

Underwater Research

Robot Company.

Alpena High School Underwater
Robotics Club
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- Adam Tucek- MAcc, CPA,
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- Sarah Rabbideau - Safety Mentor

Members:

- Kylie Gagnon - 13th year -
Fabricator
- Lydia Thomson - 12th - CEO
- Gus Wirgau - 12th - Pilot
- Taylor Widajewski - 12th - CFO
- Gunner Moe - 12th - Safety
Officer/Engineer
- Lizzie Rabbideau -11th- Payload
Manager
- Dawson Smolinski - 10th - Project
Specialist
- Matthew Kowalski - 10th - Co-
Pilot
- Ray Johnson - 10th - CTO



Team photo taken by B.Thomson

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1. Company Profile, Abstract, and Team Overview

Underwater Research Robot Company (UR²), a student-led engineering firm from Alpena, Michigan, has competed in the MATE ROV Competition since 2009. Drawing on our Great Lakes science partnership with Thunder Bay National Marine Sanctuary, UR² engineered a new 2026 ROV model, Defiance HD, to address this year's product demonstrations. The Defiance HD is a Class II ROV and features a custom four-degree-of-freedom robotic arm enabling precise manipulation for buoy sensor installation and offshore wind turbine maintenance. Our ESP32-based vertical profiling float, Perseverance, autonomously collects depth and pressure data and contributes to global ocean monitoring networks. To combat invasive species, UR² developed a proprietary Python-based computer vision system using OpenCV and HSV color-space analysis that autonomously identifies and counts European green crabs, distinguishing them from native species without operator input. These engineered solutions directly mirror the autonomous technologies marine researchers deploy to protect coastal ecosystems, maintain clean energy infrastructure, and monitor ocean health worldwide.

1.2 Team Members and Roles

Our company, UR², comprises students from grades nine through 13th year. Although we are young in age, most of our team members have been building ROVs since fifth grade. UR² has a wealth of experience.

Our team comprises 13 members: our officers are the CEO, CFO, and CTO. They have multiple responsibilities within the company. The CEO oversees all company operations and is also our lead software engineer. The CFO oversees company expenses, and the CTO oversees the development of our ROV hardware and subsystems. Each chief officer leads and works with a crew in each branch of the company. This helps the team collaborate and increases productivity.

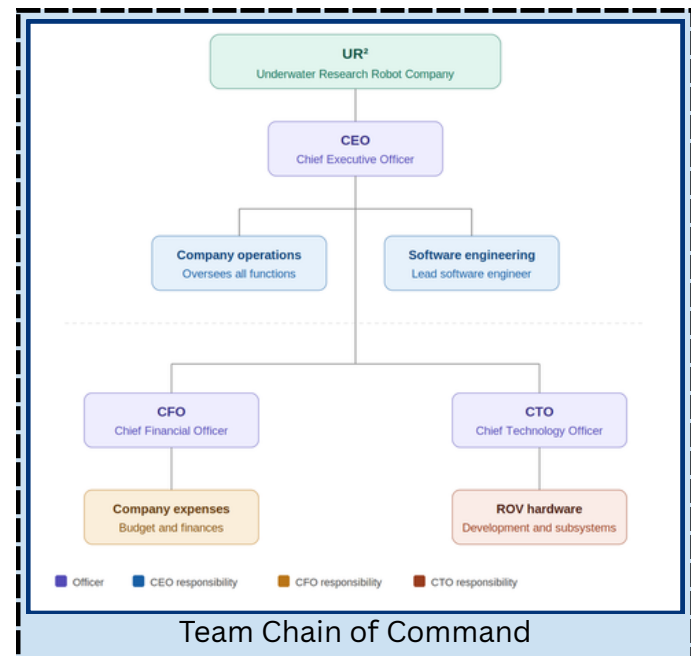


Image By Lydia Thomson

Our company may be small, but we are a motivated and passionate team. With 13 members, we share the responsibility. This is why self-reliance is one of the key traits we look for in people who want to join our company. Team members must be motivated and driven to accomplish tasks effectively. When we bring on a new member, everyone is responsible for training and bringing them up to speed. We encourage our team members to explore their passions and pursue what they love. Our company starts meeting in August for strategic planning and developing an ROV design. We developed a design criteria outline to give us structure for our design decisions. We started with three main objectives: creating a class II ROV, developing a robotic arm, and building a reliable vertical profiler, "Float." Each member of our team is committed to helping our community and growing the next generation of problem solvers. We take our tag line of Protecting, Preventing, and Preserving our local freshwater resources seriously.

What We Do:

- **Protecting:** UR² has partnered with the Thunder Bay National Marine Sanctuary and the NE Michigan Great Lakes Stewardship Initiative to support the mission of protecting and preserving our local freshwater resources.
- **Preventing:** Working with companies like Viking Cruise Line to develop substrate samplers that can be used in the Arctic to take samples that will be used to create a database of both biotic and abiotic factors to develop a health assessment of substrate ecosystems.
- **Preserving:** UR² has partnered with Alcona Community Schools and the Hubbard Lake Sportsman Association to use an autonomous surface vehicle with side-scan sonar to identify historically interesting targets in Hubbard Lake and use our new photogrammetry technology to create 3D images of targets to research.



In the image above, Kylie, a team fabricator, shares with middle school students about STEM opportunities in marine technologies during a STEM event the team hosted at the Thunder Bay Marine Sanctuary in February of this year.

1.3 Development Schedule

UR² created a new team position of Project Manager for the 2025 season to help manage the project timelines and keep tasks on track. This addition last year to the organizational structure addressed the growing complexity of UR²'s project list and the need for enhanced coordination across research, development, and fabrication teams. The Project Manager role has comprehensive responsibilities, including timeline development, resource allocation, risk management, stakeholder communication, and progress tracking across all projects. By establishing this dedicated position, UR² aims to improve project delivery predictability, optimize resource utilization, enhance cross-functional collaboration, and ultimately deliver higher-quality ROVs such as Defiance HD and a reliable float.

The first major task assigned to the Project Manager this season was to create a master timeline for developing research projects, prototypes, and the completion of the Defiance HD vehicle and float. In previous years, the organization struggled to keep track of tasks, and many projects were left untouched and forgotten. Now, with someone overseeing everything and documenting progress, we have been able to meet deadlines and achieve our goals effortlessly. The Project Coordination Survey 123 was a significant factor in this success, which was distributed at the beginning of the year.

These are the first couple of questions that members will answer every Saturday:

- | | |
|--|---|
| • What is your name and job title | • List all steps that went into completing the project so far |
| • What is the name of the project | • Was the start date of the project |
| • Give a detailed outline/summary of the project | • Was the end date of the project |
| | • How did your project correspond with the MATE mission? |

UR² Project Planning

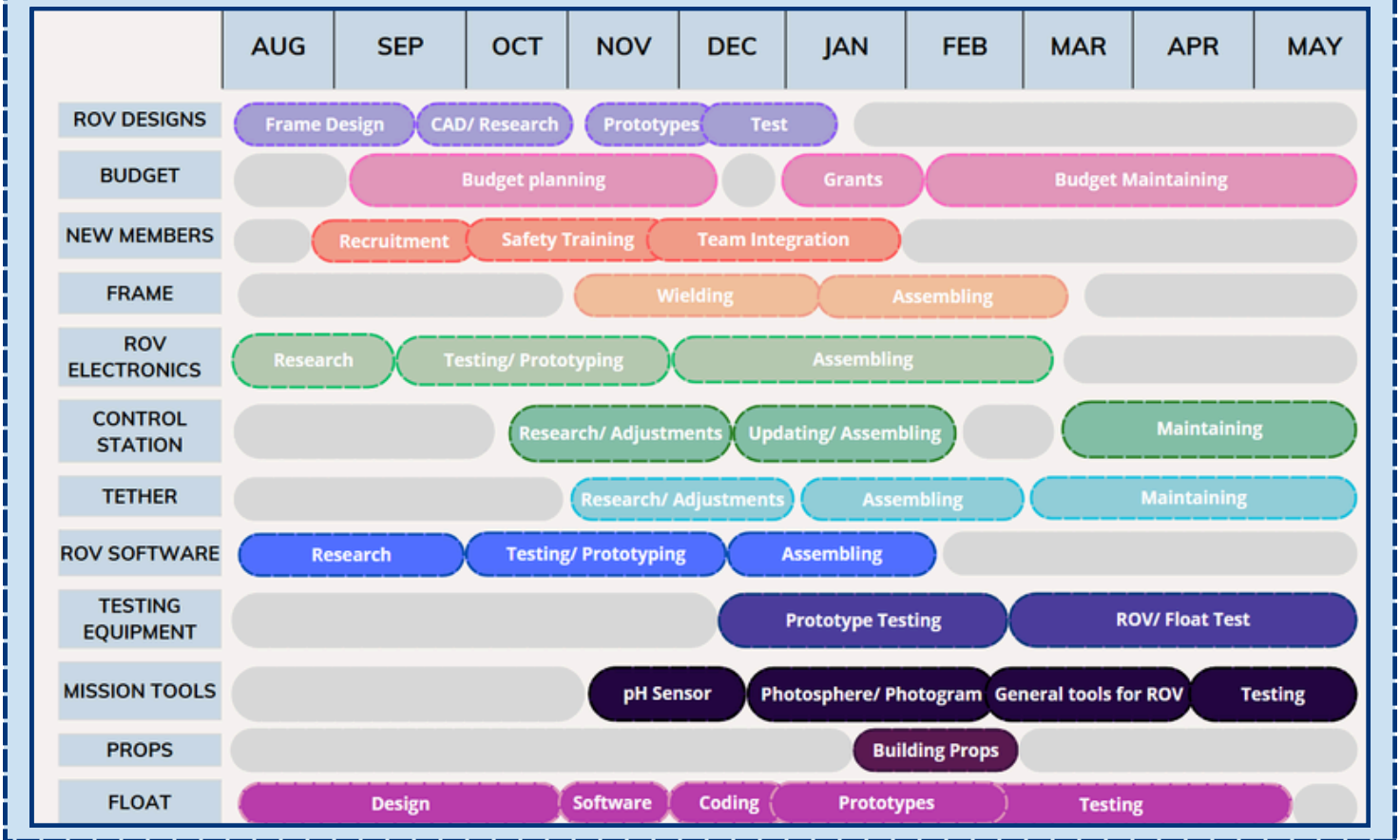
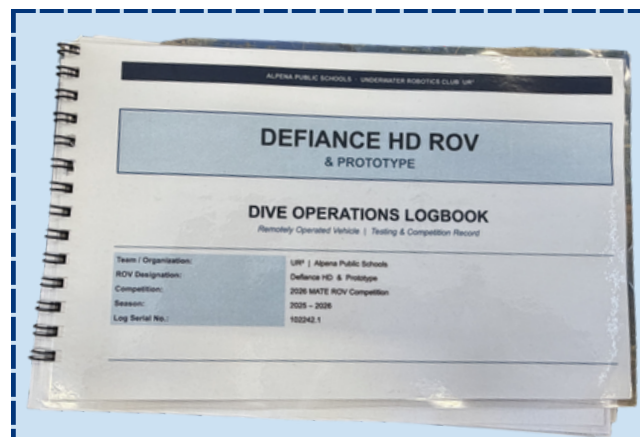


Figure By Lydia Thomson

1.4 Resource and Protocol Management – Training and Operational Procedures

To ensure mission readiness and consistent operational standards, several UR² personnel completed Introduction to Submersible Robotics at Alpena Community College (ACC). This is instructed by David Cummins, a mechanical engineering technology professional with over 15 years of industrial experience and direct ties to the offshore ROV industry. The course provided formal instruction in ROV systems, piloting procedures, subsea operational protocols, and industry safety standards.

