



2026 Technical Documentation

Wave Co. at Embry-Riddle
Aeronautical University

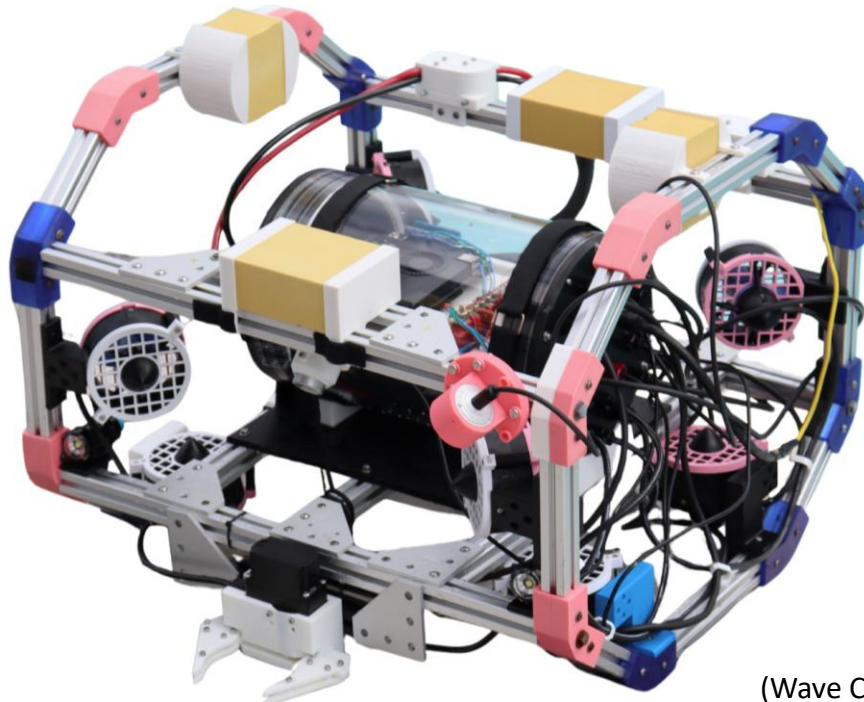
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Abstract

Wave Co., at Embry-Riddle Aeronautical University, is an undergraduate-led club that enables students to design, build, and improve the Modular Aquatic Knowledge Obtaining Unit (MAKO) in preparation for the tasks set forth by the MATE ROV World Championship. Wave Co. has improved upon previous iterations of the ROV, enhancing controllability, ease of maintenance, and reliability through changes made after rigorous research and testing. MAKO is modular, with multiple attachments that allow completion of MATE’s RFP tasks, including invasive species monitoring, underwater infrastructure assembly, and cryospheric research support. This technical document provides an overview of MAKO’s design, development, timeline, budget, and other key details. The Wave Co. team is excited to show all of the hard work performed leading up to the 2026 MATE ROV WC.

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Teamwork

Company and Personnel Overview

Wave Co. comprises students from many majors and grade levels. Wave Co.'s parent organization, the Autonomous Maritime Robotics Association (AMRA), encourages educating and mentoring younger members in important skills not necessarily taught in the classroom, like soldering and prototyping. Older members support this initiative through Wave Co.'s leadership team, where they oversee the mechanical, electrical, and software teams. Personnel roles are defined in Table 1.

Table 1. Team Personnel Roles.

Role	Responsibilities
CEO	Schedules tasks and communicates with AMRA and ERAU.
CFO	Manages team finances and orders parts.
Safety Officer	Establishes safety procedures and oversees safety documentation.
Training Officer	Plans and carries out skill training sessions for employees, like learning CAD or soldering.
Media Manager	Photographs/records developments, manages social media posts, and oversees documentation design.
Team Leads	Guide employee projects on electrical/mechanical/software teams.
Employees	Work on various projects, guided by team leads.

The company's organizational hierarchy is shown in Figure 1.

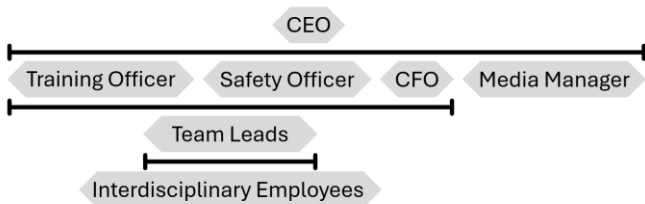


Figure 1. Wave Co. Org. Chart.

A majority of the team is pictured in Figure 2.



Figure 2. From left to right: [Top Row] Nicole Motta (Media Manager), Gabriella Anguiano (Mechanical Lead), Madison Warner (Mechanical Team), Wyatt Reinke (CFO), Adam Ahmad (Software Lead)

[Bottom Row] Robert Thibodeau (Mechanical Team), Justin Yocum (Safety Officer), Mark Thompson (CEO), John McSwiggin (Pilot), Garrett Lynn (Training Officer)

Schedule

Wave Co. planned tasks for the academic year starting from Day 1. A Gantt chart was created, planning how long it would take for the research, design, implementation, and testing of new tools and systems to be performed.

The team meets multiple times a week, including team meetings on Tuesdays from 7 PM to 9 PM, and workdays on Saturdays from 10 AM to 4 PM, along with AMRA general meetings on Fridays from 6 PM to 6:30 PM, checking on the progress of all teams from the week prior, as well as planning the work to be done the following workday. Members are also allowed to work outside of these established hours, which many take advantage of.

Table 2. Wave Co. Design Schedule.

	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Planning										
Designing										
Implementation										
Testing										

Resources and Procedures

Multiple software resources are utilized throughout the year for different tasks, such as **organization**, **software**, and **Computer-Aided Design (CAD)**.

Delegating tasks is an integral part of project management, for which **Microsoft Planner** is used,

due to its ability to assign different tasks to different personnel, even allowing for multiple users to be assigned to the same task for collaborating.

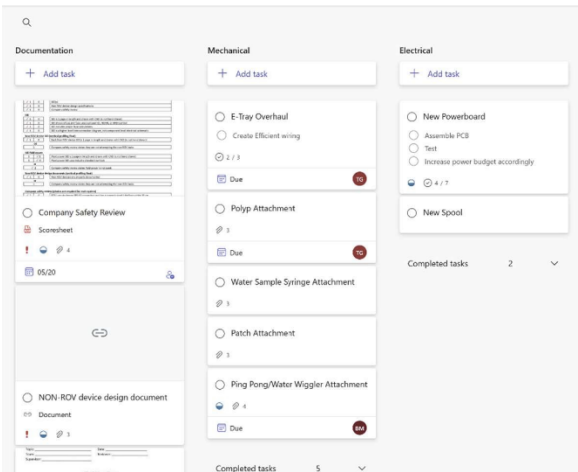


Figure 3. Wave Co.'s Microsoft Planner.

Using Microsoft Planner allows the team to utilize the **Kanban Methodology** [1], which means that the team divides the tasks based on the type of work they require. The task groups are Documentation, Mechanical, Electrical, Software, Competition, Pool Test, and Documentation Review.

Moreover, each Tuesday team meeting begins with a roundtable discussion of what everyone is doing, where they are stuck, and how they can be helped. This allows for tasks to remain on schedule.

Discord is utilized for communication, with multiple dedicated channels to maintain organization, which limits the overlap in topic conversations. For external communication, such as sponsorship connections and communication with companies, the team uses the dedicated **AMRA Gmail** (unsinkableerau@gmail.com).

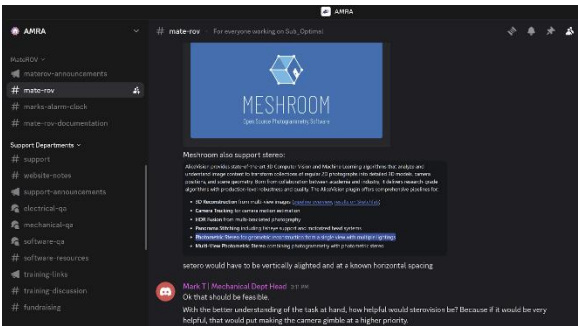


Figure 4. Discord Communication.

Microsoft SharePoint is used to centralize documents and files, with multiple folders dedicated to the different aspects of the project, such as CAD prototypes, code, and documentation. Every member has access to this SharePoint, which is continually updated throughout the year.

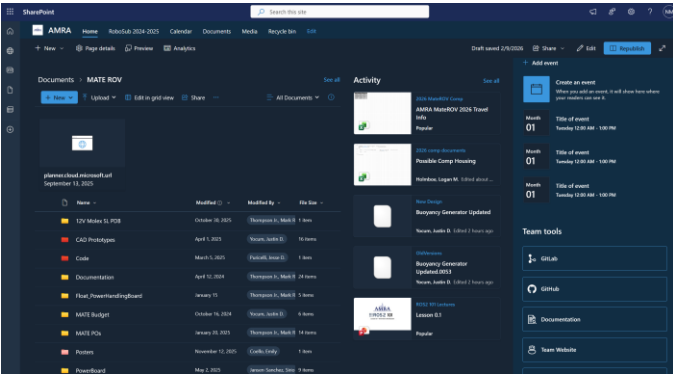


Figure 5. Wave Co.'s SharePoint.

Each sub-team uses different software applications to carry out their tasks.

The mechanical team uses **Autodesk Inventor Professional 2025**, which offers excellent capabilities with a smooth user experience. Used for part design, assembly, and finite element analysis (FEA), it allows the team to confirm adequate performance, identify potential design issues, and optimize components before physical prototyping.

For electrical work, the electrical team uses **KiCAD v9.0** on account of its capabilities and it being free. This was used for designing the powerboards of MAKO and the non-ROV float.

