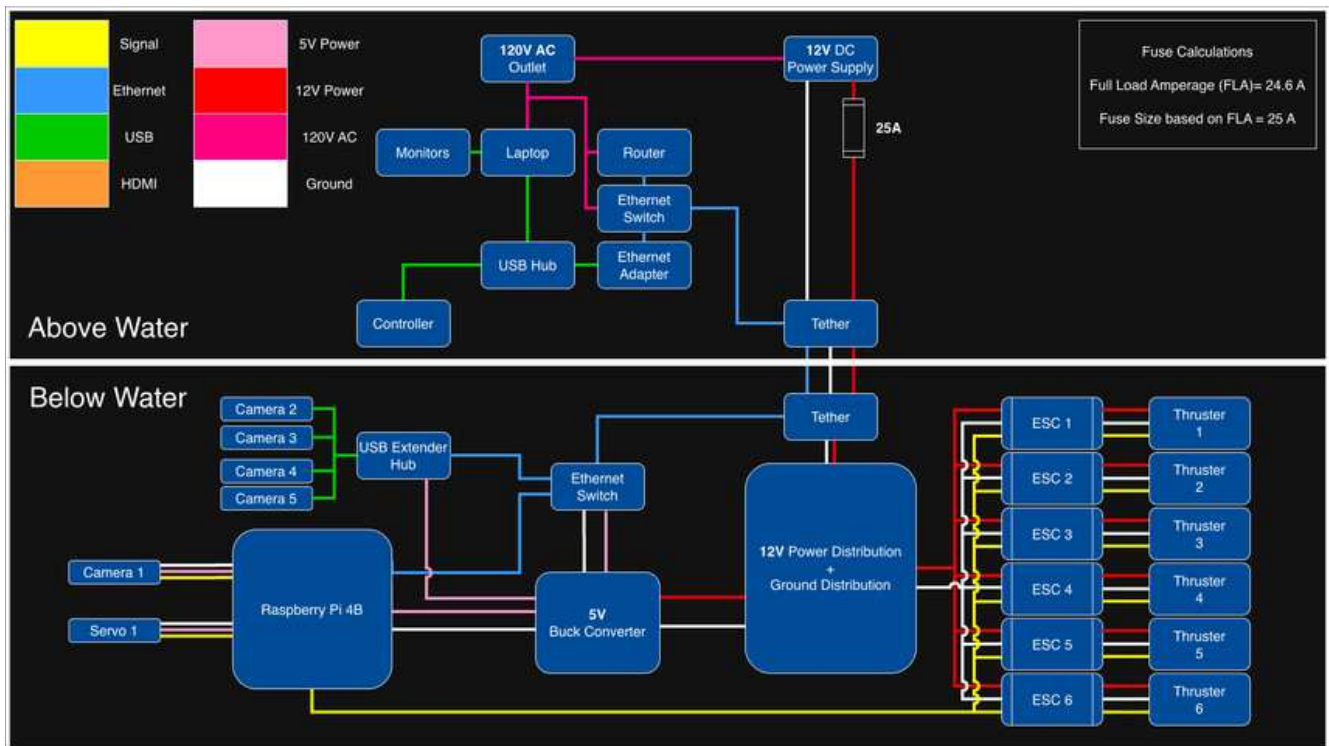


Figure 28: ROV SID

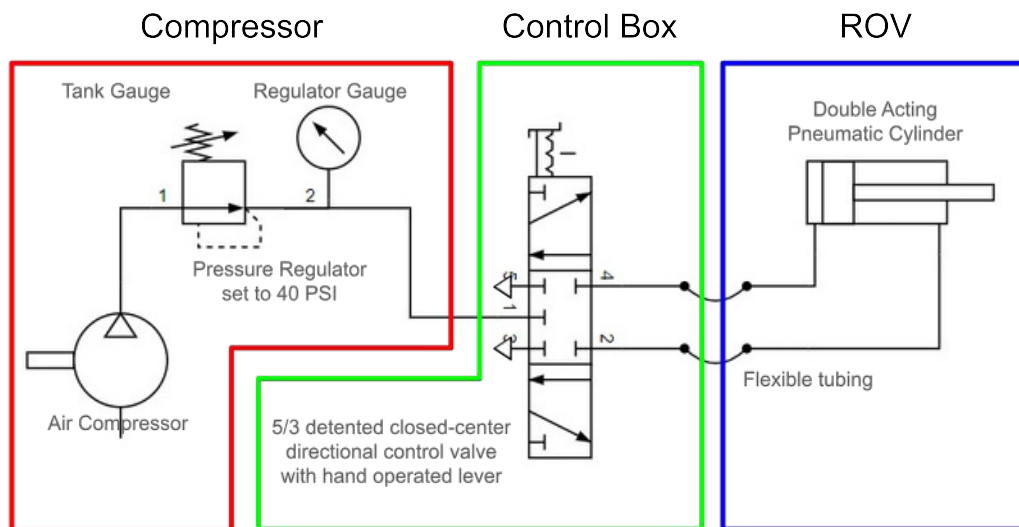


Figure 29: Pneumatic SID

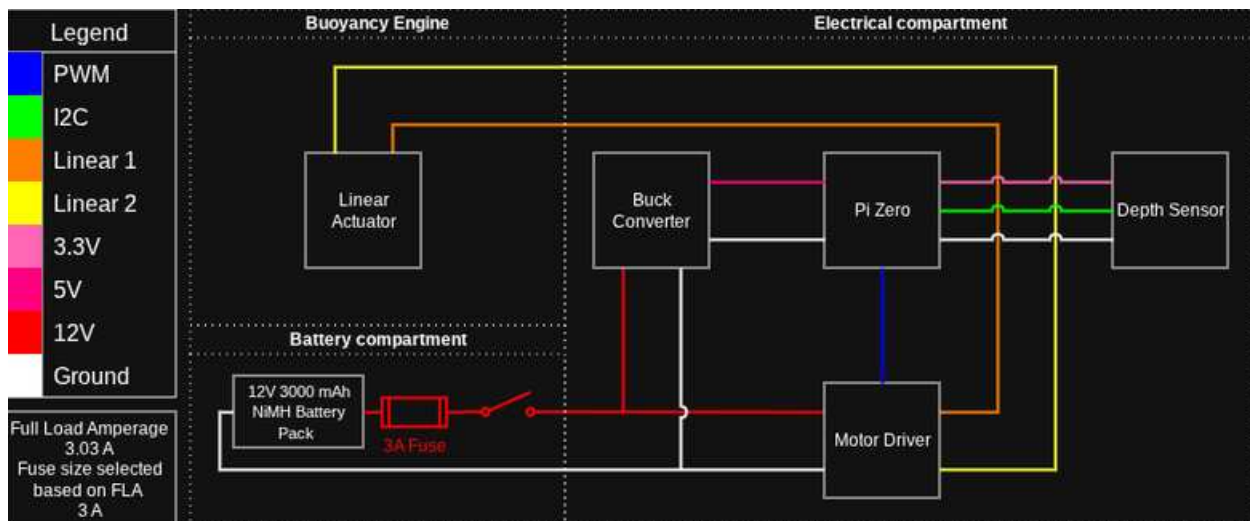


Figure 30: Float SID



6. SAFETY

A. Safety Rationale

At HEART Innovators, the philosophy of protecting both people and oceans underpins all operations. Comprehensive training, proper tools, clearly defined safety procedures, and enforced safety requirements are indispensable to preventing workplace accidents before they occur. Safety is a critical component of all operations and is a top priority, whether in the workshop, on the pool deck, or during ROV deployments. (See Appendix A for **safety checklist**)

B. Personnel Safety

HEART Innovator's safety officer is integral to the company's safety. Certified with aquatic emergency care and first aid, the safety officer is present during all construction and deployment activities to ensure adherence to safety protocols. If any employee has a safety concern regarding the ROV or another individual, they are instructed to notify the safety officer, CEO, or mentor. Additionally, HEART Innovators provides training to all team members to become first-aid certified, ensuring they can work safely with and around power tools.

