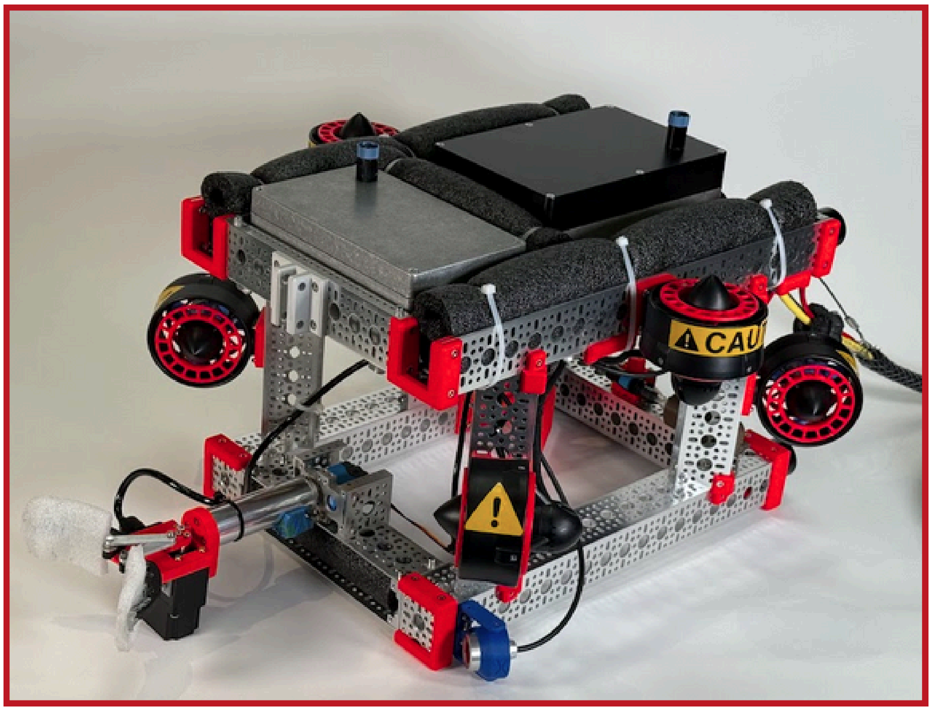
TECHNICAL DOCUMENTATION
MATE WORLD CHAMPIONSHIP
JUNE 19-21, 2025

Hephaestus Robotics

Organization: X Academy
Santa Cruz, California, USA

TALOS V



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Blaise Benoit-Corey, COO
Bennet Menzer, CTO
Nathanael Marcus, CFO
Nathan Hofmann, VP of Engineering

Mentors
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Tim Madsen
Kurt Yeager
Josh Corey
Curtis Galloway
Kai Herbst
Anoop Menon
Lars Menzer
Simona Tick
Geoff Tick
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Frame
Robert Stanford
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Max Watrous-Schumaker
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Marketing
Jesus Nazareth Garcia Romero
Amber Williams
Sophia Casaletto
Julia Tick
Orlando Cazales Mendoza

Float
Sophia Casaletto
Matthew Hofmann
Amber Williams
Ojas Shastri

Electrical
Aditya Menon
Nathanael Marcus
Samuel Imahara

Cameras
Blaise Benoit-Corey
Marco Grossman
Anthony Quintana-Arguello
Carlos Ortiz-Lopez

Tools
Nathan Hofmann
Cole Williams
Bennet Menzer

Software
Rowan Delander
Arthur Guihaire
Julia Tick

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Abstract

Hephaestus Robotics is a company based in Santa Cruz, California. It operates under the X Academy nonprofit organization, functioning independently from any school and supported by the Santa Cruz County Office of Education. Hephaestus Robotics is composed of 20 employees from seven different schools across Santa Cruz County. This unique interdisciplinary collaboration is united by a shared passion for developing technology that addresses real-world issues.

Talos V is Hephaestus' most advanced remotely operated vehicle (ROV), constructed through a philosophy of detailed planning, strong collaboration, iterative design, and rigorous testing. Its production was overseen by groups of 3-5 students, each responsible for a distinct subsystem, including but not limited to software, tooling, and electronics. Talos V features a uniquely modular design, engineered in alignment with the company's mission: creating innovative underwater ROVs that tackle critical environmental challenges while surpassing benchmarks in maneuverability and mission adaptability. The ROV directly addresses the technical requirements outlined in the 2025 Marine Advanced Technology Education (MATE) Request for Proposal (RFP).