AMRA, as an organization, is a **GitLab** group, whereas Wave Co. is a subgroup of it. Each main block of code is contained within a project in this subgroup, where all the workspaces are handled by **VCS tools**. This allows new members to easily integrate into the system, as well as easily update all the repositories. **Visual Studio Code** is used for office development code, and **VIM** is used for in-field work. Finally, **ROS2 Humble** with **Python launch files** and **C++ nodes**, and **Foxglove** is used for the ground station's UI.

These resources allow the team to effectively communicate, organize tasks, and develop the MAKO to its fullest potential.

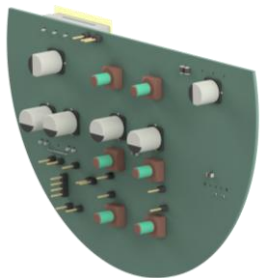
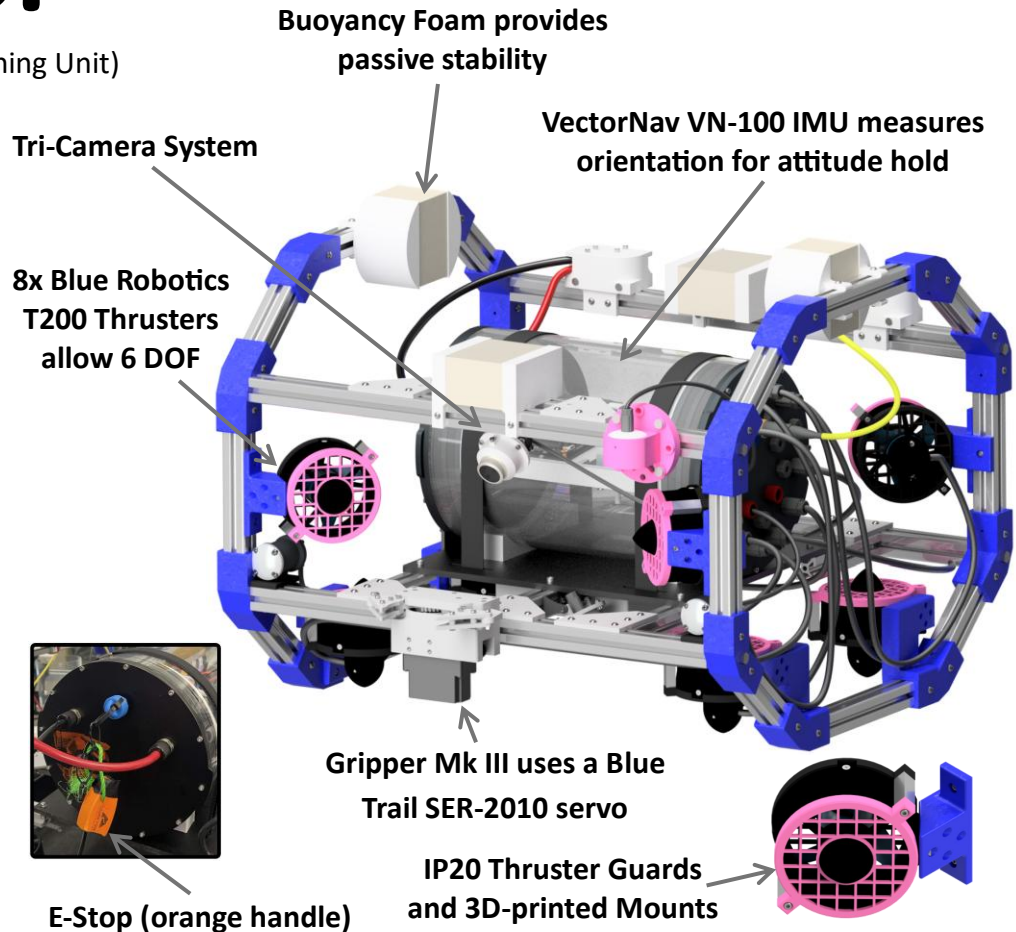
M.A.K.O.

(Modular Aquatic Knowledge Obtaining Unit)

Design Overview

MAKO is in its third year of development, iterating and improving onboard systems to reliably complete MATE's RFP tasks. Prioritizing modularity and repairability, MAKO consists of an electronics tube housed within an aluminum exoskeleton that protects all components, except a quick-adjust camera and the Gripper Mk III. Additional safety features include thruster guards, PLA bumpers, and an E-stop, accessible to divers. Major improvements this year include the gripper and a custom powerboard, which massively increases speed and maneuverability.

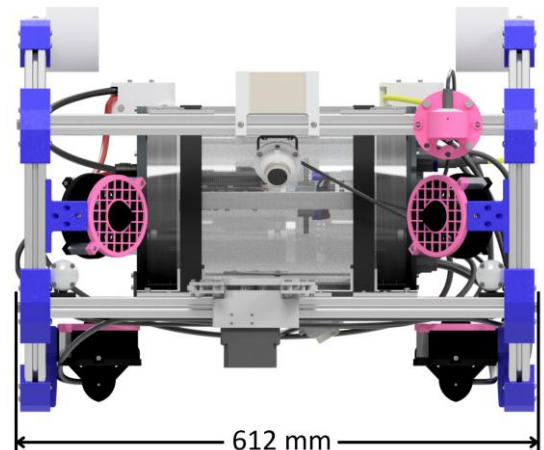
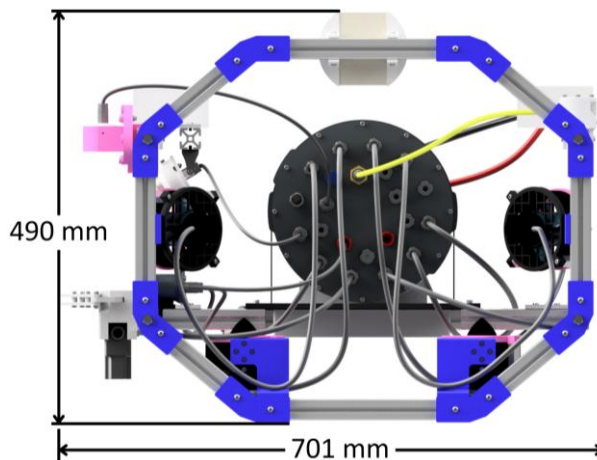
Specialty tools like a spool, a compliant carabiner, and a tail hook allow for additional grabbing of underwater objects.



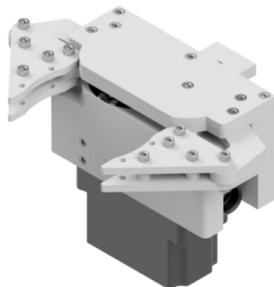
"Fangtooth"

Custom Powerboard

The new board effectively triples the ROV's power compared to before.



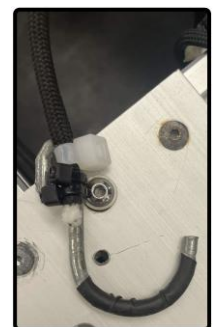
All-Purpose Quick-Adjust Camera



All-Purpose Gripper Mk III



Tasks 2.4 Carabiner and Spool



Tasks 1.1, 2.3 Tail Hook

Design Rationale

Background and Design Process

Now in its third iteration, MAKO’s design strategy focused on improving modularity, simplicity, robustness, and affordability. **Identifying problems and constraints** is integral to development.

At the beginning of the academic year, prior to the MATE ROV 2026 RFP’s publishing, major issues to solve were the Gripper Mk II being unreliable (the result of water damage to the servo), reworking the ROV’s power system to increase thrust, and improving the ROV’s controllability by adding features like position hold and coordinate frame rotation.

Once the MATE ROV 2026 RFP was released, it was decided that MAKO would be physically capable of completing each task found in the RFP. With tasks and their constraints identified, additional necessary modifications to MAKO included having a vision system to automatically identify crab species and the coral garden, developing a way to measure objects underwater, making a tether spool, and creating a way to lift the heavy lobster pot. To solve these challenges, the team began **brainstorming solutions**.

To assist in tool development, a table was made, organized by task, pool venue, required camera

positions, whether the ROV would need to surface, whether objects would have to be retrieved, what types of tools would be needed, and the maximum points that could be obtained. Once this information was tabulated, tasks were prioritized depending on how quickly and easily they could be done, and how valuable they were point-wise. This then allowed different task completion plans to be created. The finalized plan is shown Table 3, with tool names updated to match developed tools.

With the task order planned, tools were designed not only based on functionality, but how they would work in the task order as a whole and how they would integrate with other tools. For instance, in Task 2.4, the gripper and spool carabiner were developed simultaneously to ensure the gripper could clip the tether to the buoy, but the gripper had to also remain functional for other manipulation tasks. Team members closely working together allowed this development process to be successful.

Once preliminary tools were developed, they underwent **prototyping and testing**. Prototypes were made from 3D-printed materials which could be rapidly integrated with the ROV for in-pool testing and then iterated as necessary. Once a final design was settled on, certain tools were then remade from sturdier materials.

Finalized tools were then “**pushed to market**,” being integrated with the ROV for their 2026 debut.

Table 3. Task Distribution Planning.

Flume Tank					
ID	Desc.	Camera	Surface	Tool	Trip
1.1	Coral/Basket	Forward	✓	Gripper/Tail Hook	1
1.2	Coral Garden		X	Camera/IMU	2
1.3	Position hold	Straight Down		Camera/Motor Control	2
2.1	Crabs			Camera/CV	2
2.2	Iceberg	Forward/Up		Camera/IMU	2
Eng. Basin					
2.3	Fishing Gear	Forward/Down	✓	Gripper/Tail Hook	1
3.2	Oil Platform			Gripper	2
2.5	Observatory			Gripper	3
3.1	Micropile			Gripper	4
2.4	Buoy			Gripper/Spool/Line	5

Systems Approach

MAKO’s systems approach is best characterized by the **concurrent development of subsystems**. Electrical, mechanical, and software systems are developed by their respective subteams, with oversight by their leads, who are in constant contact with the other leads, negotiating on behalf of their subteam to compromise design elements with the other subteams. **This forces critical thinking and iteration**, making systems the best they can be to accomplish MATE’s RFP tasks.