C. Equipment Safety

A primary focus during the development of *The Great Eastern* was preventing injury by incorporating numerous safety features. To eliminate accidental injuries caused by misuse, hazards were labelled and made clearly visible. Additionally, all sharp edges and corners of the frame have been rounded or covered to prevent injury during ROV handling and to protect the sensitive marine environments in which it operates. Another key safety feature of our ROV is custom-made thruster shrouds, which are brightly colored and labelled with “Moving Parts” to protect the operators and the thrusters during task completion. Furthermore, any cables on the exterior of the ROV are secured as close to the frame as possible to avoid accidental tangling with task and marine objects. Finally, all electrical connections within the ROV are secured with appropriate connectors, and any exposed wiring has been wrapped with heat-shrink tubing.

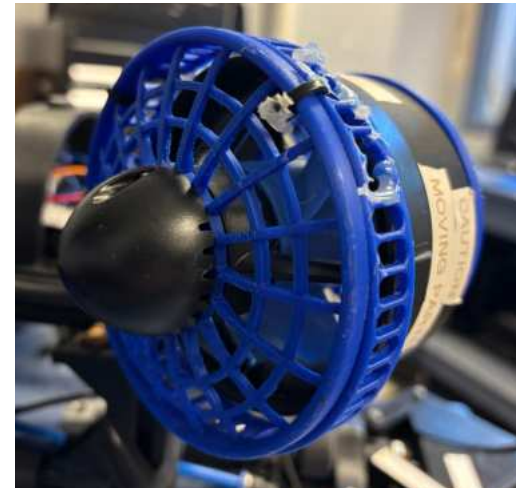


Figure 31: Custom 3D Printed Thruster Shrouds

D. Operational Safety

Potential operational hazards were identified through a Jobsite Safety and Environment Analysis (JSEA) and operational checks, and mitigation measures were implemented to mitigate safety risks. During operation, our dedicated tether manager ensures there are no tripping hazards on deck and the tether does not get tangled or coiled. We also always have at least one member certified with aquatic emergency care on our on-deck crew. In the event of water ingress, our pilots have constant, uninterrupted access to an emergency kill switch, which will immediately cut all power to the ROV and allow it to be pulled to the surface for inspection before redeployment.



7. CRITICAL ANALYSIS

A. Vehicle Testing Methodology:

As part of HEART Innovators testing process, each system is evaluated separately before full integration into the ROV. To minimize constraints and isolate potential issues, initial tests are conducted outside of the water whenever possible. Once individual components are confirmed functional, in-water testing is performed to ensure that all systems operate correctly when integrated. These full-system tests help identify any existing or potential issues, ensuring that *The Great Eastern* performs at its highest possible level. Our team tested the ROV in water, recreating each prop in MATE's mission tasks this year. Being able to test *The Great Eastern* at least once a week allowed our deck team to become comfortable with their product demonstrations. The constant testing allowed our Pilot and Deck Manager to create the most efficient plan for the product demonstration.

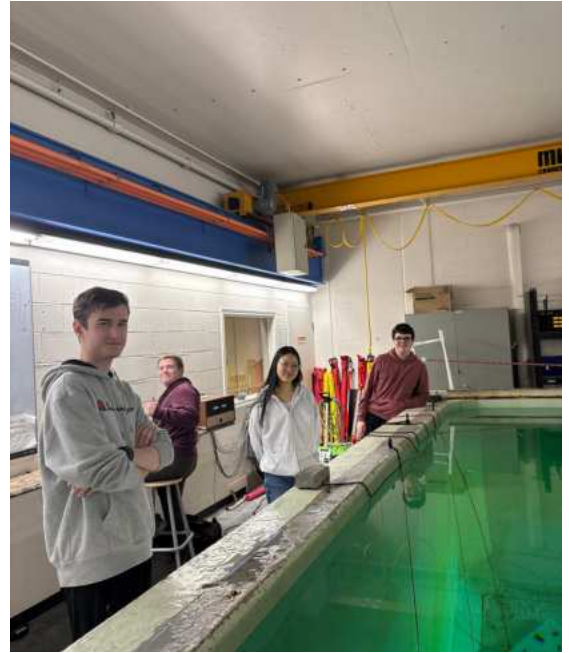


Figure 32: ROV Pool Testing

Overall, HEART Innovators believes it is important to approach troubleshooting systematically and methodically, starting with the most common and easily fixable issues before moving on to more complex problems. Communication and collaboration among the company members help to identify and resolve issues that may occur.