This technical document not only details Talos V's cutting-edge design, development process, and capabilities, but also highlights its potential to assist the global community by identifying underwater objects, properly navigating marine life, identifying healthy marine habitats and ecosystems, and collecting data to monitor ocean health, offering a powerful tool for environmental stewardship and scientific discovery.

TEAMWORK: TEAM MEMBERS

Figure 1: Team members.
Left to Right: Blaise Benoit-Corey (COO) '25, Aditya Menon (Electrical) 27', Nathan Hofmann (VP of Engineering) '25, Sam Imahara (Electrical) '26, Sophia Casaletto (CEO) '26, Amber Williams (Float) '26, Julia Tick (Float) '27, Arthur Guihaire (Software) '25, Rowan Delander (Software and Pilot) '26, Kai Herbst (mentor) '24, Ojas Shastri (Float) '26, Daphne Bingham (Tools) '26, Bennet Menzer (CTO) '25, Cole Williams (Software) '25, Matthew Hofmann (Float) '25, Zander Shulman '25 (Tools)

1. TEAM AND PROJECT MANAGEMENT

[1.1] COMPANY PROFILE

Hephaestus Robotics is a 5-year old company based in Santa Cruz, California, dedicated to designing and engineering underwater ROVs that address the impacts of climate change on underwater and marine ecosystems. Unlike many school-affiliated teams, Hephaestus brings together 20 student-engineers from seven different schools, operating under X Academy, a 501(c)(3) nonprofit that provides STEM enrichment programs to middle and high schoolers in Santa Cruz County. This unique structure creates a well-rounded, diverse team and provides students countless opportunities to develop technical skills in engineering and learning leadership while tackling real-world problems. This year, 13 new members joined the team and completed an eight-week training period to learn about the team's operations. Hephaestus's peer-to-peer training system provides all employees with a strong technical foundation and a highly collaborative, solution-driven mindset.

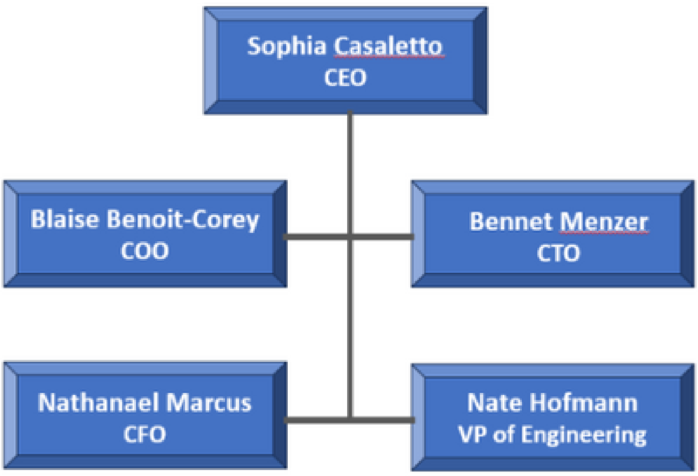


Figure 2: Executive Leadership Team (ELT) Organizational Chart. Credit: Julia Tick

Hephaestus Robotics is organized into 6 main departments: Electrical, Software, Frame, Cameras, Float, and Mission Tools, each led by an experienced team member with support from mentors. Department leads are responsible for delegating tasks and reporting progress to the Executive Leadership Team (ELT). The ELT consists of the CEO, CTO, COO, VP of Engineering (VPE), and the CFO, as presented in Figure 2, who are responsible for maintaining efficiency and the overall success of the program. Each task and need was evaluated and prioritized (or reprioritized with more data accumulated) at the beginning of each weekly in-person build day session to effectively solve day-to-day challenges as they arise, or help refocus resources once objectives are completed.

This structured approach combined with the company's organizational framework supports the development of innovative ROVs created to effectively perform mission tasks in global marine ecosystems. By prioritizing both technical excellence and team cohesion, Hephaestus ensures long-term stability and success in developing cutting edge technology.