System design starts on a whiteboard, with representatives of each subteam in attendance, planning a design concept. Once a reasonable concept is decided upon, **subteams move to their respective digital workspaces** - KiCAD for electrical, Inventor for mechanical, and GitLab for software. The team prides itself on maintaining an accurate **digital twin of MAKO** in Inventor, which allows for effective digital prototyping, ensuring new components will fit and move as they are intended before every being manufactured. This is also useful for electrical work, defining available space for boards and wiring. With a constantly updated SharePoint and GitLab, all team members can quickly access all aspects of MAKO, working across subsystems to ensure seamless integration.

By creating components digitally, we can ensure new systems will function before building them, saving time and money on prototyping, and **allowing for quicker implementation on the real ROV**. This saved time and money is then used to further refine systems or add even more systems.

Of course, **in-pool testing is very important** for system integration, with most software being difficult to test virtually. Electrical/mechanical systems also often operate in a slightly different fashion in the real world compared to their digital counterparts. In-pool testing requires **test plans** to first be written, ensuring systems are thoroughly tested. **Detailed notes** are then taken during tests, which **may inform needed revisions** to a prototype or signify that a system is finalized. **This process is used for all systems**, streamlining integration and improving ROV performance.

Vehicle Structure

MAKO prioritizes **affordability, while being adaptable and easily repairable**. To accomplish this, the frame is constructed of 25.4 mm square aluminum T-slot and 3D-printed, PLA brackets.

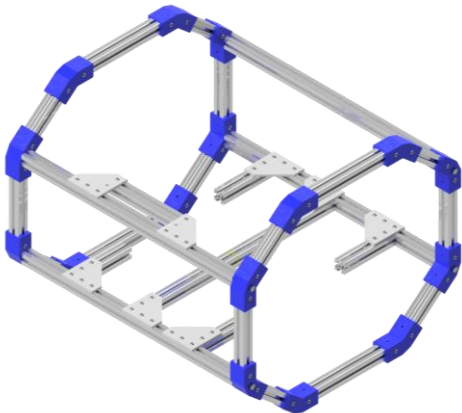


Figure 6. MAKO Frame Rendering.

While the frame makes MAKO significantly larger and heavier than many of the other ROVs at MATE ROV, reducing maneuverability, its role as an exoskeleton has prevented countless thrusters from breaking off, and the 3D-printed brackets can easily be remade. Furthermore, using standardized T-slot extrusion allows for **simple mounting of tools and sensors**.

New for this year’s frame are 316 stainless steel fasteners, replacing carbon steel fasteners which were prone to corrosion and shear failure after a year of use. These new fasteners are expected to have increased longevity, a necessity for the saltwater operation MAKO will see at this year’s competition. To further mitigate corrosion, an aluminum **sacrificial anode** has been added to the frame, which is more reactive than the frame material (different aluminum alloys) [2]. Magnesium and zinc anodes were also considered, but aluminum was the best fit after completing the following comparison table:

Table 4. Sacrificial Anode Comparison [2].

	Al.	Mg.	Zn.
Cost	–	X	✓
Fresh Water Effectiveness	–	✓	X
Salt Water Effectiveness	✓	X	✓
Brackish Water Effectiveness	✓	X	–

Beyond the aluminum frame, a 203.2 mm diameter, 304.8 mm long acrylic tube houses the ROV’s power distribution and computers. Using friction-fit aluminum end caps, accessing the internals is a matter of simply pulling a cap off on land and removing a sliding electronics tray. This mechanism has not changed from previous iterations of MAKO, but the arrangement of electronics has changed. Wave Co. has been very successful with the single-tube design, and it is expected to be used for future seasons. A new tube was purchased this year after cracking was detected in the old tube, transitioning suppliers to save money. Please see [Testing and Troubleshooting](#) for details.

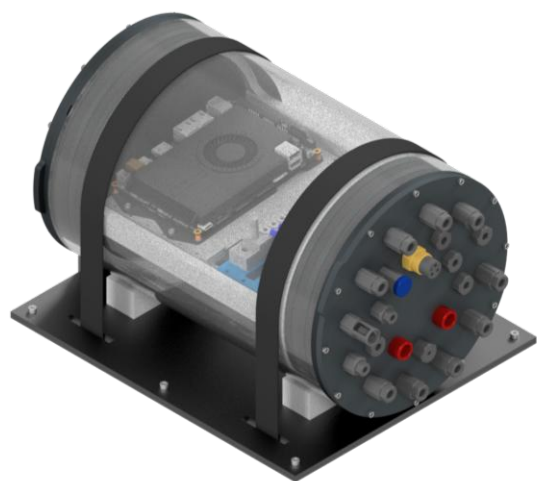


Figure 7. MAKO Tube Rendering.

Differences between the previous structure and new structure are summarized below.

Table 5. MAKO Structure Comparison.

Structure	MAKO 2025	MAKO 2026
Frame	6,758 g	6,788 g
	2,981 mL	2,990 mL
	\$67	\$115
Tube/End Caps	5,793 g	5,793 g
	10,918 mL	10,918 mL
	\$686	\$575

Vehicle Systems

Component/Material Selection

MAKO is comprised of a modular, T-slot aluminum frame, an acrylic hull for power/processing, a

foam/ballast system for buoyancy and stability, a custom gripper, and task-specific tools.

The ROV’s frame is standardized, using 25.4 mm square, aluminum T-slot, assembled with **M4 hardware**, simplifying serviceability. Custom 3D-printed brackets allowed repairs and geometry changes to be made quickly and cheaply.

The acrylic hull uses end cap and penetrator components from Blue Robotics, while the 203.2 mm diameter **cast acrylic** tube was produced by ePlastics. Producing these components in-house would not have been possible due to equipment limitations. Moreover, ensuring a watertight seal at depth is critical. Wave Co. did not want to risk a hull failure, so professionally-designed and verified materials were used. A further benefit of this setup is that the acrylic tube allows team divers to visually check for leaks while the ROV is operating.

MAKO’s buoyancy/ballast system uses **buoyancy foam** repurposed from a Blue Robotics BlueROV2 donated to AMRA, held in 3D-printed **PLA** mounts, and a PLA ballast box containing a bag filled with **carbon steel BBs**, located beneath the electronics tube. The ballast lowers the center of mass of the ROV, making the vehicle self-righting. BBs are used to make fine-tuning of the ROV’s weight possible, compensating for tool weight changes.

The Gripper Mk III and miscellaneous tooling was primarily fabricated with 3D-printed **polycarbonate**. Using a proprietary method developed by Wave Co.’s CEO, **material strength is improved by 30%** compared to traditional prints (tested according to ISO 527-2 [3]). This allows for the rapid prototyping and affordability of traditional 3D-printing with the strength of injection molded parts.

Design Evolution

This season’s iteration of MAKO differs most heavily from previous years in terms of **manipulator control, pilot visibility, and power distribution**. Previous iterations of MAKO used metal hooks as manipulators (standing in for the unreliable, earlier gripper variants). The Gripper Mk III significantly expands the ROV’s capabilities. With how manipulator-intensive the tasks are for this year’s

competition (see Table 3), having a functional gripper will define the ROV's success.

Moreover, tasks require the pilot to see upward (Task 2.2), forward and slightly down (most tasks), and directly below the ROV (Tasks 1.3 and 2.1). MAKO originally used two cameras, one looking forward at the manipulator hooks and one looking to the right, providing depth when picking objects up. To simplify camera movements, a third camera has been added to MAKO, able to look straight down. Also, a sturdier mount was designed and 3D-printed for the side-view camera. Able to be set in 45° increments, this camera is mounted along the top bar of the ROV, viewing either the gripper or anything above the ROV. This camera mount, and gripper implementation, are visible below.

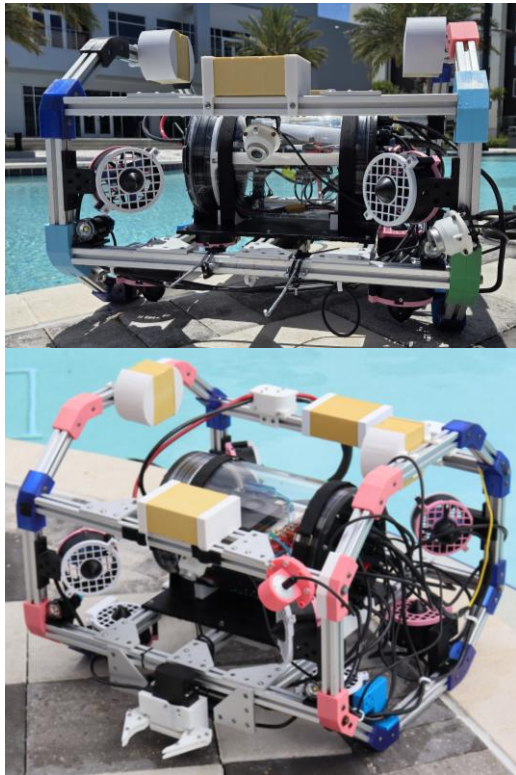


Figure 8. [Above] 2025 MAKO, [Below] 2026 MAKO.

Power distribution is now significantly more effective than in MAKO's previous iterations, allowing nearly three times as much power to reach the thrusters as before. This was achieved through the creation and implementation of Fangtooth, MAKO's custom power distribution board. This replaces two Vicor DC-DC converters, allowing for higher current flow (see [Electrical System](#) for more

details). Critically, this improves MAKO's top speed and maneuverability.