B. Propulsion Testing

When testing *The Great Eastern's* propulsion system, the thrusters were briefly operated on dry land to check for electrical issues before being put into water. Once those tests were completed, our Design and Fabrication members evaluated various thruster placement options to maximize efficiency and maneuverability. To evaluate this, the company conducted a series of in-water trials in a pool, closely observing how different motor placements and orientations affected the ROV's movement. After numerous trials, the company determined the most effective angles for optimal performance. If, during testing, a more viable orientation is found, fear not; thruster placement was designed to be customizable. To further assess propulsion, team members have conducted velocity tests at different amperages to determine the maximum amperage the thrusters can use without compromising power to other components. All 6 T-200 thrusters were reused from last year to save on unnecessary expenses.



Figure 33: Propulsion Testing



C. Pneumatics Testing

To test the Pneumatic systems, the company followed similar steps as outlined for the propulsion systems. The claw began as an experimental CAD model, then early 3D-printed models, until fully functional products were developed. The company's engineers reused the polyethylene pneumatic tubing that was used the previous year. This was tested to make sure the pneumatic system met task requirements, and could produce the proper force for the claw and support the proper pressure to use the claw. This allowed the company to calculate what tasks the ROV could complete without issue. HEART Innovators first tested the pneumatic connection to make sure it would work when the tether was fully deployed. The company then tested how well the Pilot could maneuver while a separate team member controlled the claw

D. Vertical Profiler Testing

Heart's Content went through extensive testing before deployment. This year, HEART Innovators debuted a new design using a linear actuator. To ensure it was reliable and worked properly, the float went through extensive testing. First, the profiling software aboard was tested out of the water to ensure smooth integration with mechanical parts. These tests helped resolve all problems before the float was tested in water.

Because *Heart's Content* must operate autonomously, Wi-Fi and networking were a major focus of our testing. Many stress tests and worst-case scenarios were run, including those involving massive files and invalid packets. These test cases lead to many rebuilds and discussions, strengthening our communications and improving reliability. In past years, the buoyancy engine was powered by a servo motor for simplicity. This year, *Heart's Content* utilizes a linear actuator, where the exponential movement had to be carefully tested. Dive tests were conducted in the Marine Institute acoustic tank with a line attached to *Heart's Content's* body for easy retrieval.



Figure 34: Float Pool Testing

E. Troubleshooting

While constructing *The Great Eastern* and *Heart's Content*, many problems arose that required careful thought, consideration, and identification of the root cause. We had steps to undergo clear analytical reasoning:

1. Identify reasons why the current design/approach was unsuccessful
2. Brainstorm ways to overcome current shortcomings
3. Collaborate with other members to find solutions
4. Propose a new design/approach and test again until successful

This **iterative cycle** was done for any problem that arose. In particular, custom-designing task-specific tools required a lengthy prototyping process. For example, the rotating claw for the servo was redesigned multiple times, eventually improving from a spur gear to a helical gear after the teeth slipped and were damaged. As well, the speed of the linear actuator itself on *Heart's Content* was tested for over 10 hours underwater so that the depth of the float would not overshoot, and the thickness of the buoy recovery line was identified as a key factor so that it would not become tangled with the thrusters.



8. BUDGET AND ACCOUNTING

A. Budget

For a company, effective budgeting is vital to achieving positive outcomes. The total budget for this year was \$3,475.00 USD. The budget covers a wide range of expenses, including parts for constructing the ROV, marketing materials, and any other costs that may arise unexpectedly during the process. Careful financial planning helps the team stay organized and ensure resources are used efficiently and responsibly. Appendix B and C provides in-depth details on the budget and a detailed breakdown of expenses.

To ensure sufficient funding, HEART Innovators gained corporate sponsorship from Subsea 7 and Harveys Home Heating. Additional funds were provided by MATE NL. Providing over \$3000 in total.