A key component of the coursework was hands-on time with the Oceaneering ROV simulator, which allowed UR² pilots to develop basic flying skills and experience the operational challenges of working-class ROV systems in a risk-free environment before transitioning to live operations. This simulation-based training directly informed how the company structured pre-mission checklists, pilot rotation protocols, and co-pilot communication standards can be carried over to Defiance HD operations.



During our training with the Marine Tech Program at Alpena Community College, we maintained an operational log for the ROV. This year, the team developed our own Operation Log for both our prototype ROV and the Defiance HD ROV. The operational log allows us to maintain a hard copy of our operational hours and pilot training time.

1.4 Resource and Protocol Management – Training and Operational Procedures Continued

Under the guidance of Mr. Cummins, UR² personnel then transitioned from simulation to live field operations using ACC's professional working-class ROV. Operating in the Thunder Bay River watershed, the team conducted real structural surveys, including foundation examinations of local underwater infrastructure, and reported directly to the property owner. In a separate operation, UR² was tasked with locating a firearm identified by a local fishing vessel's side-scan sonar. The mission required pre-dive planning, systematic execution of search patterns, and coordinated team communication under real-world conditions. Mr. Cummins empowered the UR² team to plan and implement the operation independently, assigning students to on-site supervisor, pilot, tether operator, and safety officer roles.

These field operations gave UR² engineers and pilots a professional industry benchmark far beyond typical pre-competition preparation, and the procedures developed during those missions, systematic task sequencing, defined crew roles, and real-time problem-solving were directly carried forward into the operational protocols governing Defiance HD at the 2026 MATE competition.



The team working on Oceanering Simulators

1.5 Acknowledgements and References

Underwater Research Robotics would like to express our gratitude towards the people who made it possible to compete in the MATE ROV competition. Our team would like to thank MATE and the Marine Technological Society, sponsors of the MATE 2025 competitions, for making everything possible. We would also like to thank the following for supporting us and contributing to our successes:

- STARBASE Alpena for providing 3D printers, and Steve Tezak for providing mentoring advice
- US Naval Surface Warfare Center Crane: Debra Walker for her help in mentoring our ROV frame
- Seafloor: Marcos Barrera provided mentoring advice for the FLOAT
- Robert Thomson and Paul Coleman for mentoring our team
- Thunder Bay National Marine Sanctuary for providing laboratory workspaces and networking opportunities
- Alpena Public Schools for donating various supplies and other resources
- Marine Advanced Technology Education provides opportunities and helps us grow
- MISTEM provided ample amounts of funding, making it possible for us to complete
- The volunteer divers who made it possible to practice and compete in NOAA's dive tank
- NOAA staff members who make our competitions and many outreach programs possible

Special thanks to David Cummins and the Alpena Community College Marine Tech program for the training and support developing this season ROV.

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All pictures of team members used in this technical documentation were taken by Lydia Thomson and Gunner Moe

2.Vehicle Overall Design Rationale

Defiance HD is UR²'s 2026 Class II competition ROV, engineered to perform precise underwater operations that mirror the work of professional marine technology companies. Every design decision, from frame material to software, was made to maximize mission performance and operational reliability. To reach this goal, we focused on feedback from judges and mentors' comments from the 2025 Regional and World Competition .

Frame & Structure

- Defiance HD is built on a welded 2.54 cm aluminum square tube frame with a PETG-CF 3D-printed outer skin. Aluminum was selected because it offers an exceptional strength-to-weight ratio while remaining corrosion-resistant in both fresh and saltwater environments. The rigid frame provides stable mounting points for all tools and thrusters, ensuring the vehicle holds position precisely—a critical requirement for installing sensors on a moored buoy or performing detailed wind turbine inspections, tasks that replicate the real-world work of offshore service ROV crews.

Propulsion System

- Defiance HD uses a six-thruster vectored configuration: two Blue Robotics T200 thrusters mounted vertically for depth control and four ApisQueen U2 Mini thrusters arranged horizontally for forward, lateral, and rotational movement. This arrangement gives the vehicle independent control in all directions simultaneously, allowing pilots to hold a precise position in a current—exactly the capability required when a professional ROV must station-keep next to a subsea structure while a manipulator arm performs work.

Robotic Arm & Manipulator

- The vehicle carries a custom four-degree-of-freedom robotic arm driven by four 25g waterproof servos controlled through a PCA9685 servo HAT on the ROV's Raspberry Pi 4. The arm allows the pilot to reach, grip, rotate, and place objects with precision. This directly replicates how industry work-class ROVs use hydraulic manipulators to install instrumentation, service subsea hardware, and recover objects—mirroring the competition's buoy sensor installation and wind turbine maintenance tasks.

Computer Vision — European Green Crab Detection

- UR² developed a proprietary Python-based computer vision module using OpenCV and HSV color-space analysis that autonomously identifies and counts invasive European green crabs in the camera feed, distinguishing them from native rock and Jonah crabs without any operator input. A single hotkey triggers the system; green bounding boxes appear around detected invasive crabs, and a real-time count updates on screen. This directly reflects how marine researchers deploy autonomous detection technology to monitor and track invasive species threatening coastal and Great Lakes ecosystems.

Control Architecture

- The vehicle uses a dual Raspberry Pi 4 Ethernet architecture. An Xbox Series X controller on the surface feeds inputs to the surface Pi (192.168.2.100), which relays commands via UDP over a hardwired tether to the ROV Pi (192.168.2.101) running BlueOS. This design isolates surface and sub-sea computing, reducing latency and providing reliability — the same principle used in professional ROV umbilical systems where surface and sub-sea processing are kept separate to protect mission-critical operations.

2.1 Design Philosophy

Team leadership began the 2026 build season in August by conducting a structured review of the 2025 Defiance ROV. The team assessed every major subsystem against three questions: Does it work reliably? Does it meet Class II design requirements? And does it align with our 2026 competitive strategy? The 2025 design demonstrated strong fundamentals; our six-thruster vector system, control architecture, and camera placement all performed well under competition conditions, but limited manipulator capability cost us points. This review produced a prioritized build agenda that balanced reuse of proven systems against targeted redesign where performance was insufficient.

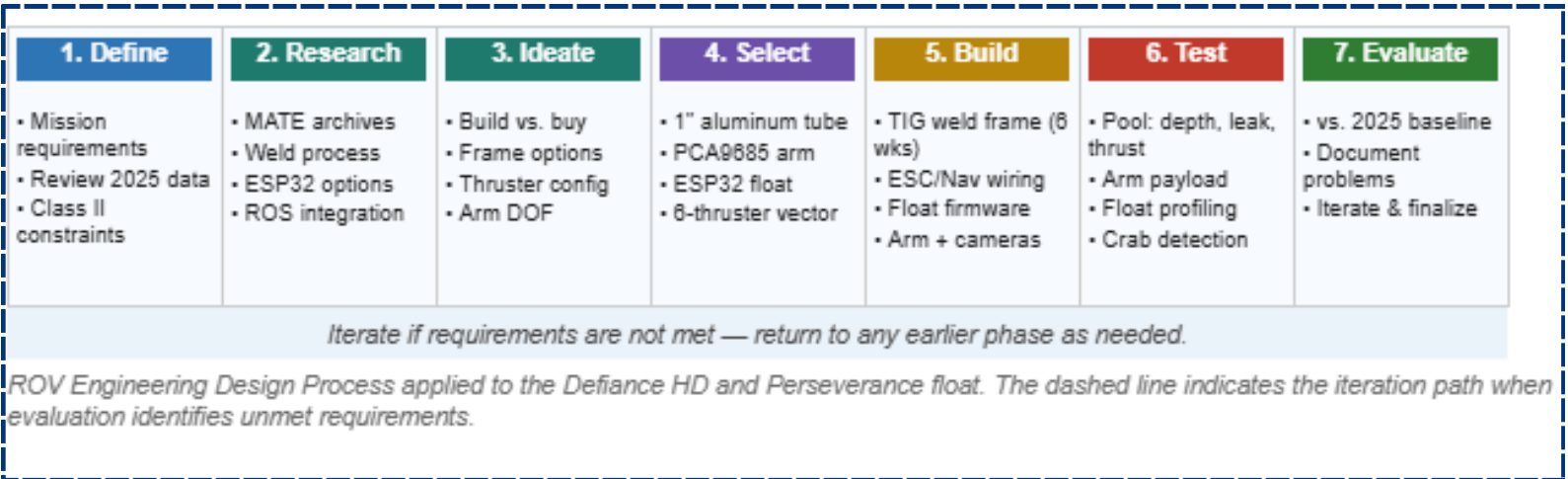
A central decision early in the season was to formally commit to a Class II design. In 2025, the Defiance competed with a Class I chassis and a single Newton Subsea gripper. We studied the location of the 2026 World Competition and studied the archived mission form 2015. After reviewing all our resources, the team determined that achieving a competitive score in the Ranger division required genuine Class II capability: a structurally welded aluminum frame, a multi-degree-of-freedom manipulator arm, and expanded sensor and camera coverage. This research shaped the decision in the build agenda.

Engineering Design Process

The Defiance HD was developed using an engineering design process adapted from industry practice and aligned with the MATE competition's emphasis on systems thinking, documentation, and critical evaluation. Rather than treating design phases as sequential checkboxes, the team treated them as a continuous feedback loop, returning to earlier phases whenever testing revealed performance gaps or constraint violations. The process is summarized below and detailed in subsequent sections of this document.