Electrical System

MAKO's electrical system starts with the tether input which utilizes Blue Trail Engineering Cobalt Single-conductor connections. An off-the-shelf solution was selected as this penetration into the ROV's enclosure is critical with the relatively high voltage and certainly high current. A connector-based solution was chosen for the ability to disconnect the tether in transit, and to easily replace a damaged tether. To bring the input power down to a usable voltage MAKO employs a custom-designed power delivery solution, Fangtooth, to convert **48 volts at 30 amps**, the maximum allowable input, to an isolated **12 volts at a 110-amp bus** for the propulsion system. This bus only supplies power to the propulsion system, minimizing the effects of artifacts, like electromagnetic interference and voltage ripple, on the rest of the system. There is an additional 12V rail, also isolated, that powers additional onboard systems. There is one final regulator, placed inline with the additional power bus, that steps the 12 volts down to 7 volts for any servo.

To distribute power throughout MAKO, this year's iteration of the ROV implements multiple PCBs for optimal repairability and expandability. Previous iterations have used screw terminal bus bars for higher current connections, and soldered pig tails for low current connections. This year almost all connections use locking or high mating force receptacles. Beyond Fangtooth, there are two main PCBs, one of which was off the shelf, the other was designed in-house. The off-the-shelf PCB is a power distribution board for the ESC bus, which was selected as it was from a reputable manufacturer and rated for the extremely high currents on that bus. The in-house PCB is for 12V and 5V power for the computers and servos, with the step down to 5V happening on the PCB. The PCB was designed with four layers, one for ground, one for 5V, and two for 12V. However, the two 12V planes are half the copper weight of the others, since they are internal. Below is an image of the PCB in KiCAD.

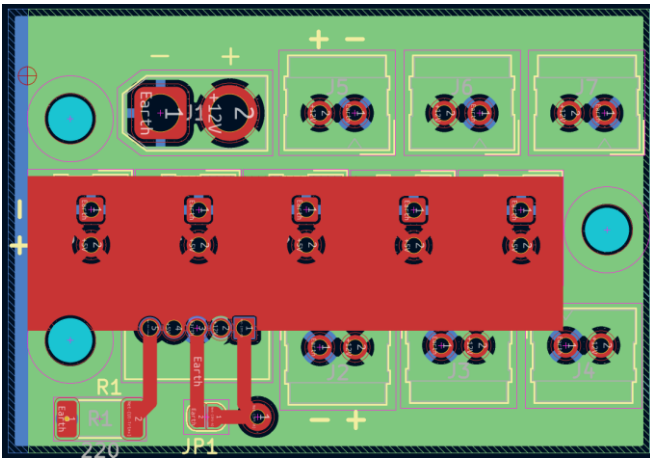


Figure 9. Computer PDB and Step-Down Board.

This board has at least three extra per voltage level for optimal expandability. Beyond PCBs and general hardware, all connections are made with either screw terminals, soldered joints, XT30, or Molex SL connectors. A key detail of the entire power system is that no connector configuration is shared between power and signal, therefore it would be incredibly challenging to accidentally apply 12V to a signal connection. Another standard that is carried throughout the ROV is that for all Molex SL connections the positive leg is always on the left side of the connector when viewed with the locking tab up. This standard prevents accidental reverse polarity connections.

Tether

MAKO's tether consists of **two 10 mm² finely stranded silicone insulated conductors** for power and **one Blue Robotics Fathom Slim Tether**. These three conductors are contained within an expandable sheath to prevent snags and friction wear over time. Power conductor sizing was done via voltage drop calculations of less than 5%, and cross checked for ampacity using tables provided in the ABYC E-11 standard. One of the focuses of the tether design was flexibility, as the previous tether used power wires with only a handful of strands and thick PVC insulation. This tether felt like it almost dragged the ROV itself around, which made doing tasks a challenge. The latest iteration of the tether is extremely flexible, small, and easy to handle.

To handle tether buoyancy, Wave Co.'s solution utilizes floats 3D printed using the previously

mentioned proprietary technique. Beyond significant improvements in strength, the technique also nearly eliminates voids within the print, allowing for untreated FDM 3D prints to be sealed to a sufficient depth for our purposes. These floats were designed to perfectly match the weight of the tether to ensure a neutrally buoyant tether.

The system for managing the tether starts with a single team member whose only task is to manage the tether. By managing the tether, they ensure that only the required amount of tether is in the water. If there is too much tether, the ROV could accidentally drag props around with it, or get caught. With too little, the tether could be dragging the ROV back towards the surface and otherwise inhibiting its motion.

Control System

MAKO utilizes a software-based control system, starting with a **Logitech X56 HOTAS** as the primary human machine interface. It consists of a throttle, used for depth and manipulator control, and a stick, for three-axis rotation and XY translational control. This system was selected as it was owned by AMRA, but also because it features a large number of buttons for customization. For instance, using the trigger, the pilot can have more precise translational control. Furthermore, a knob on the throttle can be used to reallocate thruster power between vertical and horizontal translation. For the pilot's visual interface, **Foxglove Studio** displays the ROV's three cameras, critical measurements such as depth, and a visualization of the ROV's current attitude via the manipulation of a 3D model. Foxglove Studio hooks into the ROV's ROS2 Humble based software stack to gather its data. Foxglove Studio was selected as it provides a polished and mostly plug-and-play solution for a pilot interface. An off-the-shelf program was selected because the required time and effort for our small software team to create a custom program was deemed unreasonable. That time was better spent implementing new features. The process for developing these new features starts with merging the ROS2 package's GitLab "develop" branch with the main branch to provide a workspace where error-prone code can be written without impacting the ROV's main code. Once the feature

builds without errors, its functionality is verified with benchtop testing using ROS2's topic publish and topic echo features. These features are one of the many benefits of utilizing ROS2, in this case, it allows for the simulation of a real environment without the risk and time commitment. Once this phase of testing is passed, the feature is tested during one of the team's Saturday pool tests.



Figure 10. *The Pilot's Control Interface.*

The most impactful limitation of the current control system is the complexity of it. One must understand the inner workings of ROS2 to work on it. This compounds with the code that provides all the data, which is written in **C++**, a language most team members are attempting to learn along with ROS2, presenting a significant learning curve. The result is that about a tenth of the greater organization truly understands how MAKO works. However, this complexity comes with an extreme degree of modularity and the ability to add features that off-the-shelf solutions, such as BlueOS, do not provide. After trying BlueOS, the team determined that the lack of debugging outputs and locked down system made using ROS2 worthwhile.

The ROS2 code stack developed in-house for MAKO utilizes a combination of **PID control** and **thruster direction mapping** to achieve stable operations. There are three distinct namespaces that separate the control logic for ease of debugging, maintainability, and future adaptation. These namespaces are sensors, controls, and motors.

The sensors namespace contains everything required to receive raw sensor data via protocols such as TCP/IP, UART, I2C, and USB. Should any sensor data need to be transformed, translated, or

otherwise modified, the nodes responsible for these actions also live in this namespace.

The controls namespace contains all PID control logic and the translation of the pilot interface commands. There are 3 traditional rotational PIDs, yaw, pitch, and roll, to ensure stable operation of MAKO during its operation. Additionally, there are sway (depth) and yaw rate PID to allow circumnavigation of an object while maintaining a constant horizontal thrust.

The motors namespace handles the summation of thrust efforts from the various controllers and the thrust vector transformation. This vector transformation is required to ensure thrust is applied in the proper direction when not being controlled from a head-on orientation. This namespace also handles the conversion and direct interface with the PWM generator utilized to control the propulsion system.

Propulsion

MAKO maneuvers using eight **Blue Robotics T200** thrusters. They were chosen for their strength and reliability, being able to lift and transport heavy parts, such as the lobster pot and eDNA sensors. The thrusters have been reused since MAKO's original iteration because of their reliability.

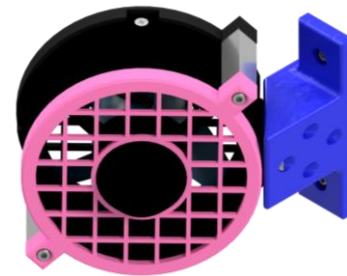


Figure 11. *A T200 with Guard and Mount.*

One of the largest changes to MAKO since the previous competition season was with the thruster power system, through Fangtooth. MAKO always struggled with thruster power, and the measurement of 12A for FLA during the 2025 WCs pinpointed the issue to the power system. The problematic power system used an Amazon-sourced 60A rated 48V to 24V DC stepdown converter. There were two issues with this setup: the converter did

not live up to its ratings, and the thrusters were running on 24V DC. T200s reduce in efficiency as voltage increases, and since teams are limited to 1.44kW, efficiency is paramount. To solve both problems, a new power conversion board was designed and built, capable of 110A at 12V, which left 10A at 12V for the remainder of the ROV's functions. This split of power was determined through a budgeting of the necessary power for computers and sensors. The remaining power was used for the thrusters.

Table 6. Sensor Current Draw Breakdown.

Item	Current Draw (A)
Main Computer	2.33
3x Cameras	0.3
2x Servos	1.67
Lights	2.5
Future Sensors	2.92
Total:	9.72

Buoyancy and Ballast

The buoyancy system is reused from the 2025 design. The ROV is intended to be slightly positively buoyant, minimizing thruster control effort while rising to the surface as a failsafe. With just the electronics tube and frame, MAKO is negatively buoyant. To counteract this, Blue Robotics' buoyancy foam is added to the top of the frame. Despite being positively buoyant, MAKO is nearly uncontrollable with PIDs implemented, having bucking oscillations. This is linked to the high center of mass, attributed to the position of the electronics tube. From senior members' control classes, the team learned that a PID-controlled system must first be statically stable for the PIDs to work properly. To achieve static stability, a ballast box is added below the electronics tube, lowering the ROV's center of mass. A diagram has been created to demonstrate how this works.