Source	Notes	Amount (USD)
Balance forward	Funds left over from June 2025	\$3,200.00
MATE NL	Funds to build the ROV	\$655.23
Subsea 7	Sponsorship	\$728.18
Harvey's Home Heating	Sponsorship	\$728.18

Table 8: Source of financial funds for HEART Innovators

B. Project Cost

HEART Innovators prioritized budgeting to produce an efficient, cost-effective ROV. The company analyzed and safely extracted reusable materials from previous models to build *The Great Eastern*. When a new component was required, we analyzed and compared alternatives. Balancing quality, longevity, and cost was a key factor in our decision. This ensures parts are of good quality and can be reused in future designs, prioritizing sustainability and reducing long-term costs. Once the best fit was determined, we ensured it aligned with our budget and ordered it from a nearby provider to support local companies. A detailed analysis of project costs is provided in *Appendix C*.



9. ACKNOWLEDGEMENTS

HEART Innovators would like to thank the following individuals and organizations for their support:

- Mr. Cole Murphy, Teacher Mentor
- Holy Heart of Mary High School
- Subsea 7
- Harvey's Home Heating
- MATE II and the Marine Institute for allowing us to compete in the competition



10. REFERENCES

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- Raspberry Pi 4b - <https://www.raspberrypi.com/products/raspberry-pi-4-model-b/specifications/>
- T200 Thrusters - <https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/>
- T500 Thrusters - <https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t500-thruster/>
- T60 Thrusters - <https://rovmaker.com/en/t60-underwater-thruster/>
- 12V Bilge Pump - https://ca.binnacle.com/Plumbing-&-Pumps-Bilge-Pumps-Electric/c31_260/p2212/Rule-10-Bilge-Pump-2000-GPH-12V/product_info.html
- MATE Competition Manual - <https://materovcompetition.org/2026>



11. APPENDICES

Appendix A - Safety Checklists

Complete each section in order. All electrical work must be done with equipment fully powered off.

ASSEMBLY ROV Construction

- ☐ ROV and all work surfaces are completely dry before starting.
- ☐ Work area is free of debris and clutter.
- ☐ All wires are secure and no bare conductors are exposed.
- ☐ No connections are loose inside the pressure hold.
- ☐ Pressure held interiors have no clouding, cracks, or moisture.
- ☐ O-rings are clean, undamaged, and properly lubricated.
- ☐ No wires are pinched between components or tube walls.
- ☐ Before sealing, remove pressure vent plug to prevent pressure buildup.
- ☐ Endcap is aligned, secured and locked to the main cylinder throughout closing.
- ☐ Tether wires face upward at the top of the endcap.
- ☐ After sealing, reinstall vent plug and fully tightened.
- ☐ Internal assembly sits level horizontally.
- ☐ Both endcaps are flush with the cylinder.
- ☐ All O-rings visually confirmed as fully seated.
- ☐ Stress relief is attached and seated above the endcap.

PRE-DEPLOYMENT Crew & Equipment Check

- ☐ Confirm integrity of the ROV frame.
- ☐ Poolside and control areas are cleared of loose items and debris.
- ☐ All ROV attachments are fully secured.
- ☐ Tether is laid out neatly with no tangles, away from walkways.
- ☐ Battery and power supply are fully charged and kept away from the water's edge.
- ☐ Surface station tether strain-relief carabiner attached to a fixed structure.
- ☐ Tether power source and pneumatic systems are connected.
- ☐ Surface laptop is powered on, connected, and plugged in.
- ☐ All personnel wearing closed-toe shoes, safety glasses, and no loose clothing. Long hair tied back.
- ☐ Recovery gear (pole, net, etc.) within reach.

PRE-DEPLOYMENT System Startup

- ☐ All connections verified secure to protect ROV electronics.
- ☐ All deck crew are clear of moving parts.
- ☐ Power supply and air compressor are powered on and set to proper values.
- ☐ Pre-submerge tests are completed.

PRE-DEPLOYMENT Water Entry & Handoff

- ☐ ROV Handler swaps any tools or payloads needed for the mission.
- ☐ Pilot calls "CLEAR FOR PICKUP" to signal start of water entry.
- ☐ ROV Handler grips the ROV by its frame, announces "HOLDING", and lowers it into the water at the deployment zone.
- ☐ Pilot confirms ROV state is stable using camera and sensor data.
- ☐ ROV Handler releases the ROV and announces "CLEAR".