Build Agenda — 2025 → 2026

2025/2026 Build Agenda	Re use	Up date	Ch ange	Design Rationale
Control Station	X			Maintained existing layout; cosmetic refresh for improved operator ergonomics.
Ground Control Software			X	Migrated from BlueOS to ROS to improve mission scripting, sensor integration, and telemetry logging.
ROV Operation Software		X		BlueOS has been updated to the latest stable release for stability and QGC compatibility.
Enclosure		X		Retained Pi/Nav board stack; upgraded O-ring seating to eliminate 2025 leak points.
Grabber / Manipulator			X	Newton Subsea gripper retained; full 4-DOF arm added on PCA9685 HAT for Class II task capability.
Cameras	X			Retained both internal cameras; added two DW Explore cameras on external mounts for expanded FOV.
Frame			X	Complete redesign: 1-inch 6061-T6 aluminum tubing TIG-welded to Class II structural standards, replacing 2025 HDPE chassis.
Tether		X		Replaced low-gauge power conductors; retained 100-Mbps Ethernet for ROV-to-surface comms.
Thrusters	X			Six-thruster vector configuration retained (4× U2 Mini horizontal, 2× T200 vertical).



2.2 Innovation

At the outset of the 2026 season, the engineering team identified frame fabrication as a critical constraint. The prior year's Defiance ROV utilized 0.625 cm aluminum tubing, which — while structurally sound — proved extremely difficult to weld due to the small cross-sectional area. The frame fabricator required approximately three months to complete the structure, creating a significant scheduling bottleneck and limiting time available for systems integration and in-water testing.

Recognizing this, the team conducted a structured material evaluation at the start of the 2026 design cycle, assessing four candidate materials against four criteria: fabrication time, cost, structural integrity, and corrosion resistance.

HDPE something we had used before and was attractive for its low cost. The natural buoyancy, but bonding HDPE sections into a rigid, complex frame structure requires specialized adhesives and surface preparation that the team determined would not be achievable within the two-

Material	Fab. Method	Est. Time	Cost	Structural Integrity	Corrosion Resistance
0.625 cm aluminum (2025)	Welding	~12 weeks	Moderate	High	High
HDPE	Mech. fastening/bonding	Too lengthy	Low	Moderate	High
Carbon fiber 0.25" rod	Adhesive bonding	Too lengthy	High	Very High	High
2.54 cm aluminum (2026) ✓	Welding	~3 weeks	Low	High	High

month build window. The 0.25" carbon fiber rod offered exceptional strength-to-weight ratio but presented similar adhesion challenges—epoxy bonding carbon fiber joints to competition-grade rigidity is a time-intensive, iterative process that fell outside the team's fabrication timeline and budget.

The square 2.54 cm aluminum tubing emerged as the clear solution. It retained all the reliability and structural integrity that made aluminum the team's material of choice in 2025, while the larger cross-section made welding dramatically more accessible. Frame fabrication time dropped from approximately 12 weeks to 3 weeks (a 75% reduction), freeing the remaining build window for subsystem integration, software development, and in-water testing. Per-unit material cost also decreased due to wider availability of 1-inch stock.

This decision reflects a core engineering principle: innovation is not always about adopting a novel material—it can mean rigorously evaluating alternatives and optimizing a proven solution to eliminate a process bottleneck. By applying structured comparison and lessons learned from the prior build cycle, the team transformed fabrication from the season's biggest risk into one of its earliest completed milestones.

2.3 Problem Solving

Ideation and Design Process

At the start of each season, UR² dedicates the first phase to brainstorming and gathering inspiration. The team attends regional ROV events and engages with the marine technology community in Northeast Michigan to expose members to real-world engineering solutions. This helps the team start thinking about new ideas and engineering future solutions. Once a design direction is identified, the project manager develops a structured build plan that maps each decision to a specific MATE mission requirement and establishes a timeline. The CFO then analyzes costs, identifying the least expensive path to accomplish each goal and determining what can be sourced, reused, or built in-house.

Robotic Arm and Claw Development

This year, the team drew inspiration from the Magnum Ocean Engineering ROV, encountered while taking courses at Alpena Community College (ACC). Studying that system's manipulator prompted UR² to develop its own improved claw, the UR² Robotic Arm, a four-degree-of-freedom manipulator built for Defiance HD.

Development began with a large-scale prototype built by one of our team members as a capstone project at ACC, constructed from 1-inch square aluminum tubing, an Arduino Uno Rev 3, an HC-05 Bluetooth module, one SG90 servo, and five MG996R servos. Components were modeled in Fusion 360 and SolidWorks

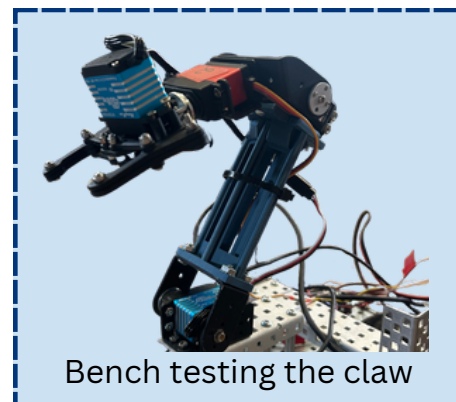
and printed on a Stratasys F170 using ABS filament, selected for its strength and suitability for functional prototyping. During fabrication, initial prints lacked sufficient infill density and failed under servo load. Maximizing infill density in the GrabCAD slicer resolved the issue. We also added a fault indicator light and a hardware reset button to improve field serviceability.



Magnum ROV from ACC

Bench-Test Prototype and Claw Selection

Before integration onto Defiance HD, the team built a bench-test prototype to validate the arm's mechanics independently of the ROV hull, reducing integration risk during the final build phase. For the end effector, the team first evaluated a commercially available claw but found it mechanically inadequate and overpriced. The team chose to use a 3D-printed claw instead, reducing cost, improving durability, and keeping the design in-house where it could be modified and repaired as needed.



Bench testing the claw

2.4 Systems Approach

Defiance HD was engineered as a fully integrated system in which each subsystem was designed with direct awareness of the others. The vehicle is built around a 2.54 cm welded aluminum frame that serves as the structural foundation for all other systems, providing rigid, predictable mounting points for thrusters, enclosures, cameras, and manipulators while maintaining a compact system for competition maneuvering.

The control architecture runs across a dual-Raspberry Pi 4 network. The surface Pi (192.168.2.100) reads Xbox Series X controller input and relays JSON command packets over UDP via the tether to the ROV Pi (192.168.2.101), which runs BlueOS and simultaneously manages the Navigator flight controller, thruster outputs, and the servo arm controller.

The Manipulator systems include a 4-DOF robotic arm driven by four 25g waterproof servos via a PCA9685 HAT and a Blue Robotics Newton Gripper, both controlled through the same Xbox input mapping, keeping pilot workload consolidated.

The Vision is provided by two cameras: a fixed wide-angle and a 180 degree servo-tilting camera, supplemented by an OpenCV-based European Green Crab detection module that runs autonomously on the video feed.

All subsystems share a common power bus protected by a 25-amp inline fuse, with leak detection sensors providing a final safety layer across the entire vehicle.

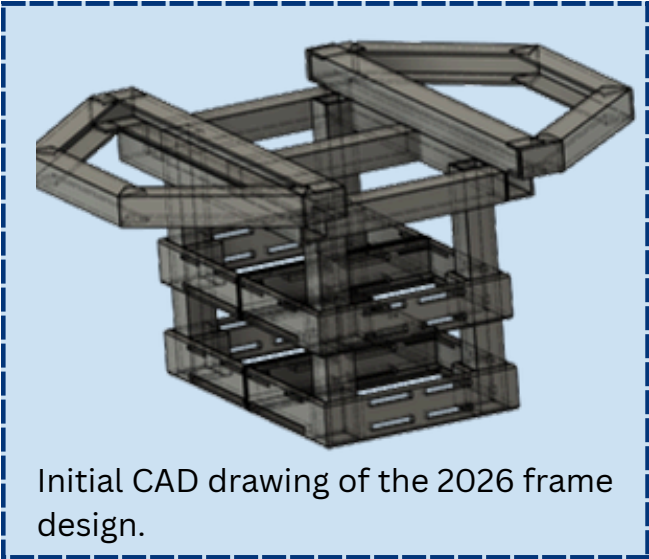
3. Vehicle Structure

For the 2026 vehicle structure, the team retained the six-thruster vectored configuration that gave the 2025 Defiance its maneuverability advantage, four horizontal thrusters for surge, sway, and yaw, and two vertical T200 thrusters for depth control. This arrangement was proven and cost-effective to replicate, requiring no redesign of thruster mounts or BlueOS motor mapping. With this design made, we proceeded to the structure design.

The trade-off made was in frame stock: upgrading to 2.54 cm aluminum tubing increased material weight and per-foot cost compared to rod stock but returned significant structural dividends. The larger tube diameter produced wider, more consistent weld joints that distribute stress across a greater cross-sectional area, qualifying the vehicle as a true Class II platform capable of supporting the 4-DOF robotic arm, Newton Subsea Gripper, 2 cameras, and dual Raspberry Pi electronics without frame flex under load. Fabrication time dropped from over three months to approximately three weeks.

The team describes the aluminum frame as the "bones" of the vehicle. Around this skeleton, subsystem panels and mounting surfaces are 3D-printed in PETG-CF, providing a lightweight, corrosion-resistant outer structure—the "skin"—that can be reprinted and replaced quickly if damaged, keeping repair costs low and downtime minimal.

Defiance HD was engineered to be compact without sacrificing capability. The vehicle measures 45 cm wide, 34 cm high, and 14.5 cm in length—a footprint deliberately kept tight to maximize maneuverability in confined competition spaces while still accommodating a full six-thruster vectored propulsion system and a 4-DOF robotic arm. The wider stance relative to the vehicle's length provides a low, stable platform that resists roll during arm operations. At 34 cm tall, the vertical profile keeps the center of buoyancy well above the center of gravity, contributing to passive pitch stability during hover.



Parameter	Defiance 2025	Defiance HD 2026	Change	Trade-off Rationale
Frame Material	0.625cm rod	2.54 cm tubing	↑ Larger	Stronger joints; easier TIG weld
Fabrication Time	~12 weeks	~3 weeks	↓ 75%	More time for systems integration
Material Cost	Moderate	Lower	↓ Cost	1-inch stock more widely available
Joint Strength	Moderate	High	↑ Stronger	Wider weld bead; better stress

Frame Analysis

4. Vehicle Systems

Every system aboard Defiance HD was selected through a deliberate evaluation of mission requirements, cost, and build feasibility. Each reflects lessons learned from the 2025 Defiance build cycle.