[1.2] PROJECT MANAGEMENT

Hephaestus Robotics implemented an extensive project management system and general task breakdown rubric to manage mission objectives and perform functionally as a team (Figure 3). At the start of the season, Hephaestus aimed to redesign the ROV for improved space efficiency and reliability to complete mission tasks. Compared to last year, the team focused on improving not only internal organization but also streamlining the build process, documenting the process earlier and with a higher degree of detail, increasing collaboration across the whole team. Starting in September, the team met every Sunday to learn about robotics and begin building the ROV. During the Sunday sessions, members worked on tasks alone or in small teams, with leadership ensuring that no member was confined to working on just one aspect of the ROV. This approach allowed every member to gain experience in multiple areas and explore their interests.

To meet mission objectives and generate smoother operations, Hephaestus Robotics is guided by its ELT, a group of experienced members who play a crucial role in the program's success. The ELT leadership team meets for 30 minutes before each Sunday session to establish goals for the day, and meets for one hour after each session to discuss the company timeline and upcoming objectives and tasks. This helps all team members stay accountable, engaged, and committed to a strong work ethic.

Subsystem	Task Breakdown
Float	Redesign float for compactness, build and test buoyancy control system
Software	Rewrite code for clarity, shift computation to topside, integrate thrust limiting + precision system
Mission Tools	Redesign medusa jellyfish tool, research ways to complete MATE tasks, create modular tool system
Frame	Mount mission tools and electronics, optimize space and test different designs to see which is most efficient
Electrical	Wire ESCs, build and waterproof electronics housing, integrate tether penetrators and monitor power
Cameras	Research camera options, install cameras + GoPro Max 360, develop photosphere, test streaming reliability

Figure 3: Task Breakdown Rubric by Subsystem. Credit: Julia Tick.

From September to December, the team began a training period in which all members learned about essential engineering and programming concepts. This training covered CAD, Raspberry Pi, Arduino, software, and camera streaming. By the end of December, the team members finished general training and self-assembled into designated departments (Electrical, Software, Frame, Cameras, Float, and Mission Tools) based on interests. Following the training phase, the team entered a focused build period (Figure 4) from December to April (Regional Competition) and April to June (World Championship Competition).

Subteams had weekly meetings to establish goals using Trello, a web-based kanban-style list making application, which was newly integrated to organize and prioritize tasks. This allows the team to efficiently complete ROV mission tasks as defined in the MATE Manual. This year, Hephaestus Robotics implemented Slack as the primary communication platform in order to streamline day-to-day communication, as well as solve real-time challenges as they arise and enhance communication across sub-teams.

REGIONAL COMPETITION PREPARATION								
TEAM COMPONENTS	New Members	Goals	To Do	Software	Electronics	Cameras	Float	Mission Tools
September	Recruitment & Training	Train & introduce mentors	Create presentation to introduce new members to each subsystem	Training	Training	Training	Training	Training
October	Training	Training & subsystem overview	Host skill workshops to gain knowledge	Training	Training	Training	Training	Training
November	Training	Deepen technical skills	Assign roles for the build season	Research	Research	Research	Research	Research
December	Team integration	Understand the mission tasks & build props	Build props, prep mission tools, review rubrics	Research & early development	Plan layouts & research components	Research parts (i.e., 360 photosphere) & mounting/ layout options	Research & order parts (i.e., pump for buoyancy engine)	Evaluate tool options & ideas
January	Start building ROV & split into subsystems to work	Start building ROV	Set weekly build milestones within subsystems	Re-factor a completely new code & paradigm	Assemble electronics housing	Continue to brainstorm camera options & use CAD to see layout on ROV & order parts	Test individual parts & gather quantitative & qualitative data	Assemble tools & do basic testing
February	Continue subsystem development	Finish developing ROV	Continue developing ROV in each subsystem	Modularize & improve code	Cable management & waterproofing	Mount cameras & test streaming	Integrate parts with each other & test	Test tool handling & if designs properly work
March	Testing & make necessary adjustments	Test ROV & iterate	Prepare for the competition & go through mission tasks with props	Test & de-bug	Run diagnostics	Finalize configuration	Finalize design & finish assembling float	Test each tool & improve based on performance
April	Team building & practicing for Regional's	Ready for Regional Competition	Pool practice, mission tasks, failure tests, team roles	Final testing, de-bug, & improvements	Pool testing, run diagnostics & fail checks	Finalize configuration, mission tasks & testing in pool	Finalize assembly & testing in pool for Regional's	Test and practice in pool to perfect mission tasks