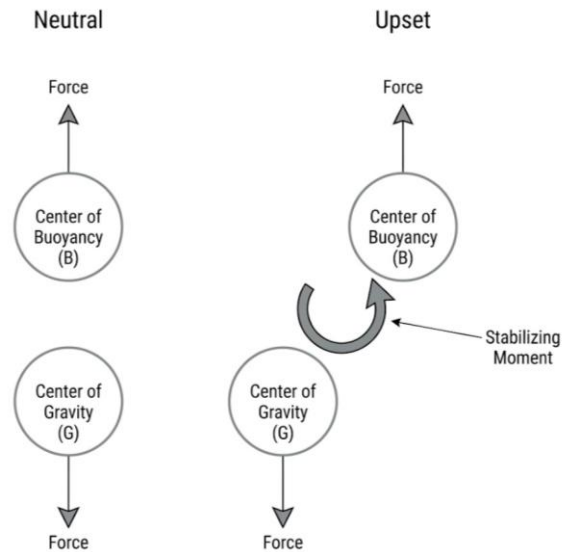


Figure 12. Static Stability Diagram for Watercraft.

With changes in thruster power, the team is considering removing some of the buoyancy foam. This will begin by removing the foam on the left and right of the ROV, decreasing roll stability to improve maneuverability. This will require retuning PIDs. Furthermore, as MAKO will now operate in both fresh water and salt water/brackish water, changes to the ballast weight will be considered, with more ballast being added for salt water operation to account for the denser environment.

Payload and Tools

Cameras

MAKO utilizes **three ExploreHD 3.0 cameras** from DeepWater Exploration, allowing the pilot to view MAKO's surroundings. Each camera plays a unique role with the different tools on MAKO and their tasks. ExploreHDs were chosen for their IP69K rating (rated for 400 m depths underwater), advanced color and refractive correction, and integration simplicity, being plug-and-play [4].

One camera watches the gripper and anything in the forward direction to assist in gripper-related tasks. Another looks straight down for the tail hook and coral garden task. The last camera is adjustable to angle up or down and is used to provide depth perception and guidance for the pilot.

The camera facing downward is also used to assist in completing any vision related tasks. An example is

Task 2.1, in which we need to distinguish which crab is native and which crab is invasive. MAKO uses a trained YOLO model to help identify these species. Upon identification, a box is drawn on each invasive crab, and the number of crabs detected is then displayed and returned to the user.

The Gripper Mk III

The Gripper Mk III is an essential tool on MAKO, allowing the ROV to complete most RFP requirements. It is used to manipulate objects with a grip strength of 50 N and a maximum opening of 70 mm.

Consisting of a **Blue Trail SER-2010 servo**, a 302 stainless steel torsion spring, and a gear-driven parallel linkage, this gripper represents an improvement over the previous two iterations. The first iteration had a worm gear, driven by a stepper motor. That design's parallel linkages were prone to inverting, and the motor was eventually destroyed due to water ingestion.



Figure 13. The Gripper Mk I with Inverted Linkage.

The Gripper Mk II improved the design by incorporating a donated Volz DA 22-SUB Servo and simplifying the claw mechanism, but it was still prone to jamming, and that servo was also destroyed due to water damage.

The Gripper Mk III improves upon the previous iteration by incorporating a properly waterproofed servo. Gear geometry has also been modified to prevent jamming.

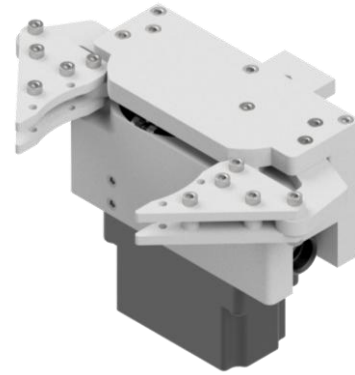


Figure 14. The Gripper Mk III.

The Carabiner and Spool

To complete Task 2.4, in which a tether must be attached to an anchor buoy using a spool, a spool and compliant carabiner have been designed and **3D-printed in PLA**. The carabiner has a flat portion to be held by the gripper before clipping onto the anchor buoy. Meanwhile, a **nylon cord** is spooled within a container mounted onto MAKO's frame and looped through the carabiner. Once the carabiner is clipped to the buoy's U-bolt, the gripper lets go and the cord unspools as the ROV returns to the surface.



Figure 15. Custom Carabiner and Spool Holder.

A compliant plastic carabiner was chosen over a pre-made carabiner so that a custom shape could be added to attach to the gripper. Moreover, PLA is light, being less unwieldy than a pre-made carabiner.

To assist in spooling, note the notched portion of the spool sticking out of the tether container in Figure 15. A power drill with a custom attachment interfaces with the slot, allowing for quick respooling.

Tail Hook

MAKO's final unique tool is its tail hook. Consisting of a **nylon cord with a steel hook** tied to the bottom of the ROV's frame, the tail hook is designed for heavy equipment lifting, like the lobster pot in Task 2.3, or the eDNA sensors in Task 2.5. Being situated beneath the ROV, the tail hook does not generate as much of a pitching moment as the gripper when lifting objects, allowing MAKO to remain maneuverable.

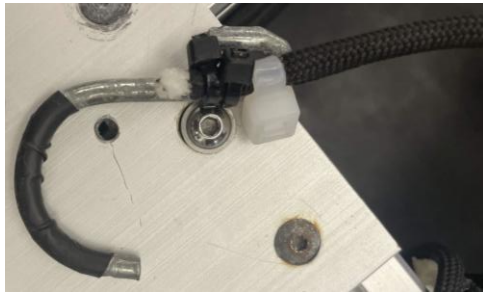


Figure 16. MAKO's Tail Hook.

Note that steel and nylon were chosen for the tail hook due to their strength and longevity.

Sensors

MAKO uses two primary sensors, a **Blue Robotics Bar30 depth sensor** and **VectorNav VN-100T-CR IMU/AHRS**. The Bar30 feeds data to the depth holding algorithm. It was selected as it is a reliable, widely used sensor, and it was purchased for a previous project. One of the extraneous usages for this depth sensor is aiding in measuring the keel depth of the iceberg in Task 2.2, and potentially the height of the coral garden in Task 1.2. With a resolution of 2 mm, according to the sensor's datasheet, this depth sensor meets the requirements of the two tasks [5].

The VectorNav IMU, graciously donated by VectorNav to Wave Co., plays a crucial role in **providing the heading and overall orientation** of the ROV. This data is used both to provide the pilot with a sense of attitude via the rotation of a 3D model in their main interface, and to stabilize the ROV about its three rotational degrees of freedom. For the Flume Tank venue this year, the plan is to use the IMU's heading output along with some pilot interaction to completely counteract the current in

the tank. One issue with using an IMU, and by extension magnetometer, to determine heading in an ROV is heading drift. BLDC motors and their accompanying ESCs produce a magnetic field and can cause heading drift over time. According to an email conversation with VectorNav's wonderful support team, there were multiple ways to reduce heading drift. The VN-100's Kalman filter fuses the gyroscope and magnetometer of the IMU to determine heading, and these two sensors may need to be calibrated in-situ. The gyroscope could suffer from a consistent angular rate offset, while the magnetometer needs to compensate for the surrounding magnetic environment, with the latter being more impactful. Following a calibration of both sensors, the drift reduced from $0.028^\circ/\text{s}$ to $0.005^\circ/\text{s}$. It would be possible to further reduce the drift by informing the VN100's Kalman filter of known magnetic disturbances, and that the magnetometer's measurements should not be trusted. This system would be optimal for short-term, high-power situations, such as returning to the surface with the lobster pot. Another solution would be to create multiple different magnetometer calibration profiles for different somewhat long-term operating situations, like mapping the coral garden. However, neither of these solutions were implemented, as the total drift per product demonstration would be 4.5° , which would be sufficient for the needs of counteracting the flume tank current.

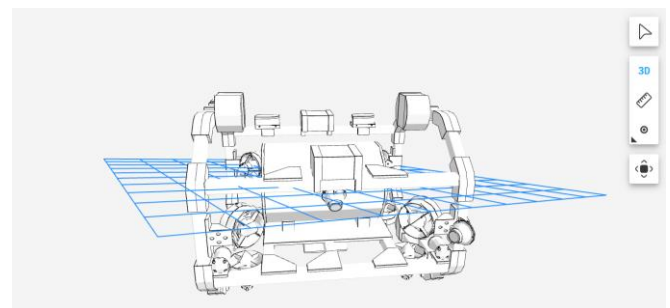


Figure 17. The MAKO Model showing Orientation.

Float Design

Wave Co. presents its third and highest performance vertical profiler yet, now named Atolla. The external dimensions and housing remain the same as the previous two iterations, with a maximum diameter of 89 mm and overall length of 440 mm. The housing is held together solely by negative internal gauge pressure, allowing for the entire 76 mm internal diameter to be opened in the event of overpressure. The electronics were completely overhauled this year, with a new, custom-designed PCB, machined in-house. This PCB significantly reduces the internal clutter because smaller components and connectors can be placed on the PCB.

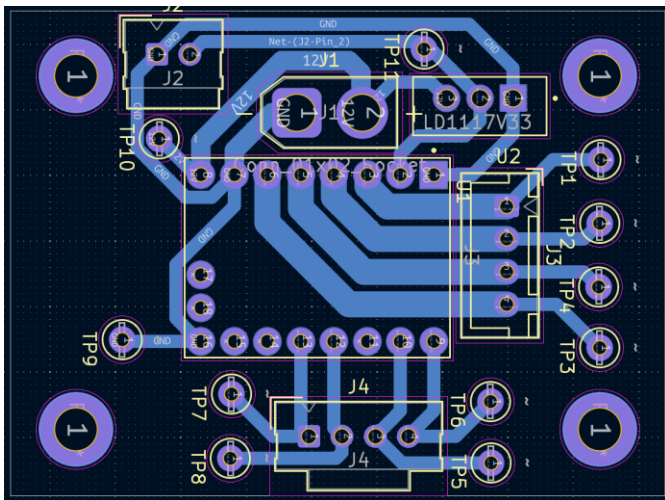


Figure 18. Custom PCB for Atolla.