- Propulsion uses a retained six-thruster vectored configuration: four ApiQueen U2 Mini horizontal thrusters for surge, sway, and yaw and two Blue Robotics T200 thrusters for vertical control. Both thruster models were carried forward from 2025 because they performed reliably and required no new motor mapping in BlueOS—eliminating re-engineering costs while preserving the maneuverability needed for precise station-keeping during wind turbine inspection and buoy sensor installation tasks.
- Manipulation evolved significantly from 2025. The Newton Subsea Gripper was retained as a proven, cost-effective single-point gripper. To it, the team added a custom 4-DOF robotic arm driven by four 25g waterproof servos via a PCA9685 HAT—a student-fabricated solution chosen over commercial alternatives because it offers full control customization at a fraction of the cost and directly enables object placement and sensor installation tasks in the 2026 mission. We now can use this more dynamic manipulator to turn and remove biofouling from the observatory camera.
- Vision utilizing two cameras, one fixed external DW Explore is added for wide-angle task coverage, and two internal servo-tilting cameras are retained for navigation. The enclosed servo-camera was reused for its ability to rotate 180 degrees and USB compatibility with the existing Raspberry Pi architecture, requiring no additional interface hardware.
- Computer vision, an OpenCV-based European green crab detection module, was developed entirely in-house, adding autonomous invasive species identification capability at zero component cost beyond student development time.

5. Electrical System and Control

The Blue Robotics acrylic enclosure guarantees Defiance HD's underwater safety and efficiency due to its sturdy and watertight design. It is versatile for various underwater tasks with dimensions of 100mm by 1000mm and a depth rating of up to 100m. Its electronics are securely housed inside, so it is primed for dependable performance in aquatic environments.

Defiance HD features two electronic speed controllers (ESCs) connected to two T200 brushless thrusters for vertical movement within the enclosure while the four vectored U2 horizontal thrusters contain waterproof ESC that are external to the enclosure. This helps with cooling and space in the enclosure. These ESCs receive their Pulse Width Modulation (PWM) signal from the Blue Robotics Navigation board, guaranteeing seamless integration and operation. The Navigation Board interfaces with a Raspberry Pi 4 processor running the Blue Operating System, offering advanced functionality and control for Defiance HD's underwater tasks.

Defiance HD is equipped with an HD camera with a 180-degree view, mounted on a single servo to regulate the camera's vertical scanning. This feature allows the pilot to adjust the camera position downwards or upwards by an additional thirty degrees of view. The enclosure also houses leak detection sensors that are placed throughout the enclosure to make sure all internal electronics have protection systems in place.

5. Electrical System and Control Continued

Defiance HD's surface operations and command control are powered by the HP EliteDesk 800 G3 Mini Business Desktop, which operates on a Linux-based system. This compact topside computer is small enough to be held in one hand, making it ideal for operational needs. Its portable command-and-control system can easily fit in your pocket, providing added convenience. The HP Elite Mini can be powered by a standard AC outlet or a 12V DC supply, ensuring seamless transitions for remote operations.

We designed Defiance HD to be lightweight and compact to facilitate easy storage and transport at the control station. To enhance Defiance HD's mobility, our team developed a mobile control station. This mobile surface control station is a complete 12V system, capable of housing its own 12V battery or sourcing power from another 12V system. The station is built on an aluminum dolly, allowing for easy transport from a vehicle to a ship. It features a 19-inch LCD screen that provides a clear video feed from the ROV, making piloting straightforward and efficient.

Defiance HD's tether is hardwired directly into the control station, carrying power, video, and control data between the ROV and the surface. All subsystems — thruster control, camera feeds, and the crab detection overlay — feed into a single display so pilots receive consolidated feedback without switching between screens. Tether protocol can be found in section 8

5.1 Control System

Requirements Determination

UR²'s control system requirements were driven by the 2026 RANGER mission tasks and Defiance HD's upgraded subsystems. The team identified three core requirements before finalizing any design: monitor outputs to display ROV video, computer vision detection, autonomous 3D modeling, and navigation data simultaneously; a stable platform capable of running the surface computer under competition conditions; and a layout that kept pilot and operator workstations separated to reduce communication errors.

Hardware Design and Component Integration

Rather than purchasing a new control station, the team repurposed a welded-steel desktop workstation slated for recycling by the school district, reducing cost while gaining a more capable platform than a standard control box. This idea came from the team's time aboard the *Octanist*, a Viking Explorer Class cruise ship with a fully functional research lab and ROV station. Our team was invited to participate with staff members and observed the multi-monitor stations used by professional ROV pilots. This experience allowed us to see how the surface control systems are used in a professional setting and provided us with a model for creating our own reliable, industry worthy control station.

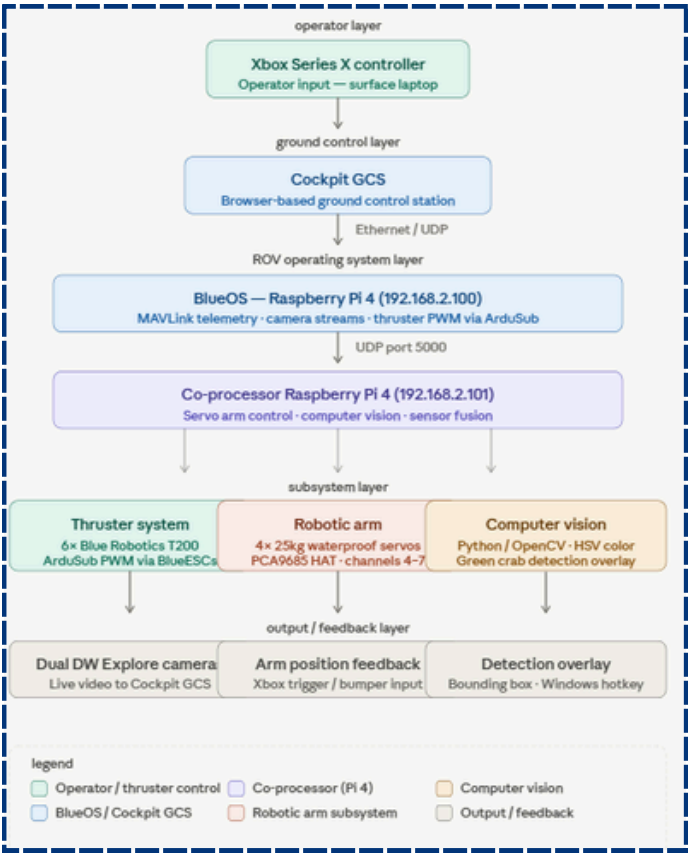
Build Process and Connection Methodology

Wiring in both control stations is labeled and strain-relieved to meet MATE standards. Each connection is documented in the system integration diagram. Joystick input, video signal, and thruster response were each bench-tested independently before full in-water testing with Defiance HD. In addition to this we created a testing criteria to make sure each part was meeting or above standards. Some of our standards involved enclosure pressure and temperature, runtime capabilities, structural integrity, and reliability.

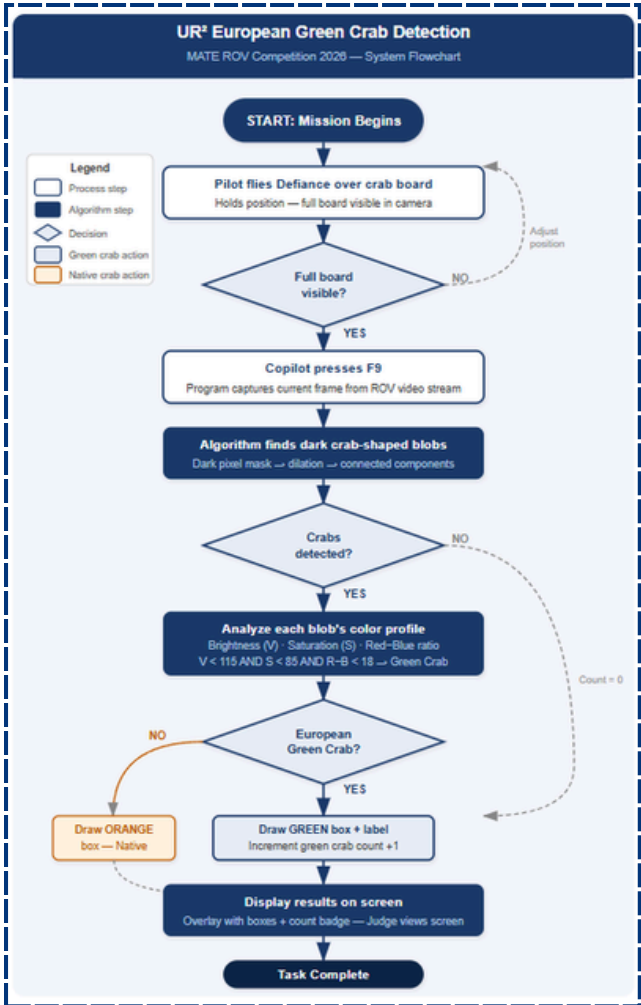
5.2 Control Architecture

The Defiance HD operates on a dual Raspberry Pi 4 architecture. The primary Pi (192.168.2.100) runs BlueOS, an open-source ROV operating system that manages MAVLink telemetry, six-thruster PWM output through ArduSub, and dual live camera streams from our two DW Explore cameras. Operators interface with the vehicle through Cockpit, a browser-based ground control station, using an Xbox Series X controller for full vehicle piloting. The secondary Pi (192.168.2.101) receives formatted UDP command packets from the primary on port 5000 and handles robotic arm control through a PCA9685 PWM HAT, driving four 25g waterproof servos assigned to shoulder, elbow, wrist, and gripper functions—keeping arm servo timing isolated from the flight control stack.

The secondary processor also runs a Python/OpenCV computer vision pipeline for European green crab (*Carcinus maenas*) detection, supporting the 2026 MATE task requiring teams to identify and count invasive green crabs on a 50×50 cm sample board while distinguishing them from native species such as rock and Jonah crabs. The system analyzes the live camera feed in the HSV color space, evaluating brightness, saturation, and red-to-blue ratio to differentiate invasive from native species under variable underwater lighting conditions. During a detection run, the operator presses a single hotkey to trigger the system — from that point, identification is handled autonomously. Detected European green crabs are highlighted with green bounding boxes, while native species receive orange boxes and are labeled but excluded from the count. A large count badge in the top-left corner of the display updates in real time after each run. Figure (#) shows the program interface and startup procedure used on deck.



The above chart outlines the main control system of the Defiance HD, and below is the flow chart for the green crab detection software.