WORLD CHAMPIONSHIP COMPETITION PREPARATION								
TEAM COMPONENTS	New Members	Goals	To Do	Software	Electronics	Cameras	Float	Mission Tools
May	Team building & practicing for World's	Improve task efficiency for World's	Pool practice, mission tasks, failure tests, perfecting team roles	Final testing, topside efficiency, de-bug, & improvements	Pool testing, run diagnostics & fail checks	Improve configuration, mission tasks & testing in pool	Improve upon assembly, final iterations & testing in pool	Test and practice in pool to perfect mission tasks
June	Team building & practicing for World's	Team building & practice	Pool practice, mission tasks, failure tests, perfecting team roles	Final improvements & testing, build in redundancies & backups	Pool testing, run diagnostics & fail checks for World's	Finalize configuration, mission tasks & testing in pool for World's	Final testing and lessons in prep for World's	Intensive practice in pool to perfect for World's

Figure 4. Hephaestus Project Planning Schedule to Aid Building the ROV and in Preparation for Regional and World Championship Competitions. Credit: Julia Tick.

[1.3] DETAILED PROJECT PLANNING/ SCHEDULING

In July of 2024, leaders and mentors from last year's team convened to plan for this season. The leadership team, led by CEO Sophia Casaletto, developed a schedule to facilitate the creation of a Remotely Operated Vehicle (ROV) and Float. This ROV would incorporate updated components and software, aiming for a more streamlined design tailored to the new mission objectives. Figure 5 clearly outlined task breakdowns and overall goals for each subsystem. Adhering to this schedule, team leaders began each session by providing updates on important events, announcements, and other pertinent information. They also conducted individual checkins with members to ensure deadlines were being met and to help identify suitable tasks. For example, Rowan Delander, the lead software engineer, mapped out the software development plan for the season, encompassing software for components such as the gripper and pH sensors. Another example includes Sophia Casaletto's detailed planning regarding the documentation and engineering presentation, issuing clear assignments and organizing meeting times outside of the team's weekly meeting to practice and revise. This exemplifies how Hephaestus clearly exhibits highly detailed and structured planning.

Date	Activities
Dec 8	Organize team by interests. Layout plan for ROV/Float team.
Jan 12	Development starts. Course on ROS software starts. Review comp manual, design float buoyancy engine.
Jan 19	Design frame + electronics in CAD. Photogrammetry planning, design buoyancy engine.
Jan 26	Finish CAD for ROV. Design tool/camera systems. Continue ROS course. Purchase parts.
Feb 2	Assemble ROV + electronics + cameras. Begin assembling float. begin ROS control system.
Fed 9	Continue assembling ROV + electronics + float. Camera troubleshooting and writing the software.
Feb 16	Finish ROS course+integrate it into ROV. FInish ordering parts. Plan tech docs.
March 2	Begin ROV testing with practice pool
March 8	ROV can be driven and submerged. STEAM expo, all in attendance for this community outreach event.

Date	Activities
March 9	Fundraising temp prep. ROV buoyancy calculations. Add tools, assemble topside
March 16	Add tool control to ROV, test photogrammetry system. Finish camera system.
March 28	Finish Tech docs
March 30	Competition ready ROV complete and in water
April 6	Begin test runs with full ROV setup
April 13	Plan engineering presentation.
April 13-26	ROV pool practice and demo runs. Engineering presentation practice.
April 26	Regional competition!
April 26-June 1	If applicable, prep for world championship. Review scores and make final design changes.

April 27	Break
May 4	Regionals debrief and review scores
May 11	Parent meeting/Discuss travel to worlds and demonstrate the ROV in the pool
May 17	Meet to finish tech docs and submit
May 18	Practice mission tasks in the pool
May 25	Plan engineering presentation and review scores to make it better
June 1	Practice in the pool and practice engineering presentation
June 2-15	Practice in the pool and practice engineering presentation, practice practice practice
June 16-23	World Competition

Figure 5: Hephaestus Detailed Project Planning and Scheduling. Credit: Julia Tick.

2. ENGINEERING DESIGN RATIONALE

[2.1] OVERALL DESIGN

Talos V (Figure 6) is a compact ROV built around a rectangular frame made from 1120 GoBilda aluminum channel. Talos V uses 6 thrusters, two placed perpendicular to the frame for vertical movement, and four placed horizontally in a vectored configuration for precise control over horizontal movement. The frame's modular GoBilda channels allow tools and electronics to be repositioned in seconds, enabling rapid reconfiguration.