All of the electrical components are powered by **eight NiMH 2Ah AA format batteries**, all of which are wired in series to produce a maximum pack voltage of 10.8V. This battery pack is **fused at 1A**. Depth control is handled using a buoyancy generator, which is made of a syringe with a plunger that is moved by a stepper motor with a leadscrew nut inside the core, allowing for linear motion. Wave Co. intends to complete all portions of Task 4 this year. The depth controller to do this is a **bang-bang type**, as it is simple to program and tune. The communications approach remains the same, an ESP32-S3 with the WROOM module connects to a mobile hotspot on the surface and hosts a webserver. On this webserver, the defined data packets are displayed and the dive command is sent through an HTTP_GET command. This year, Atolla's

code has been refactored to be primarily asynchronous using the ESP32-S3's FreeRTOS to allow for more efficient STEP/DIR control of the TMC2209 stepper driver, while polling the depth sensor at >10Hz. Below is an image of Atolla.



Figure 19. Atolla.

Build vs. Buy, New vs. Used

Wave Co. reuses components on the ROV when they meet requirements, are properly working, and do not affect performance. Reusing components saves on development costs and integration time, allowing the team to focus on new systems. Last season, an effective frame and PID system were developed. The primary focuses of this year were designing and implementing a functional gripper and adding automation, through crab identification.

Wave Co. has some in-house manufacturing capabilities, with AMRA owning a Bambu X1C and Wave Co.'s CEO having a benchtop mill, prototyping was consistently performed with 3D-printing and sometimes with small, machined aluminum components (like gears for the gripper). However, with store credit provided by SendCutSend, some manufacturing was outsourced. They laser cut aluminum brackets that will be used to upgrade MAKO's frame next season. Overall, components for this season's ROV were made in-house.

Table 7. Reused Purchased MAKO Systems/Components.

System	Justification
Blue Robotics ESC/T200 x8	Meets Requirements: excellent thrust, maneuverability, reliability
DWE exploreHD Cameras	Meets Requirements: good visibility, specialized for underwater
LattePanda Sigma	Meets Requirements: compute, power, ROV controls
Pololu Mini Maestro	Meets Requirements: functional, reliable, allows for servo control
Logitech X56 HOTAS	Meets Requirements: reliable, pilot familiarity, customizable
Dell Latitude 7330 Rugged Extreme	Meets Requirements: good screen visibility, durability
Fathom-X Tether Interface	Meets Requirements: data, compatible with existing tether
Blue Robotics Bar30	Meets Requirements: reliable, sufficient resolution
VN-100 (Donated)	Meets Requirements: steady heading output, well understood

Table 8. Reused Custom MAKO Systems/Components.

System	Justification
MAKO Frame + Buoyancy System	Meets Requirements: modular, repairable, strong
MAKO Electronics Tray and Structure	Meets Requirements: functional, easy to use
Tether	Meets Requirements: power, data, safety, strength
Thruster Guards	Meets Requirements: IP20 rated, compatible with T200s
Float (minor upgrades, like a new ESP32)	Meets Requirements: waterproof, feasible concept, cheap

Table 9. Newly Purchased MAKO Systems/Components.

System	Justification
DWE exploreHD Camera	Additional views were needed, and this model has been proven.
Blue Trail SER-2010 Servos	High torque and waterproof are ideal for a gripper.
Acrylic Tube	Replaced the previous tube, which was experiencing cracking.
Stainless Steel Fasteners + Anode	Increased frame longevity and structural strength.
ESP-32-S3	A dual-core chip was needed for comms and control.

Table 10. New Custom MAKO Systems/Components.

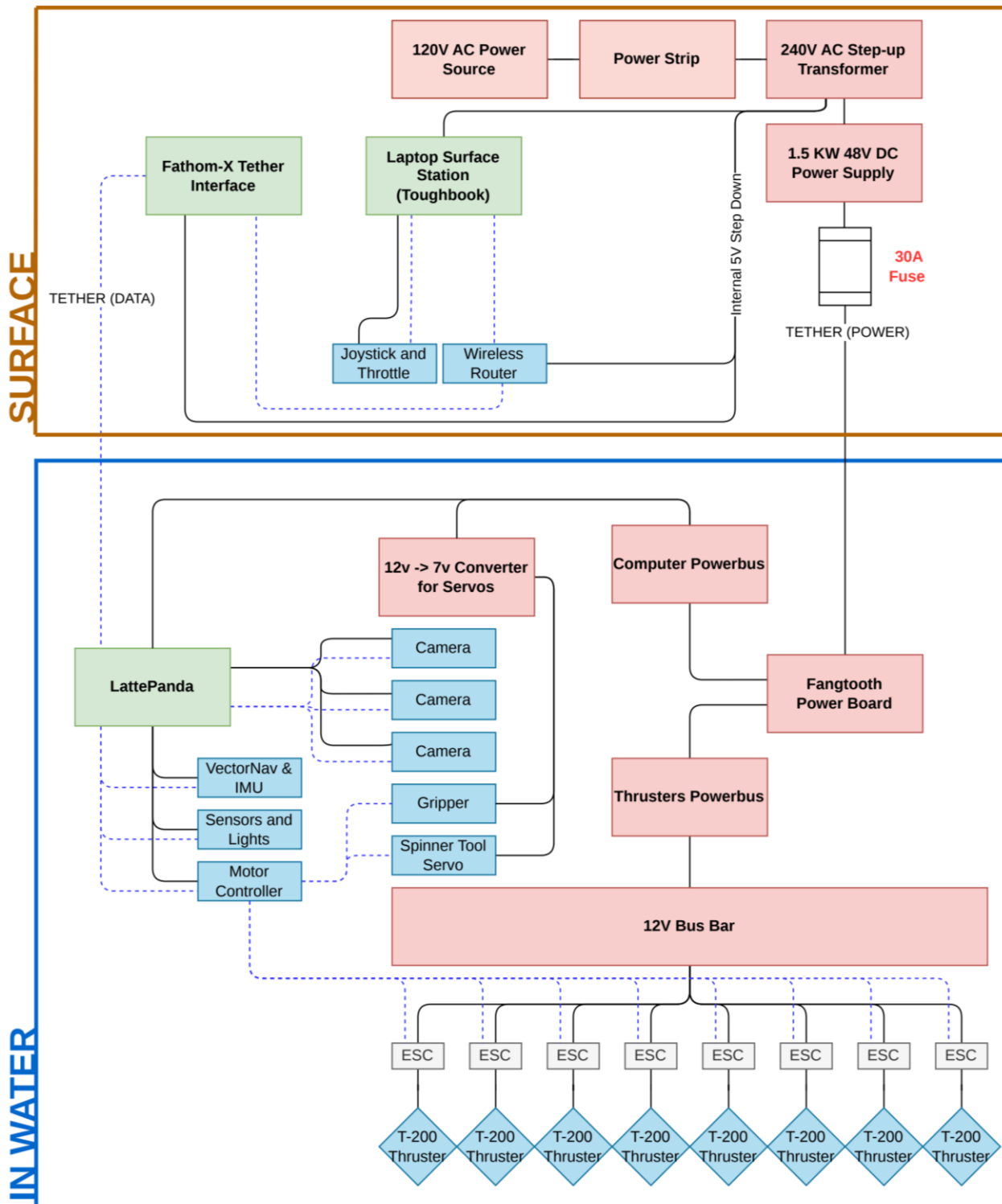
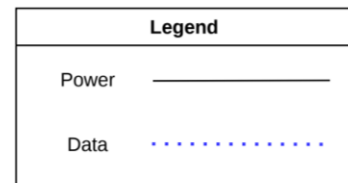
System	Justification
Fangtooth	MAKO's old power system was limited. This improves thrust.
Gripper Mark III	Previous grippers were unreliable. This one has been successful.
Tail Hook	This is a cheap and effective solution to lift heavy objects.
Carabiner and Spool	3D-printed in-house, it is cheap, customizable, and functional.

System Integration Diagrams (SIDs)

MAKO Electrical SID

Condition: Full Down Thrust, Full Forward Thrust
Full Load Amps (FLA) = 27.4A

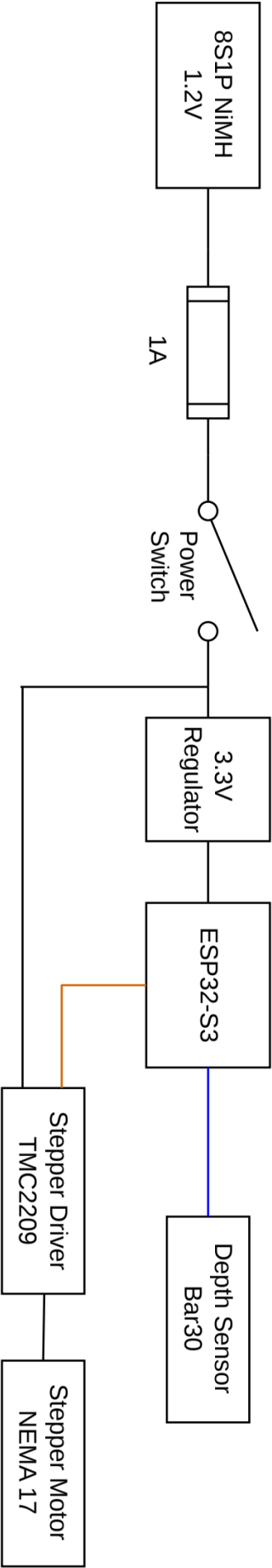
Fuse size selected based on table and FLA
Fuse = 30A



Non-ROV Device SID

Full Load Amps (Motor On) Full Load Amps (Motor Off)
960 mA **350 mA**
Fuse Size Selected
1A

Legend	
Power	—
i2C	—
GPIO	—



Safety

Safety has been a primary consideration during the design, construction, and operation of MAKO. Our approach focuses on protecting personnel while preventing damage to equipment and ensuring safe and reliable operation during all phases of construction and operation. To accomplish this, Wave Co. implements multiple electrical, mechanical, and operational safety features in accordance with MATE ROV competition standards, which are enforced through detailed Job Site Safety Analysis procedures and safety checklists.