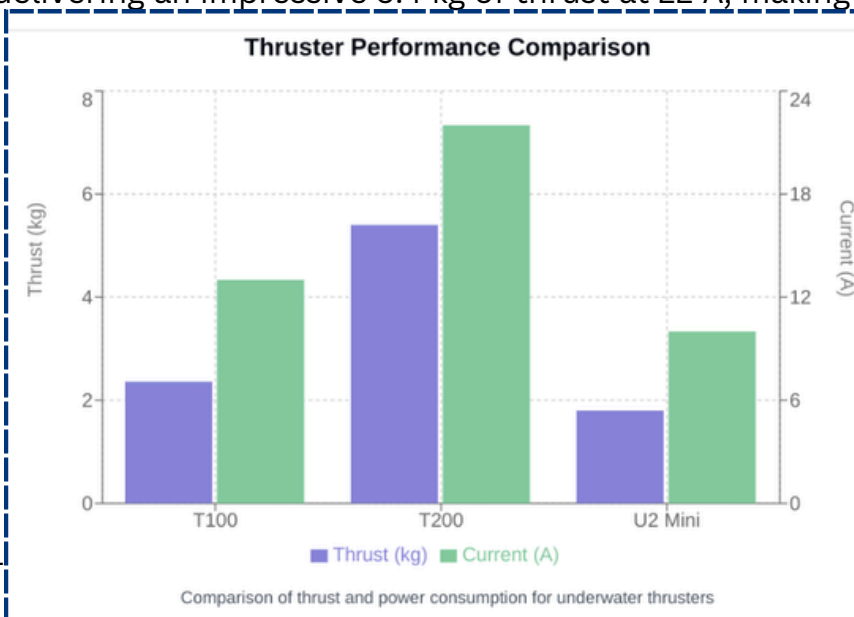


6. Propulsion

Our team has been working with the Blue Robotics T-100 for a few years. Last year, we chose a smaller thruster with lower power requirements; however, this decision resulted in a loss of overall power. Given the location and depth requirements for our regionals as well as adhering to a stronger class II ROV, we felt it was necessary to reevaluate our thrusters.

The design team conducted a comparative study of the thrusters we used, focusing on reliability. We analyzed the Blue Robotics T200, T100, and the ApisQueen U2 Mini. We have not designed an ROV with the T200 before, but we have discussed them with other ROV teams that have used them. The T200 emerged as the most powerful option, delivering an impressive 5.4 kg of thrust at 22 A, making it ideal for large, demanding

underwater vehicles. In contrast, the Blue Robotics T100 offers a balanced middle ground, providing 2.36 kg of thrust with a 13A current draw—suitable for medium-sized ROVs. The ApisQueen U2 Mini, on the other hand, is the most compact option, delivering 1.8 kg of thrust at 10A, making it perfect for lightweight, space-constrained underwater vehicles. Each thruster has its advantages: the T200 excels in raw power, The T100 offers versatility, and the U2 Mini prioritizes efficiency and size. The team chose to use a six-thruster vectored configuration



made up of four 45 degree angled ApisQueen thrusters and two T200s for lateral movement to help with swift precise movements and efficiency in recovering mission related props.

7. Buoyancy and Ballast

Buoyancy and ballast are among the most critical factors in the performance of our ROV. When it comes to having excellent control, precise movements, or being able to return to the surface while carrying assets quickly, having the correct buoyancy for the job is essential. Buoyancy was always something we considered before the ROV hit the water. So that is why we did extensive research beforehand on the parts we used, such as our aluminum frame, to keep it lighter than our previous year's designs. Buoyancy calculations are grounded in Archimedes' Principle, which states that any object submerged in a fluid experiences an upward force equal to the weight of the fluid it displaces. For each component, the team calculated:

Net Buoyant Force (g) = Weight of Water Displaced (g) – Weight of Component in Air (g)

A positive net buoyant force indicates the component adds lift; a negative value indicates it adds weight relative to its displacement. Freshwater density of 1.0 g/cm³ is assumed, meaning water displacement in cm³ equals grams of water displaced directly. We started our calculation with our enclosure $V = \pi \times r^2 \times L = \pi \times (5.715 \text{ cm})^2 \times 30.48 \text{ cm} = 3,124.7 \text{ cm}^3$

With the enclosure assembly weighing 2,334 g in air, the cylinder generates a net buoyant force of +790.7 g – the single largest source of positive lift on the vehicle. This is a significant improvement over previous ROV designs that used smaller enclosures. The aluminum frame of Defiance HD has a dry weight of approximately 2,000 g but displaces only 316.6 cm³ of water, resulting in a net buoyant force of -1,683.4 g. Combined with the negative contributions of the Newton Gripper, robotic arm, cameras, steel hardware, and plastic covering, the vehicle without supplemental buoyancy would have a net negative buoyancy of approximately -2,033 g.

To achieve the target positive buoyancy margin, the team added closed-cell polyethylene foam to the frame structure. Closed-cell foam is ideal for this application because it does not absorb water over time, maintains consistent displacement properties throughout a dive, and can be easily shaped and secured to the frame with minimal added weight. The foam used has a density of approximately 30 kg/m³, meaning 2,233 cm³ of foam weighs only approximately 67g in air while displacing 2,233 g of water—providing a net lift contribution of +2,166 g.

Foam blocks are distributed symmetrically across the upper frame rails to maintain trim and prevent pitch or roll bias during operation. Placement was verified through in-water trim testing in the school pool prior to competition.

8. Tether

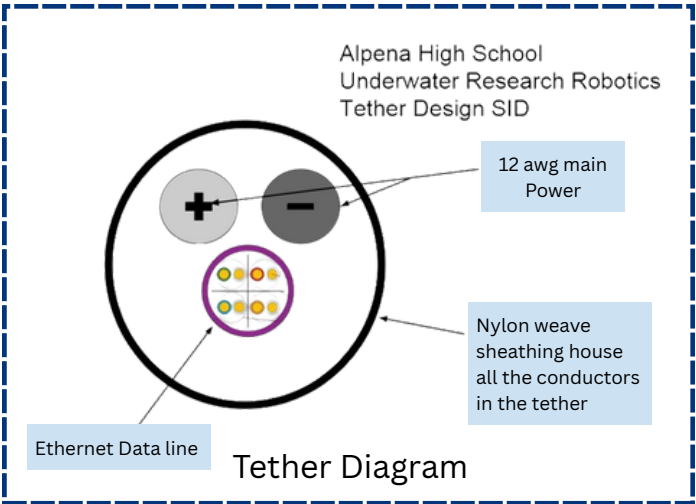
Another advantage for our ROV is our neutrally buoyant tether, which reduces the pull, furthering the amount of control we have operating Defiance HD. We are also going to add foam on the surface a

Component	Water Displacement (cm³)	Weight in Air (g)	Weight of Water Displaced (g)	Net Buoyant Force (g)
Newton Gripper	203.6	529.0	203.6	-325.4
Thrusters (×6)	871.7	850.0	871.7	+21.7
External Cameras	47.0	84.0	47.0	-37.0
Enclosure (12" × 4.5" cylinder)	3,124.7	2,334.0	3,124.7	+790.7
Plastic Frame Covering (3D printed)	598.1	807.0	598.1	-208.9
Steel Hardware	115.5	906.0	115.5	-790.5
Aluminum Frame	316.6	2,000.0	316.6	-1,683.4
Closed-Cell Foam (buoyancy)	2,233.0	67.0	2,233.0	+2,166.0
TOTAL	7,510.2	7,577.0	7,510.2	+133.2

ttached to the tether to lessen the drag even more. Factoring in all of the parts allows us to assess if we need to add ballast or buoyancy and we discovered that Defiance HD would be slightly negatively buoyant. With this information, we knew how much to add to make our ROV ideally slightly positive.

Tether Protocol

- Tether is stored under the control station in storage tub
- Check if topside tether carabiner is clipped to the I-bolt on control station
- Remove ROV end of tether from storage tub
- Make sure tether is not twisted or tangled
- Lay tether out on deck and avoid placing it in high foot traffic area
- Recheck connections on both ROV side and control station ends of the tether



9. Payload and Tools

The Cameras

This season’s ROV, Defiance HD, is equipped with two UVC-compliant HD USB cameras that incorporate patent-pending hardware to improve underwater vision in low-light conditions. Each camera uses a high-sensitivity Sony image sensor paired with a proprietary four-layer PCB design, delivering clear, low-noise video suitable for operation in the 5 m dive tank environment. Both the cameras are IP69K rated for robust waterproofing and are integrated into the ROV’s control system for direct, low-latency video to the pilot station.

9. Payload and Tools Continued

cameras are IP69K rated for robust waterproofing and are integrated into the ROV's control system for direct, low-latency video to the pilot station.

One camera provides a forward view for navigation and task awareness, while a dedicated claw camera offers a side perspective focused on the claws. The claw camera gives pilots a precise view of gripper alignment and a view of props from the side, improving placement accuracy during the mission. Complementing the video feeds, the team developed custom software that renders a real-time 2D replica of the claw's position on the operator display. This software mirrors the physical gripper orientation, enabling pilots to confirm alignment and motion even when the camera view is partially obscured.



The ROV with both cameras.

The Grippers

The UR² chose to reuse their stationary Newton Gripper from the previous year, which featured a large claw surface that allowed the team to grip PVC objects evenly and securely. However, this design lacked mobility, as it could not change direction without manual adjustment by a team member. This led to the creation of the UR² Robotic Arm, a four-degree-of-freedom manipulator designed for the MATE 2026 ROV competition. Mounted on the ROV Defiance HD's arm enables the pilot to perform precise underwater object-handling tasks. The system is controlled using an Xbox Series X controller connected to a Raspberry Pi 4 at the surface, which transmits commands through an Ethernet tether to another Raspberry Pi onboard the ROV that runs the servo control system. The team then worked together to create the software to run on the Raspberry Pi.



Newton Grabber

Given that mission tasks require lifting and connecting multiple devices, the team evaluated whether to rebuild or replace their existing gripper, which had been used for three competition seasons, the Newton gripper. Ultimately, the team decided to reuse a Newton gripper from Blue Robotics.

Feature / Criteria	UR ² Robotic Arm (New)	Blue Robotics Newton Gripper
Primary Function	Precision manipulation, alignment, lifting, connecting	Secure gripping of mission props and larger objects
Degrees of Freedom	4 DOF	1 DOF
Mobility	High—fully pilot-controlled	Moderate—fixed mount with actuated jaws
Control System	Xbox Series X → Surface Pi → ROV Pi	Xbox controller via brushed ESC
Actuation	Servo-driven joints	Linear actuator with brushed motor + lead screw
Grip Capacity	Depends on end-effector	Up to 6.2 cm diameter
Advantages	High precision, versatile	Durable, corrosion-resistant, proven reliability
Limitations	More complex, requires software + electronics	Limited dexterity compared to robotic arm
Best Use Cases	Turning valves, aligning connectors	Coral samples, lobster pot, eDNA sensor, PVC pipes

Gripper comparison chart

Sensors

An integral part of Defiance HD is its sensors. One of our sensors is a depth sensor that is very important and programed for the function of depth holding. Which is helpful when trying to keep in a certain position in the pool and to endure we stay at the same depth vision for flying a transit. Our other sensor is a leak detector inside of the enclosure. More information on this can be found within the safety section.

10. Build vs. Buy, New vs. Used

UR² evaluated each subsystem for build, buy, or reuse using a consistent set of criteria—cost, reliability, development time, serviceability, and mission fit—and recorded the results in a decision table to guide procurement. When revenue was constrained, we prioritized reuse and in-house builds that offered clear cost savings without compromising reliability. Parts were classified as reusable when they had been in service for only one season and passed functional checks; these items were logged with provenance and a conservative fair-market reuse value. For purchases,

We recorded invoice price, vendor, and approval; for donated items, we recorded FMV and attached donor letters. This disciplined workflow let us compare true net spending (cash outlay) against predicted costs and ensured the team made repeatable, auditable decisions.