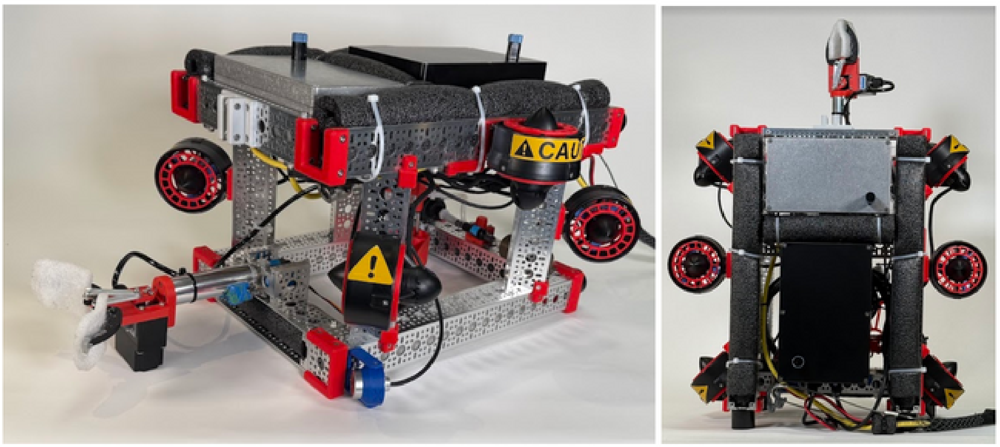


Figure 6: The Talos V ROV; Full View (left panel) and Side View (right panel) Credit: Nathan Hofmann

The design of Talos V builds directly from lessons learned from last year's Talos IV, with a focus on optimizing space and ensuring system dependability as illustrated in Figure 7. The team began by reviewing Talos IV's performance and identifying limitations, specifically how the bulky mission tools and onboard processing resulted in high latency and restricted space on the frame.

After reviewing, the team decided to focus on designing a more compact system that freed up space on the frame and improved responsiveness in order to meet MATE RFPs with better resource utilization (Figure 8). The first major design challenge was accommodating a complex set of mission tools without expanding the ROV's size. For example, these principles informed design decisions on the camera networks on the ROV, by implementing a new configuration: four ExploreHD 3.0 underwater cameras for piloting, and one GoPro Max camera for the 360º photosphere. This freed up space on the frame for mission tools while also simplifying the process and reducing potential failure points. By rewriting the ROV's code and offloading computation to topside controls, latency dropped from 0.5s to <30ms, critical for time-sensitive tasks like jellyfish capture. The code of the ROV was completely rewritten for efficiency, and as a result, the responsiveness has improved. By carefully balancing functionality, spatial efficiency, and reliability, the team has successfully evolved the Talos IV into the more capable, responsive, and mission-ready Talos V.

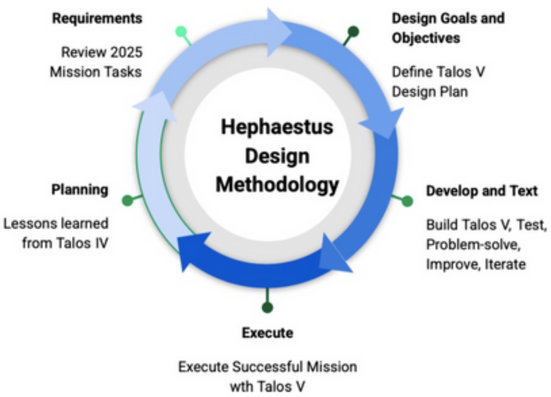


Figure 7: Talos V Iterative Design Methodology. Credit: Julia Tick.

Key Design Objectives				
Talos V Key Design Goals	Agility	Dependability	Efficiency	Decision Taken
I. Optimize Space Use - Accommodate a complex set of mission tools without expanding the ROV's size.	Yes	Yes	Yes	Use a new camera configuration
II. Increase system dependability through simplicity	Yes	Yes	Yes	Write new code for ROV to offload computational load to the topside controls, eliminate half second delay.

Figure 8: Talos V Design Decision Matrix Credit: Julia Tick.