From an electrical safety perspective, the ROV runs on a 48-volt system connected through the required **SBS50 Anderson Powerpole connector**, which provides power from the MATE power supply. To reduce the risk of an electrical damage or fire, a 30-amp Littelfuse is installed on the positive power lead, 15 centimeters from the power connector. The fuse size was determined based on MATE's recommended ranges.

During all setup and breakdown procedures, all electrical connectors are inspected to ensure they are dry and undamaged. These procedures reduce the likelihood of short circuits, electrical shock, and equipment failure.

Additionally, the ROV system is equipped with multiple emergency shutdown and motor isolation features to improve safety. An emergency stop (E-stop) mechanism is mounted to the ROV and is designed to be easily accessible to anybody in the water. When pulled, all thruster power is immediately cut, safely disabling the vehicle in the event of entanglement, loss of control, or other hazardous situations. This feature provides an additional layer of protection for nearby personnel and prevents damage to the vehicle and equipment.

The control station also includes a pilot-operated arming and disarming switch for the thrusters. Before placing the ROV in the water, and during setup or retrieval operations, the thrusters remain disarmed to prevent accidental motor activation. This procedure reduces the risk of accidental contact with moving propellers during handling,

transporting, and maintenance. It also prevents overheating of the thrusters since they are not designed to operate when out of the water.

Mechanical safety was also incorporated into the ROV's design. All eight thrusters are equipped with guards that cover both the thrusters' intake and exhaust. These guards **meet IP20 and MATE safety standards** by preventing finger access to the propellers. Sharp edges on the aluminum frame were removed or covered to prevent cuts during handling and operations. Additionally, all watertight housings are pressure-rated well beyond the required depth, minimizing the chance of flooding.

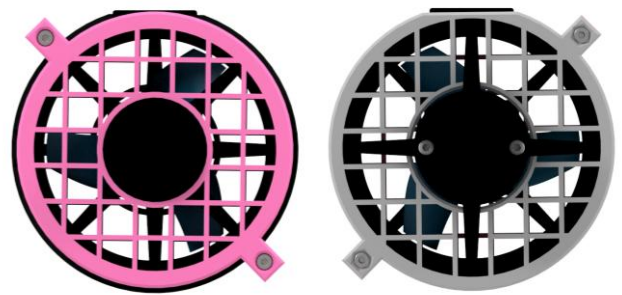


Figure 20. *The Front and Rear Thruster Guards.*

Operational safety procedures further protect both personnel and equipment. Specific procedures were established for lifting the ROV, managing the tether, and safely launching and retrieving the vehicle from the water. The team's JSEA identifies hazards associated with each phase of operation and establishes mitigation steps for each task. Hazards such as slipping, dropping equipment, improper electrical connections, tether entanglement, and pinching injuries are addressed through procedural controls, PPE requirements, and assigned responsible personnel. During operations, the Safety Officer has the authority to halt all operations if unsafe conditions arise. [Appendix A](#) covers the safety procedures during pool testing. Furthermore, [Appendix B](#) outlines lab safety policies and procedures used during the fabrication of the ROV.

Critical Analysis

Wave Co's testing strategy involves first performing a thorough analysis of new systems on land before implanting them on the ROV. For electrical tests,

quantitative findings are used to determine if a new system is ready for integration with MAKO. Mechanical tests tend to focus on **qualitative** aspects. If parts break under standard operation, material and geometry changes may be made.

Once systems are determined to be safe for ROV integration, a pool test plan is written up. This is a checklist that outlines different in-water tests that must be completed, and in what order. If a component fails a test, the component may either be redesigned or testing parameters may be reevaluated.

This competition season, MAKO was **pool-tested 22 times** (not including university outreach events), equating to **nearly 100 hours of systems testing** and pilot practice.

Powerboard Testing

The Fangtooth powerboard underwent an intensive testing procedure. The board was designed to handle 110A at 12V on the ESC output bus with a factor of safety of 1.2. Given the extremely high current, the initial full-load validation tests were deemed too hazardous to run onboard MAKO. Instead, a test rig was created using spare thrusters. The testing focused on quantifying full load amps, regulator temperature rise, and E-stop capabilities. This was accomplished by initially ramping up the PWM signal sent to the motors in increments of 50 μ s until maximum thrust was achieved. Once a steady-state current draw was achieved, the thrusters were left running for approximately 15 minutes, then the E-stop was pulled. The temperature of regulators with a passive heatsink was found to be 93°C, and the full load was found to be 80A, which was within the design specification. Integration into MAKO has since shown no issues, with the board behaving as expected.

Gripper Testing

The Gripper Mk III underwent thorough testing this year to ensure the new design was truly functional. The biggest challenge for the design was determining how to not overload the servo when an object was grabbed. Several choices were considered, like current limiting, a mechanical end

stop, or the chosen solution: a torsion spring that allows the input shaft of the claw gears to have an angular mismatch from the output shaft of the servo. Early iterations of this mechanism failed. Being constructed of 3D-printed PLA, the housing for the torsion spring, and the adapter to the servo shaft, would fracture under any reasonable load. To identify the stresses the components were under, **finite element analysis** was performed using Autodesk Inventor. Simulations showed stress concentrations well above PLA's yield strength of 35 MPa [6] when at the gripper servo's stall torque. Substituting PLA for polycarbonate and adding fillets to geometry to reduce stress concentrations alleviated this issue, with the new parts having a factor of safety of at least 1.3.

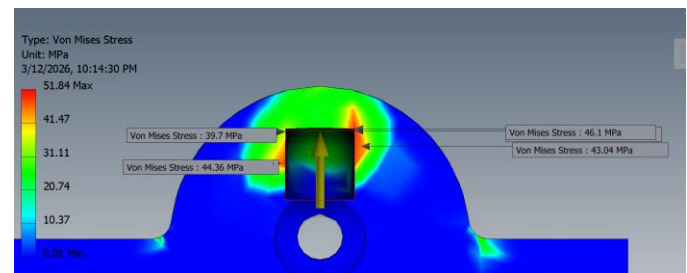


Figure 21. Gripper Shaft Adapter FEA Results.

Electronics Tube Cracking

During routine inspection of the ROV and supporting equipment, it was found that the acrylic electronics tube had signs of cracking. After discussions with Dr. Yizhou Jiang, an Aerospace Engineering Materials professor at ERAU, it was concluded that the artifacts were a form of microscopic cracking known as “crazing”. While this does not necessarily impact the structural integrity of the acrylic [7], the team still thought it best to replace the tube altogether.

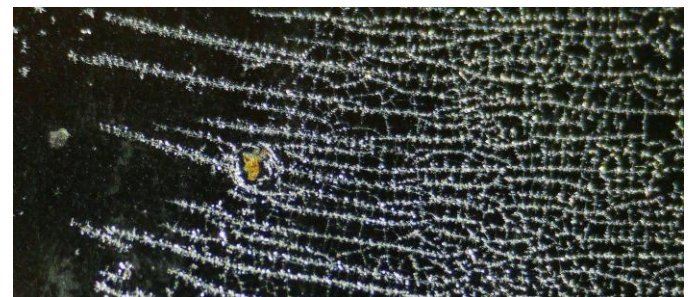


Figure 22. A Microscopic View of the Crazing.

Accounting

Budget

In Fall 2025, a budget was created, based on budgets from Wave Co.'s 2024 and 2025 competitions, and adjusted with predictions for the current competition. Travel was expected to be a significantly more expensive and complex ordeal than in previous years due to St. John's remoteness, requiring purchases like ferry tickets, a VRBO rental, and an ATA Carnet for the border crossing. Furthermore, planned upgrades to MAKO's power and vision systems were expected to increase ROV spending compared to the previous year, which had focused on PID implementation and gripper development.

To compensate for these predicted expenses, an early emphasis was placed on external fundraising, something the team had done minimally in the past. In October 2025, a fundraising packet was created to be shared amongst the friends and families of Wave Co.'s team members. In January 2026, a business-focused sponsorship packet was created by Wave Co.'s parent organization, the Autonomous Maritime Robotics Association (AMRA), which was shared with multiple organizations for financial and tool sponsorships. The success of fundraising was beyond expectations and allowed the team to reevaluate the original budget. This provided the means to buy a spare Blue Trail servo and a third DWE camera to improve pilot vision. Leftover funds will go toward buying a stereovision system next season to allow for enhanced image mapping and measuring.

Table 11. 2026 World Championship Travel Estimate.

Travel Estimate				
Category	Description	Cost (USD)	Qty.	Subtotal
Airfare	Full Coverage per Team Member	\$450	6	\$2,700
Ferry	Six Travelers + Passenger Pods + One Van	\$1,700*	1	\$1,700
Lodging	Hotel in Saint John, NB and VRBO in St. John's, NL	\$3,500	1	\$3,500
Gas	Ford Transit® Van, ≈4,800 mi, 14 mpg	\$1,100**	1	\$1,100
Border Docs.	ATA Carnet	\$500	1	\$500
Total:				\$9,500

*From Marine Atlantic's online booking service [8].

**Considered pre-2026 Iran Conflict avg. gas prices of \$3.20 /gal [9, 10].

Table 12. 2026 Wave Co. Budget Plan.