Two examples illustrate our build-vs-buy approach. The frame was identified as a build priority: the 2025 frame exhibited chips and hairline cracks, which required significant redesign to accommodate the new claw and thruster layout. Reusing it would have required extensive modification and increased the risk of hidden fatigue failures. Building a new aluminum frame in-house enabled us to create a Class II ROV that is fully customizable for the 2026 MATE mission. The design is fully documented with CAD files, torque specifications, and a spare-parts list so future teams can reproduce or adapt it. An additional advantage of the in-house build was rapid iteration and repair: small changes or fixes could be handed to our welder and returned the same day—for example, when we decided to add a front camera, the welder produced a threaded aluminum mount within an hour, and we installed it immediately.

Secondly, the Newton Gripper was handled as a buy/build. We purchased a proven, serviceable gripper that the team has relied on for the past two seasons—to save development time and ensure mission reliability, while keeping the option to modify or repair it in-house. That familiarity reduced risk during testing and freed the team to focus on developing a custom claw tailored to this year's tasks; both the Newton Gripper and our custom claw were available for use on the ROV. By building the frame in which customization and safety were critical and selecting a familiar, serviceable gripper, we struck a practical balance among cost, schedule, and reliability while maximizing reuse wherever appropriate.

Decision Driver Table

Decision driver	Build	Buy	Reuse
Cost	Lower if materials/time available	Higher upfront cos	Lowest cash outlay
Time to deploy	Longer (design + test)	Shortest	Short (inspection/repair)
Reliability	Depends on testing	Proven vendor reliability	Proven in-field performance
Top side control Desk	Exact customization,	Saves Time and money, Good condition, Durable	Durable, saves some time
Serviceability	High (custom)	Varies	High if familiar

Pros Vs Cons List

Components Name	Build		Reuse		Buy		End Decision
	Pros	Cons	Pros	Cons	Pros	Cons	
Thrusters	Customization	Challenges to water proof, longer testing period	Saves money, trustworthy Product, already know how it works, and wired up	Having to take apart 2025 ROV, ESC issue, not supper reliable	We know the quality of the thruster, provide longevity through the 2025 season	Costs money	Buy
Claw	Customization, creating exactly what needed for mission	Challenges to water proof, Longer testing period, Take longer to make	Saves money, Trustworthy Product, Already familiar with the part	Having to take apart 2025 ROV, several stripped Screws	Provide longevity, durable	Costs money, same part we have already	Buy/build
Frame	Customization, creating exactly what needed for mission	Takes a long time and would have to test the efficiency	Saves time troubleshooting, Saves money	Frame will have to be updated and has cracks from last years	Saves time, Durable	Non customizable to our tasks	Build
Top side control Desk	Exact customization,	Time consuming and costly for new desk and materials	Saves Time and money, Good condition, Durable	Nothing major just a couple adjustments and add ons	Durable, saves some time	Cant customize	Reuse
Tether	Exact customization	Time Consuming	Worked well in 2024, Neutrally buoyant	Has a small amount of damage that needs to be repaired	Reliable and durable	May not have the right amount of wires or gauges needed	Reuse
Encloser	Exact customization, Can make it smaller then what we have	Would have trouble sealing, costly to prototype with different materials	We know it works, seals, already customized, and reliable	Taking apart 2025 ROV, having to remove all the electronics from the year before	Little work to get it assembled and sealed	Cost money, have to add customizations to it	Reuse

11. System Integrated Diagrams

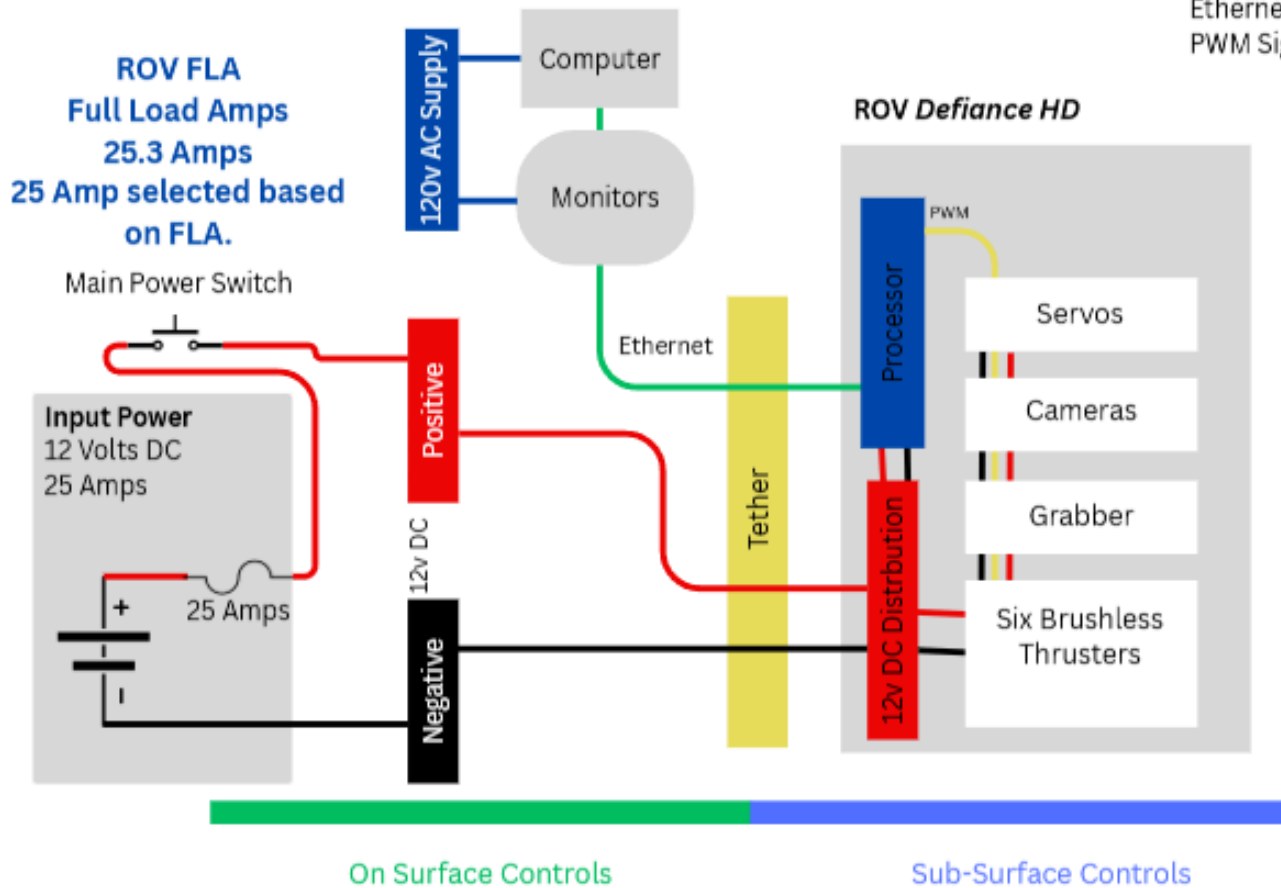


UR2
Alpena High School

System Integrated Diagram (SID)

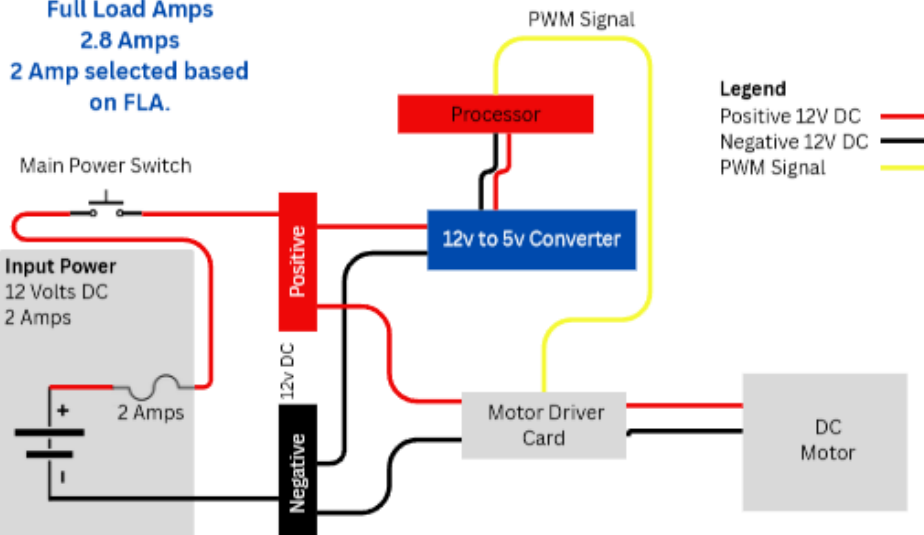
Legend

- Positive 12V DC —
- Negative 12V DC —
- Ethernet —
- PWM Signal —



Non-ROV Device Float System Integrated Diagram (SID)

Non-ROV FLA
Full Load Amps
2.8 Amps
2 Amp selected based on FLA.



12. Safety

At UR², our team follows a "check twice" policy and encourages everyone to reference our safety checklist regularly. Before working on equipment or handling parts, every team member completes a rigorous ten-hour OSHA health and safety class. This training helps ensure a safety culture and significantly reduces the risk of accidents. Additionally, we have two certified lifeguards on deck at all times. In addition, when the ROV took the ACC class, we underwent real-world training for actual operations. The team used the Oceaneering America Region HSE Employee Handbook in class to ensure every team member knows how to be safe. For example, the team conducted a foundation inspection for a local business and incorporated all the safety speeches.

We extend our commitment to safety beyond the team to include the ROV and our working environment. Defiance features two strain-relief systems that prevent the tether from being forcibly disconnected. The first strain relief is on the back of the ROV and is a simple carabiner clip that clips onto a cable thimble. This setup attaches to all the wires from the enclosure, preventing strain. The second strain relief is connected to the side of the control station, so the tether is securely attached. The ROV also has an in-line fuse positioned 30cm from the power source. In addition, all thrusters have a 3D-printed guard over them so that fingers or other hazards can enter the vicinity of the propeller. Finally, all of the ROV's edges are rounded, so there is no risk of anyone cutting themselves while picking up or working with the frame.