[2.1.1] INNOVATION

Hephaestus Robotics introduced several innovations in the development of Talos V, focusing on improving performance and reliability. One of the core innovations this year was offloading the main computational tasks, such as calculating current usage and thrust to pwm, from the ROV to the top-side control system. In the past, calculations were handled on the ROV using a Raspberry Pi 4. Now, joystick inputs are processed on the topside, where linear velocity, thrust, and current usage are calculated in real time. The Raspberry Pi on the ROV now only handles tasks such as controlling the motors and returning status updates. These changes have improved gripper response time from 0.5s to near-instantaneous (under 30ms), critical for precision tasks like the pCO2 sensor deployment in Task 1.2. In addition, the team developed a binary search based algorithm that limits the current, and keeps total power draw within the 18 amp (A) budget. This protects the system from electrical overloads and damage. A "precision mode" toggle was also introduced this year, which can dynamically scale thrust for delicate movements during tasks. This feature is an important innovation, especially after observing issues during last year's missions, where the absence of "precision mode" made it harder to execute precise maneuvers. Pilots reported that the joystick inputs were sensitive and often gave too much thrust, making it hard to do particular tasks. These improvements reflect a design philosophy that is centered on increasing efficiency through cost effective and creative solutions.

[2.1.2] VEHICLE STRUCTURE AND DESIGN

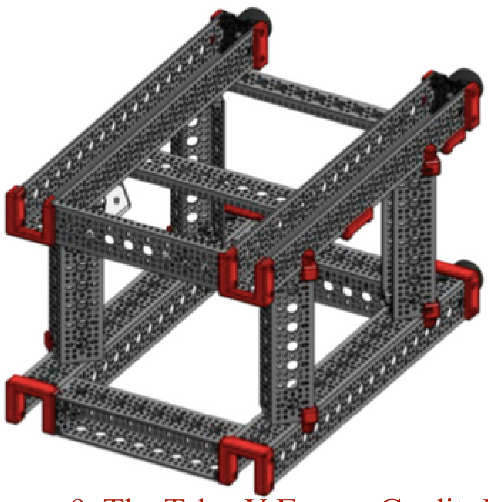


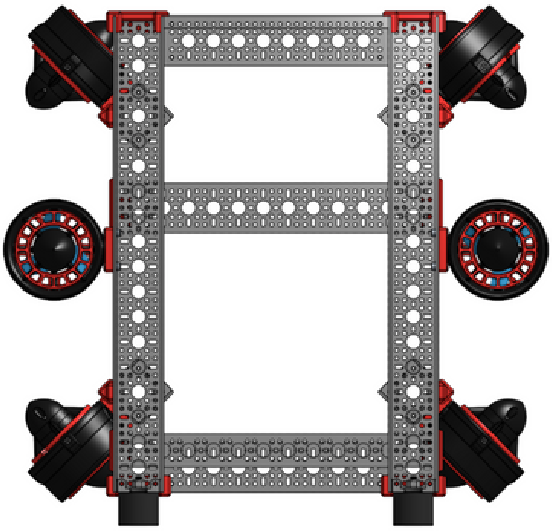
Figure 9: The Talos V Frame. Credit: Bennet Menzer.

Talos V's frame builds on last year's successful design, with significant improvements to meet the new mission requirements. The team retained the 1120 Series GoBilda Aluminum Channel structure (Figure 9), due to their rapid prototyping capabilities and adaptability. The channels are assembled in a rectangular prism that allows flexible placement of many peripherals, making iteration an easy process. Four horizontal translational motors were then mounted on vertical channels rotated 45 degrees, enabling strafing, turning, and forward and backward motion. Two vertical motors are attached to the top channel on the left and right sides. The main gripper tool protrudes from the front, being attached to a second servo controlling yaw (see Figure 10).

The GoBilda system has a metric pattern on an 8mm grid, allowing segments to be attached in multiple positions similar to LEGO blocks. This flexibility makes it easy to modify designs or reposition peripherals. The reusable aluminum channel is environmentally friendly compared to 3D printed or laser-cut materials, as it offers flexibility for future improvements without having to be remanufactured. With its rubber feet positioned on the back, Talos V is able to stand vertically while out of the water to avoid fragile mission tools located on the bottom contacting the ground. Hephaestus designed the frame and components in OnShape before purchasing parts, allowing the ROV to be fully assembled to meet design objectives before manufacturing. These objectives included creating new mission tools, an improved gripper, and new electronics enclosures. The Talos V frame, shown in Figures 6 is a 31-cm x 37-cm x 41-cm rectangular prism assembled from GoBlida aluminum channel. It supports two aluminum rectangular enclosures, the six propulsion motors, and an array of tools and sensors.