Budget Allocation				
Category	Description	Yearly Cost (USD)		
		2024	2025	2026*
Equipment/Tools	In-lab fabrication: Wire strippers, soldering materials, etc.	\$500	\$775	\$500
Ground Station	Surface controls: Laptops, HOTAS, misc. wires, etc.	\$4,275	\$230	\$450
ROV Electronics	Internals: Sensors, cameras, tether, etc.	\$5,400	\$3,900	\$1,250
ROV Structure	Frame/tube: Extrusion, brackets, fasteners, etc.	\$880	\$70	\$500
Float	Non-ROV float: Electronics, stepper motor, etc.	\$150	\$100	\$200
Registration Fee	For MATE ROV World Championship.	\$350	\$550	\$650
Travel	See Table 11.	\$4,800	\$6,300	\$9,500
Sustainability	For trash clean-up initiatives: Bags and gloves.	N/A	N/A	\$100
Total:		\$16,355	\$11,925	\$13,150

*Estimated, while 2024 and 2025 columns reflect actual spending.

Cost Accounting

Table 13. 2026 Wave Co. Funds.

Name	Category	Amount (USD)
Comp. 2025 Winnings + Dues	Carryforward Balance	\$4,050.00
ERAU Student Government	University Funding	\$4,340.00
ERAU College of Engineering	University Funding	\$6,150.00
Familial Donations	Fundraising	\$3,340.00
Aspen Utility Company	Sponsorship	\$1,999.99
iFixit	Equipment Donation	\$449.80
SendCutSend	Store Credit	\$250.00
VectorNav	Equipment Donation	\$1,200.00
Total:		\$21,779.79

Table 14. ROV Total Cost.

Category	Type	Item(s)	Est. Value (USD)
Ground Station	Reused	Logitech X56 HOTAS	\$250
Ground Station	Reused	Dell Latitude 7330 Rugged Extreme	\$2,000
Ground Station	Purchased	Dell 90W Laptop Charger x2	\$130
Ground Station	Reused	Fathom-X Tether Interface	\$490
ROV Electronics	Reused	Blue Robotics ESC/T200 x8	\$2,620
ROV Electronics	Reused	DeepWater Exploration exploreHD Camera x2	\$600
ROV Electronics	Purchased	DeepWater Exploration exploreHD Camera	\$300
ROV Electronics	Reused	LattePanda Sigma	\$680
ROV Electronics	Donated	VectorNav VN100T-CR	\$1,200
ROV Electronics	Reused	Pololu Mini Maestro	\$76
ROV Electronics	Purchased	Blue Trail Engineering SER-2010 x2	\$750
ROV Electronics	Purchased	Custom Powerboard	\$380
ROV Structure	Purchased	8" ID Acrylic Tube and End Caps	\$575
ROV Structure	Purchased	Aluminum Extrusion	\$62
ROV Structure	Fabricated	Misc. 3D-Printed Parts	\$30
ROV Structure	Purchased	Stainless Steel Fasteners	\$23
Total:			\$10,166

Table 15. Wave Co. Expenses (September 2025 to May 2026).

Category	Example Item(s)	Budgeted	2026 Spending	Total Value
Equipment/Tools	PC Filament, Zip Ties	\$500	\$170.89	\$4,175.16
Ground Station	New Laptop Chargers	\$450	\$129.98	\$2,870.25
ROV Electronics	New Cameras, Tether	\$1,250	\$1,549.99	\$6,605.18
ROV Structure	316SS Fasteners, Tube	\$500	\$302.79	\$690.70
Float	ESP32-S3, Wifi Antenna	\$200	\$42.99	\$210.67
Registration Fee	For MATE ROV WC	\$650	\$650.00	\$650.00
Travel	See Table 11.	\$9,500	\$11,310.56	\$11,310.56
Sustainability	Trash Bags, Gloves	\$100	\$50.89	\$50.89
Total:		\$13,150	\$14,362.53*	\$26,563.41

*Final spending exceeded the original budget due to significant donations after the budget was made. Additional funds raised will go towards next season's carryforward balance.

Acknowledgments

What Wave Co. accomplished for the 2025-26 season would not have been possible without our sponsors and our school's personnel. We want to thank our gracious supporters:

- MATE II and the Marine Technology Society for organizing the MATE ROV competition,
- The National Science Foundation for continued support of the competition,
- Embry-Riddle Aeronautical University for providing a workspace and a pool to test in,
- The ERAU Student Government and ERAU College of Engineering's EECS Department for university-provided funding,
- Aspen Utility Company for financial sponsorship,
- SendCutSend, iFixit, and VectorNav Technologies for store credit/equipment donations,
- The Anguiano, McSwiggin, Thompson, and Yocum families for their financial contributions,
- Our faculty advisor, Daniel Penny, for travel support, along with additional ERAU faculty and staff: Demi Bentley and Wanda Rodriguez for travel and funding logistics, Dr. Leo Ghelarducci for engineering advice, Dr. Yizhou Jiang for material science knowledge, and Bill Russo for machining help,
- AMRA President - Emily Coello, AMRA COO - Joseph Rigo, and AMRA COS - Kellan Shew for managing club duties, helping with finances, meal planning, and media,
- Tatum Kelley for being our T-shirt liaison.

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Appendix A - ROV Pool-Testing Procedures

Pretest Inspection:

- ☐ Look for missing components: Emergency Stop, Bulkhead Penetrators, Fasteners, Sensors, and Internal Electronics
- ☐ Ensure wiring is in the testing configuration and not benchtop configuration.

Leak Check:

- ☐ Connect Vacuum Pump to one-way valve for main ROV hull.
- ☐ Power on Vacuum Pump and monitor pressure down to maximum vacuum (approximately -760 Torr), then pinch Vacuum line after pressure gauge.
- ☐ Monitor Pressure for 1 minute to estimate leak rate and ensure that the pressure did not raise more than 5 Torr over the course of one minute.
- ☐ Remove Vacuum Pump From one way valve and vent the vacuum using the one-way valve.
 - There should remain a slight vacuum inside the main hull (approximately -60 Torr) to ensure a better seal during operation.
- ☐ Attempt to pull the enclosure off the end of the ROV - you should not be able to. Move on to deployment.

Deployment Procedures:

- ☐ Clear the reserved and adjacent pool lane of swimmers.
- ☐ Ensure there are enough members to initiate Deployment Procedures (at minimum, three people).
- ☐ Deploy the ROV safely with one person on the bow, one person on the stern of the ROV, and ideally a third person in the water holding the bottom to avoid hitting the side of the pool.
- ☐ The lifters count “one, two, three, lift” and raise the ROV while gripping on the designated lift points
- ☐ Rest the bottom of the ROV over the edge and lower into the pool.
 - Be mindful of the sensors present
 - If there is a third person, hold the bottom rails and help guide the ROV
- ☐ Swimmers look under the ROV for pools of water that form at the bottom of the clear sections of the hull if there are leaks. If no pools of water have formed after a minute of floating in the water, continue testing.
- ☐ Ensure tether is not tangled and clear from any hazards.
- ☐ Launch MAKO start file on ground station laptop.
- ☐ Pilot announces “arming” to team, indicating they will arm the thrusters. This is then done with the HOTAS.
 - If the ROV behaves in an unexpected manner (not stabilized in place), the pilot should quickly disarm the motors and the team’s diver should recover the ROV to the side of the pool.
- ☐ If ROV behaves as expected once armed and the pilot verifies they have control, continue with that day’s test plan. After completing the test, the pilot must disarm the motors and inform the diver to recover the ROV.

Posttest Procedures:

- ☐ Bring the ROV to the edge of the pool and have two lifters grasp the top rails of the sub closest to the pool side.
- ☐ Lift the ROV straight up and move to the ground near the pool side.
- ☐ Once removed from pool, make sure to rinse ROV thoroughly with fresh water to prevent excessive corrosion and buildup of mineral deposits.
- ☐ Dry the ROV with either towels or “wireless towel” (leaf blower).
- ☐ Store ROV back in lab with new desiccant packs.

Appendix B – Lab Safety Policies and Procedures

1. Ensure that lab work is supervised.
2. Use proper PPE at all times when work is being conducted, including: safety glasses, close-toed shoes, gloves (except with rotary tools), a respirator (when soldering). Loose clothing should not be worn, and long hair must be tied back.
3. Injuries and accidents must be reported to AMRA's Safety Officer and ERAU's Senior EHS and Risk Specialist. If severe, call 911 and notify Campus Safety & Security.
4. If unclear on appropriate procedure, consult AMRA's Safety Officer.
5. Do not eat or drink in the lab.
6. Report hazards or unsafe conditions. If possible, correct them.
7. Be knowledgeable of the equipment you are using. Certain equipment, like the 3D printer, arbor press, hot air station, and power tools require training within the club before use.
8. Only use tools for the intended purpose.
9. Never leave a machine or equipment running unattended (except 3D printer). Ensure it is turned off before leaving the lab.
10. Debur or sand rough part edges.
11. Properly secure workpieces before attempting work.
12. When working with any lubricants, adhesives, or chemicals, read the SDS and take proper safety measures, including using a respirator and gloves, and completing work in a well-ventilated area or outside.
13. Eliminate distractions and avoid conversations when operating equipment.
14. Watch for and eliminate tripping hazards.
15. Note and report any damaged, missing, or malfunctioning equipment to a club officer.
16. Before leaving the lab for the day:
 - a. Power down all computers, monitors, and laboratory equipment.
 - b. Disconnect or place on standby all ROVs, test rigs, and electronic devices.
 - c. Return all hand tools, measuring instruments, and specialty equipment to their designated storage locations.
 - d. Remove personal belongings and project materials from work surfaces.
 - e. Place ongoing projects in labeled bins, cabinets, or other designated storage areas.
 - f. Properly dispose of trash, scrap material, and consumables.
 - g. Wipe down benches, desks, and equipment surfaces if necessary.
 - h. Unplug and allow to cool all soldering irons, heat guns, or hot tools.
 - i. Seal and store chemicals and adhesives appropriately.
 - j. Confirm fire extinguishers and first aid kits remain accessible and unobstructed.
 - k. Close all cabinets and drawers.
 - l. Log out of shared computers and accounts.
 - m. Turn off lights.
 - n. Close both doors leading to the lab upon final exit.