Safety Procedures

Our motto is simple: a safe company is a happy and productive company. We adhere to this principle every time we meet, build, and launch. When working in the makerspace, all team members are required to wear safety goggles and closed-toed shoes. Additionally, team members with long hair must tie it back when using tools or machinery such as hand drills or drill presses. When team members use equipment in the practice tank, they must ensure the floor is dry and remove any standing water that could pose a slip hazard. A "Wet Floor" sign must be displayed during all tank activities. All 120V service in the practice tank must be connected to a GFI plug or adapter. This requirement also applies to all 12V power supplies. Finally, any team member can call a stop-work order if they believe a safety issue has occurred. All work must cease until the situation is assessed and resolved.

Safety Training Chart

Crew Member Name	Job Title	Company Safety Training	10-Hour Osha Safety Certification	15-Hour Osha Safety Certification	Lifeguard Training	First Aid Training
Lydia Thompson	Ceo	✓	✓	✓	✗	✓
Gunner Moe	Safety Officer/Engineer	✓	✓	✓	✓	✗
Taylor Widajewski	CFO	✓	✓	✗	✗	✗
Ray Johnson	CTO	✓	✓	✓	✗	✗
Gus Wirgau	Pilot	✓	✓	✗	✗	✗
Matt Kowalski	Co-Pilot/Prop Specialist	✓	✓	✗	✗	✗
Kylie Gagnon	Fabricator/Weider	✓	✓	✗	✗	✗
James Rawlings	Fabricator	✓	✓	✗	✗	✗
Dawson Smolinski	Prop Specialist	✓	✓	✗	✗	✗
Alexa Blumenthal	Software Engineer	✓	✓	✗	✗	✗
Myah Rondeau	Project Manager	✓	✓	✗	✗	✗
Elizabeth Rabbideau	Payload Specialist/Media Manager	✓	✓	✗	✓	✓

Safety Check Sheet

Pre-Power	Yes	No	If No...
Area is clear of tripping hazards			Clear the deck of tripping hazards before moving on
All team members have proper PPE ☐ Safety Goggles ☐ Hair pulled Back ☐ Closed toed shoes			Obtain proper PPE before going near the ROV
Tether is free of tangles			Untangle tether and lay out on the pool deck
Strain relief is attached			
No visible damage inside the enclosure			Do not put ROV in water. Fix the damage first
The enclosure is sealed fully			Make sure the enclosure is sealed before placing in water
Thrusters are guarded and free of debris			Clear debris and attach guards
ROV Launch			
Control box powered on			Power control box and ROV on
Pilots keep hands off controls			
Payloader shouts "Hands on" before grabbing the ROV			
ROV placed in water and visually checked for leaks showed by bubbles			
If no leaks the payloader shouts "Launch" then lets go of ROV			
When payloaders hands are off ROV the payloader must shout "Hands off"			
Pilot shouts "Power on" and begins driving ROV			
ROV Retrieval			
pilot shouts "returning to surface"			
when ROV is at surface payloader			

13. Testing and Troubleshooting

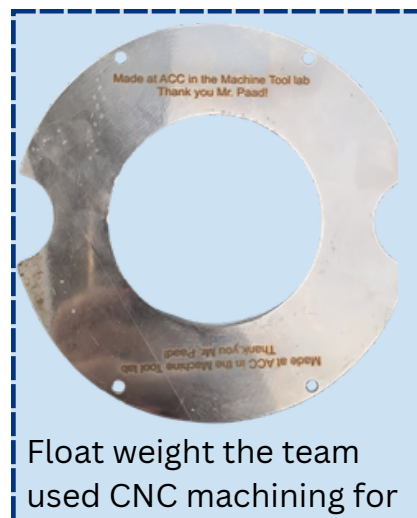
The UR² team follows an iterative engineering process in which new design ideas are first explored through rapid prototyping and proof-of-concept testing. When the team decided to evaluate VEX aluminum components for the 2026 ROV frame, we began by constructing a prototype ROV to assess durability, rigidity, and ease of assembly. This prototype, built in early September, was field-tested at the Square One ROV Competition. Competing with the prototype allowed the team to gather real-world performance data and verify that the VEX aluminum could withstand operational loads and mission stresses.

Testing showed that while the VEX aluminum performed well overall, the team identified a need for increased thickness and rigidity on the bottom portion of the frame, where the claws and camera would be mounted. This led to the development of a hybrid frame design using two different aluminum types: 2.54 cm square tubing for the base to provide structural strength and VEX aluminum for the side structures to reduce weight and maintain modularity.

The Float: Testing and Troubleshooting

A similar iterative approach was used during the development of the FLOAT system. Initial pool tests revealed that the FLOAT was excessively buoyant and unable to descend as required. The FLOAT sub-team re-evaluated their buoyancy calculations, recalculated the required ballast, and produced a revised 3D CAD model in SolidWorks. The final weight component was machined at ACC and installed by a teammate, resulting in a FLOAT that achieved neutral buoyancy during subsequent pool trials.

Throughout the season, the team relied heavily on recalculating, validating, and cross-checking engineering data whenever troubleshooting issues arose. Whether addressing buoyancy, structural integrity, or component placement, the team consistently returned to the underlying math and physics to guide design decisions. This data-driven testing process ensured that each subsystem of the ROV met mission requirements before integration into the final vehicle. As the team entered the 2025–2026 season, it became clear that the float needed a significant redesign. The previous float faced two persistent



Float weight the team used CNC machining for

challenges: its size made it difficult to return to the surface after diving, and several weak points in its construction allowed water to leak in. Reliability had been an ongoing issue, and this year UR² was determined to solve it.

The result is Perseverance—an autonomous vertical profiling float designed and built from the ground up by UR² to collect oceanographic data at programmed depth intervals as part of the 2026 competition mission. Perseverance profiles to a depth of 2.5 meters, holding position for 30-second data collection intervals, and operates entirely independently of the ROV tether.

To achieve this level of reliability and autonomy, the team made a key decision: replacing the Raspberry Pi 4 with an ESP32 as the float's primary controller. This shift allowed for a leaner, power-efficient, and more dependable system.

Perseverance has completed five major engineering iterations this season alone. Each iteration drove meaningful improvements in performance, waterproofing, and control. Another key design change from previous years is that we previously used PVC for the electronics housing, resulting in a larger, bulkier design. When the team switched to an ESP32, they were able to source an acrylic enclosure that was significantly smaller than any previous design. Reducing the float's length from 53 cm to just 25 cm, a 52.8% reduction.

13. Testing and Troubleshooting

A central engineering challenge was sizing the buoyancy engine. To transition between positive and negative buoyancy, the float needs a minimum net buoyancy swing—the team set a design target of ±100 g (200 g total). Plunger stroke was calculated using the following relationship:

Stroke (cm) = Volume (cm³) ÷ 20.27 (for a 2" diameter plunger)

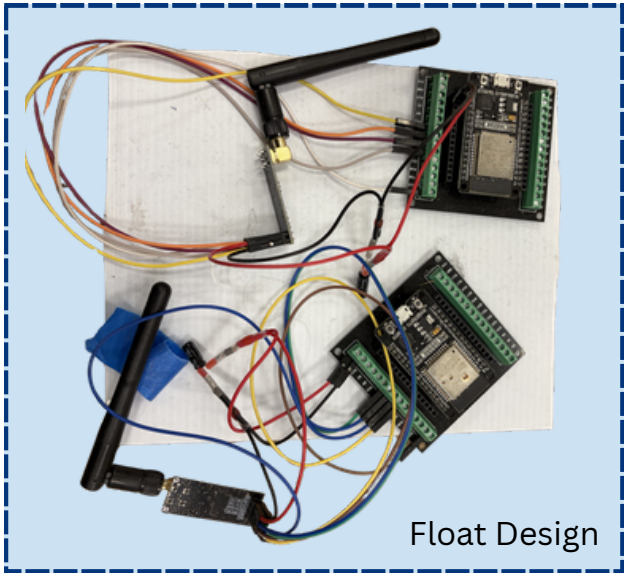
The table to the right shows displaced volume and buoyancy change across a range of stroke lengths. The team selected a 4.5" (11.43 cm) stroke, yielding approximately

237 g of buoyancy change – 19% above the design minimum – ensuring reliable depth transitions within the physical constraints of the cylinder housing.

Stroke(inches)	Stroke(cm)	PlungerArea	VolumeDisplaced	BuoyancyChange (g)	Buoyancy (oz)& Notes
1.0"	2.54 cm	20.27 cm²	51.5 cm³	52.8 g	1.86 oz — Insufficient for control
2.0"	5.08 cm	20.27 cm²	103.0 cm³	105.6 g	3.72 oz — Marginal; not recommended
3.0"	7.62 cm	20.27 cm²	154.5 cm³	158.4 g	5.59 oz — Minimum viable stroke
3.9"	9.9 cm	20.27 cm²	200.7 cm³	205.7 g	7.26 oz — Design target (✓ SELECTED)
4.5"	11.43 cm	20.27 cm²	231.6 cm³	237.4 g	8.37 oz — Recommended build stroke
5.0"	12.70 cm	20.27 cm²	257.4 cm³	263.8 g	9.30 oz — Conservative max margin
5.5"	13.97 cm	20.27 cm²	283.2 cm³	290.3 g	10.23 oz — Exceeds float length limit

The table below highlights several versions of the float hardware we built and tested for this year’s mission task.

Version	Controller	Key Components	Challenges Encountered	Outcomes & Lessons
v1.0	Pico W + NRF24L01	VEX 393 Motor + VEX 29 ESC; Bar30 sensor; NRF24 radio	Radio signal loss in water; NRF24 instability requiring 100µF caps	Proved basic depth sensing concept; identified radio limitations
v2.0	ESP32 (standalone)	ESP32 WiFi AP; Bar30 sensor; VEX 393 + VEX 29 ESC	WiFi signal degradation at pool surface; ESP32 AP range limitations	Eliminated external radio module; simplified wiring significantly
v3.0	ESP32 + RPi 4 Surface	ESP32 float + RPi 4 surface station; Bar30; VEX 393; dedicated WiFi network	Bar30 requires 100ms min read interval; VEX 29 needs servo-style PWM (1000–2000µs)	Reliable two-device architecture; full GUI telemetry display for judges
v4.0	RPi Pico W (WiFi mode)	Pico W controller; Bar30; VEX 393; BTS7960 H-Bridge motor driver	Pico WiFi less robust than ESP32; motor driver swap needed for adequate current	Proved BTS7960 as viable driver; 12-bit ADC for smoother piston position control
v5.0 (Current)	ESP32 + WiFi + Plunger Engine	ESP32; Bar30 sensor; VEX 292 motor; threaded rod; 2" dia. plunger/cylinder; PID depth control	Water pressure at depth (~50N on 2" piston); plunger stroke must overcome ~3.6 psi	Autonomous PID depth control; buoyancy engine achieves full competition profile



The image above is an early design we were developing using two ESP 32s using an RF transmitter with antennas. The programmed software was working using WiFi with both ESPs, but when we attempted to use the RF to increase the distance the two ESPs could communicate, we could not get them to send a batch. We got them to connect, but could not get data. The image to the right is our current float. We stayed with the ESP32, and we used the ESP’s WiFi to connect and communicate to the float. We used this method with a Pi, but the Pi was too big for this float. We managed to achieve the function of the Pi with the ESP 32.