IN-WATER Active Operation

- ☐ Tether Manager follows designated tether handling procedures to avoid entanglement.
- ☐ Deck Manager actively coordinates communication between pool and surface.
- ☐ All crew are mindful of tripping hazards and stay clear of pool side.

POST-OPERATION Recovery & Retrieval

- ☐ Pilot guides ROV to the deployment zone and calls "CLEAR FOR PICKUP".
- ☐ ROV Handler lifts the ROV out by its frame and announces "HOLDING".
- ☐ ROV handler lays the ROV in the designated area and announces "CLEAR".

POST-OPERATION Rinse & Storage

- ☐ Confirm integrity of the ROV frame and pressure hold.
- ☐ If deployed in saltwater, fully rinse or soak the ROV in fresh water to prevent corrosion.



Appendix B - Budget

Category	Name	Amount (USD)
Funding	Holy Heart of Mary High School	\$3,200.00
Sponsorship	Subsea 7	\$728.18
Sponsorship	Harvey's Home Heating	\$728.18
Funding	MATE NL	\$655.23
Total:		\$5,311.59

Table 9: 2026 Funding and Sponsorships

Category	Example Items	Budgeted	Total Value*	2026 Spending
ROV Build	Frame, Thrusters, Computing, Enclosures, Cameras, Pneumatics, Tools	\$1,000.00	\$2,108.52	\$218.18
Float Build	Pi Zero, Enclosure, Linear Actuator,	\$1,000.00	\$639.21	\$606.41
ROV Surface Station	Controller, Laptop, Pelican Case, Additional Screens	\$500.00	\$478.88	\$452.54
Team Operations	Team Uniforms, Embroidery, Marketing Display, Printing	\$500.00	\$500.55	\$500.55
Competition Fees	Ranger Registration Fees, Fluid Power Quiz Registration	\$475.00	\$475.00	\$475.00
Competition Travel	Airfare, Car Rental, Lodging (Hosting Worlds)	\$0	\$0	\$0
Total:		\$3,475.00	\$4,202.16	\$2,252.68

Table 10: 2026 Budget and Expenses



Appendix C - Cost Accounting

Category	Type	Item(s)	Value (USD)
Float Build	Purchased	Blue Robotics 400mm Enclosure	\$430.00
Float Build	Reused	2 x Raspberry Pi Zero 2	\$45.09
Float Build	Purchased	Ethernet/USB Hub Hat for Pi Zero	\$37.22
Float Build	Purchased	DC Motor Driver Board	\$18.60
Float Build	Purchased	Rechargeable NiMH Battery	\$67.51
Float Build	Reused	Wi-Fi Router	\$40.79
Float Build	Purchased	Linear Actuator	\$53.08
Float Build	Reused	Blue Robotics 300mm Enclosure	\$348.00
Float Build	Reused	6 x T200 Thrusters	\$1,108.39
Float Build	Reused	6 x Blue Robotics ESC	\$163.25
ROV Build	Reused	V Slot Aluminum Extrusions	\$107.39
ROV Build	Reused	2 x 5-port Ethernet switch	\$32.00
ROV Build	Reused	Raspberry Pi 4B (8 GB)	\$98.77
ROV Build	Reused	100ft 14 gauge wire	\$21.40
ROV Build	Reused	50ft Waterproof Ethernet	\$20.36
ROV Build	Reused	70kg 360° IP68 Brushless Servo	\$45.41
ROV Build	Manufactured	Custom PCBs	\$112.77
ROV Build	Reused	Pneumatic lines	\$7.03
ROV Build	Reused	Pneumatic fittings	\$43.75
ROV Surface Station	Reused	8BitDo Pro 2 wired controller	\$26.34
ROV Surface Station	Purchased	4 x Dell Laptops (Computers for Schools)	\$218.28
ROV Surface Station	Purchased	Dual Screen Extender	\$234.26
All	Purchased	3D Printer Filament	\$218.18
Team Operations	Purchased	Uniforms	\$336.83
Team Operations	Purchased	Marketing Poster	\$163.72
Total:			\$3,945.34

Table 11: Company Expense History