14. Accounting

UR² 2026 Predictions:

UR² 2026 Purchase Request Form:

	Price of ROV	Price of Control Box	Total
2022	\$ 3,680.00	\$ 1,200.00	\$ 4,880.00
2023	\$ 3,360.00	\$ 1,020.00	\$ 4,380.00
2024	\$ 3,460.00	\$ 1,170.00	\$ 4,630.00
2025	\$ 3,475.00	\$ 1,100.00	\$ 4,575.00
Predicted Cost of 2026	\$ 3,493.75	\$ 1,122.50	\$ 4,616.25
2026 Cost	\$ 3,787.28	\$ 1,056.00	\$ 4,843.28

Name: _____
 Date: _____
 Budget Request Cost: _____
 Task Description: _____

Items and quantity	Price	Link of Item	Item Approved	Approved By (CEO, CFO, Mentor)
1.				
2.				
3.				
4.				
5.				

During our first month of practice in September, we review and discuss the budget. We use the costs from our 2022, 2023, 2024, and 2025 ROV builds to estimate expenses for the 2026 model. At the same time, we itemize reusable components—such as our enclosure and tether—and factor them into the projected budget. UR² takes a detailed and proactive approach to financial planning. For the development of Defiance HD, we created a comprehensive Profit & Loss (P&L) analysis. This includes all expenditures over the one-year development period, unit costs for manufacturing each production ROV, and revenue projections based on current market pricing. (See Appendix the full report)

At the beginning of the season we analyzed costs from the previous four ROV builds and, using the season-comparison table, forecast the 2026 total at \$4,616.25 (ROV \$3,493.75; control box \$1,122.50). The CFO reviewed this forecast and calculated a separate budget for a new robotic claw, and the team set aside \$250.00 for that planned upgrade; those claw funds were intentionally added to the final total rather than treated as an unexpected overrun. The final audited cost for 2026 was \$4,843.28, a net increase of \$227.03 versus the table-based prediction; this variance breaks down to a \$293.53 increase in the ROV component and a \$66.50 savings on the control box. Excluding the budgeted claw, the adjusted final cost is \$4,593.28, which is \$22.97 below the table prediction, demonstrating that the historical average forecast was accurate once the planned claw purchase—documented and approved by the CFO—was accounted for. Receipts and donations are included in the appendix.

To manage funds responsibly, all team purchases of tools, hardware, or equipment require a purchase request submitted in advance. Each request must include the item description, estimated cost, vendor, and intended project and must be approved by the CFO and the head coach before any team funds are spent. The CFO verifies budget availability and cost reasonableness while the head coach confirms technical necessity; approved requests are recorded in the master budget with the purchase rationale and approval notes. This formal approval workflow prevents unnecessary or duplicate purchases, ensures purchases align with team priorities, and creates a clear, auditable trail for judges and sponsors.

The team maintains a centralized inventory of parts and tools that logs part numbers, locations, and quantities. Every incoming purchase or donated item is entered and linked to its budget line so physical parts can be traced to financial entries; reused components are tagged to document savings and provenance. Monthly reconciliations match bank and card statements to budget entries, and receipts are scanned and attached to each line item to support transparency.

The CFO oversees all financial operations: maintaining the master budget with version control, enforcing the approval matrix and spending thresholds, producing monthly variance reports, and compiling the final submission package (budget, receipts, donation letters, and reconciliation log). This structure keeps spending cost-effective, protects team resources, and ensures accountability across projects while enabling the team to make informed decisions throughout the season.

Every component used on the ROV was logged in our Excel accounting system and categorized by subsystem and type (New, Reused, or Donated). We coordinated efforts to reduce costs through reuse and sponsorships, applying sustainable practices throughout the engineering process; for example, all thrusters, handwear, and enclosures were repurposed from prior builds, and donated supplies provided high-value components that would otherwise have strained our budget. The complete list of expenditures is detailed below, with a description, component type, and subsystem.

ROV Cost Breakdown							
Underwater Research Robotics (UR2)							
Category	Description		New or Reused	Quantity	Unit Price (FMV)		Total Cost
ROV Structure							
	PEPG-CF	3D Printing Material	New	1	\$	40.00	\$ 40.00
	Aluminium	Square 2.56 cm Aluminium	New	8	\$	6.67	\$ 53.36
	Flat Bar	Vex Flat Bar	New	3	\$	10.83	\$ 32.49
	Hardware	Nuts and Bolts	Reused	1	\$	8.00	\$ 8.00
Total ROV Structure						\$	133.85
Propulsion							
	V2 Mini Thruster	Brushless Thrusters	Reused	4	\$	59.99	\$ 239.96
	Blue Robotics T200 Truster	Brushless Thrusters	Reused	2	\$	258.00	\$ 516.00
Total Propulsion						\$	755.96
Enclosure							
	Navigator Board	Navigation Used for Robot	Reused	1	\$	61.00	\$ 61.00
	DWE HD Cameras	Camera Used for Navigaiton	Reused	1	\$	400.00	\$ 400.00
	Low-Light HD USB Camera	Camera Used for Navigaiton	Reused	1	\$	110.00	\$ 110.00
	Camera Tilt System	Titls Camera	Reused	1	\$	62.00	\$ 62.00
	ESC	Speed Controller	Reused	2	\$	38.00	\$ 76.00
	Bar30 Depth/Pressure Sensor	Measures Water Pressure and Depth	Reused	1	\$	85.00	\$ 85.00
	Electronics Tray	Used to hold all electronics in the enclosure	Resused	1	\$	55.00	\$ 55.00
	Watertight Enclosure End Caps	Used to seal the enclosure	Reused			\$	-
	Cast Acrylic Tube	8 Inch tube for eltronics to go into	Reused	1	\$	330.00	\$ 330.00
	Pressure Relief Valve	Used to releif pressure from the enclosure	New	1	\$	30.00	\$ 30.00
	Wet Links	Used to seal the enclosure	Resused	1	\$	8.00	
	SOS Probes	Leak Sensors	New	2	\$	3.00	\$ 6.00
	Wiring	12AWG Wiring (Spools)	New	2	\$	39.99	\$ 79.98
Total Electronics						\$	1,294.98
Tether							
	Mesh Casting	Nylon Mesh Binding and Protecting Cables	Reused	1	\$	53.00	\$ 53.00
	Fathom ROV Tether	Neutrally Bouyant Tether	Reused	1	\$	245.00	\$ 245.00
Total Tether						\$	298.00
Mission Tools						\$	-
	Agjewsoft	Softwear for Photogramitry	New	1	\$	50.00	\$ 50.00
	pH Sensor	pH sensor used for the MATE Tasks	New	2	\$	12.00	\$ 24.00
	Syringe	Pack of 10 Liquid Measuring Syringes	Reused	1	\$	9.99	\$ 9.99
	Newton Sedimate Sampler	A claw that help the ROV grab iteams	Reused	1	\$	290.00	\$ 290.00
Total Mission Tools						\$	373.99
Hardware							
	Robotic Arm	Robotics Arm with 4 servos to move props	New	1	\$	250.00	\$ 250.00
	Newton Subsea Gripper	Claw for ROV	Reused	1	\$	680.00	\$ 680.00
Total Hardware						\$	930.00
Miscellaneous							
	Foam	2x4 foam	Reused	1	\$	0.25	\$ 0.25
Total Miscellaneous						\$	0.25
Total ROV Cost						\$	3,787.28

The team funded their trip to the 2026 MATE World Championship in Canada through three fundraisers, presentations to local businesses, and a presentation to the Economic Growth Network (EGN), which offered a matching grant up to \$15,000. By raising \$15,000 themselves, the EGN match brought their total to \$30,000 – making the trip possible.

UR ² World Championship 2026 — Donation Tracker	
Memorial University of Newfoundland, St. John's, NL — June 2026	
FUNDING GOALS	
Lodging	\$12,259
Team Transportation (9 students)	\$10,000
Chaperones Transportation	\$7,000
Equipment Transportation	\$1,000
TARGET RANGE	\$30,000

Underwater Research Robotics (UR2)
Statement of Account

	PY 2025	CY 2026	CHANGE YOY	Percent Change
Revenues				
Contributions / Donations	\$ 12,000	\$ 750	\$ (11,250)	-94%
Total Contributions	\$ 12,000	\$ 750	\$ (11,250)	-94%
Fundraising				
Popcorn Sale	\$ -	\$ 1,000	\$ 1,000	N/A
Total Fundraising	\$ -	\$ 1,000	\$ 1,000	N/A
Grants and Awards				
State 99h Grant	\$ 6,000	\$ 4,500	\$ (1,500)	-25%
MISTEM Grant	\$ 5,000	\$ 1,976	\$ (3,024)	-60%
Samsung Award	\$ 2,500	\$ 2,500	\$ -	0%
Total Grants and Awards	\$ 13,500	\$ 8,976	\$ (4,524)	-34%
Total Program Revenue	\$ 25,500	\$ 10,726	\$ (14,774)	-58%
Expenses				
Robot Development				
Robot Prototype (Square One)	\$ 1,000	\$ 500	\$ (500)	-50%
Robot Prototype (Viking)	\$ 1,000	\$ 500	\$ (500)	-50%
Robot Parts (Defiance)	\$ 3,000	\$ 4,200	\$ 1,200	40%
Robot Parts (Float)	\$ 500	\$ 500	\$ -	0%
Total Robot Development	\$ 5,500	\$ 5,700	\$ 200	4%
Research				
Water Acidification Research Project	\$ -	\$ 300	\$ 300	N/A
Total Research Expense	\$ -	\$ 300	\$ 300	N/A
Equipment				
Test Equipment	\$ 500	\$ 300	\$ (200)	-40%
Total Test Equipment	\$ 500	\$ 300	\$ (200)	-40%
Outreach				
Mentoring	\$ 800	\$ 1,400	\$ 600	43%
Workshops	\$ 600	\$ -	\$ (600)	N/A
LEGO Competition	\$ 1,500	\$ 1,500	\$ -	0%
Total Outreach	\$ 2,900	\$ 2,900	\$ -	43%
Other				
Apparel	\$ 500	\$ 1,000	\$ 500	100%
Travel	\$ 12,000	\$ 1,100	\$ (10,900)	-91%
Competition Fees	\$ 665	\$ 870	\$ 205	31%
Total Other Expenses	\$ 13,165	\$ 2,970	\$ (10,195)	40%
Total Program Expenses	\$ 22,065	\$ 12,170	\$ (9,895)	46%
Total Change in Net Assets	\$ 3,435	\$ (1,444)	\$ (4,879)	

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