[2.1.3] PROPULSION

To maneuver the ROV precisely, Talos V uses six Blue Robotics T200 thrusters for propulsion. Four vectored thrusters are used to enable movement in all horizontal directions as well as yaw control (Figure 11). Two vertical thrusters are used to move vertically while maintaining stability. The six thrusters arranged in the described configuration will allow for maximum control and agility to accomplish mission tasks efficiently. While eight thrusters would enable pitch control, simulations showed six thrusters met all MATE agility requirements while staying within the power limit, a trade-off that saved $480 without significantly compromising performance.



In the design of Talos V, propulsion and thrust systems tradeoffs between power consumption, cost, and performance had to be considered strategically. The Talos V cannot run all T200 thrusters at their maximum speed simultaneously, otherwise Talos V would use more power than allowed for the Ranger class. The following calculations show the constraints for power considerations when running the thrusters at maximum speed:

$$16.91A \times 12V \times 6 \text{ thrusters} = 1217.5W > 300W$$

Figure 10: Top Down View of the Talos V Frame with 4 Vectored and 2 Vertical Thrusters. Credit: Bennet Menzer.

Additionally, some power must be allocated for the Raspberry Pis and cameras, so our current budget for the thrusters is 18A to avoid brownouts on the Raspberry Pis. The software dynamically scales thruster speed so that the current does not exceed 18A. The thrusters do not use the same amount of current forwards and backwards. Since they are about 30% more efficient running forwards, we decided to have two vectored thrusters facing more forwards and two facing more backwards. This configuration gives equivalent thrust when moving forwards and backwards. The software control system correctly accounts for changes in current usage and thrust depending on the motor's direction when calculating the final PWM values to send.

[2.1.4] BUOYANCY AND BALLAST

The majority of Talos V's buoyancy comes from foam and the electronics enclosures, both of which are positioned at the top of the ROV to have the center of buoyancy positioned above the center of mass. This keeps the ROV extremely stable while in the water. By submerging the ROV and attaching it to a scale to determine its weight in water, the correct amount of foam was calculated using Archimedes' principle. The team used foam pipe insulation which is affordable, fits well on the ROV and is easy to alter the amount of foam, allowing for quick changes while testing the ROV in the water. One issue with this foam is that it compresses when in deep water, so to compensate, more foam was added to achieve neutral buoyancy at the depth required for the product demonstration.

3. VEHICLE STRUCTURE AND SYSTEMS

[3.1] ELECTRONICS OVERVIEW

Talos V's onboard electronics consists of two main Polycase enclosures, four DeepWater Exploration cameras, various servos, and sensors. The electronics system supports key requirements for completing mission tasks, such as camera streaming, thruster control, and tool operation. Without it, Talos V would not be able to perform the complex and multi step tasks required by the MATE RFP. The rear enclosure houses the control Raspberry Pi 4B, which is responsible for controlling thrusters and reading sensors. Our custom PCB Pi Hat integrated 12-5V power conversion, PWM, I2C, and GPIO connectivity on a single board, reducing overall wiring complexity. This directly supports MATE's emphasis on reliability by minimizing points of failure. The Pi Hat contains four I2C channels for sensors and supplies 5V to power the Raspberry Pi and PWM channels. A PCA9685 chip on the Pi Hat allows the Raspberry Pi to send Pulse Width Modulation (PWM) signals to the motor controllers through an I2C bus. These signals are carried to the ROV's ESCs with two ribbon cables. The front enclosure is responsible for camera interfacing and ethernet distribution. It contains a Raspberry Pi 4B connected to a DeepWater Exploration multiplexer to interface with the ROV cameras.

A SwitchBlox Small Ethernet Switch interfaces the topside computers with the two Raspberry Pis on Talos V. An additional 12V to 5V converter was designed to provide power to the Raspberry Pi and DWE cameras. The front electronics enclosure receives the tether Ethernet connection, while the rear enclosure receives the power and ground wires, which are interfaced through four twenty-six gauge conductors to the front electronics enclosure to power the ethernet switch and the 12V to 5V converter.

[3.1.1] ESC CONNECTOR BOARD

Last year's Talos IV used a separate enclosure for interfacing the motors to the main Raspberry Pi controller. The enclosure had two stacks of three ESC's on custom acrylic mounts and clamps and a custom breakout board was designed to interface the PWM connectors to the motor controllers. (Figure 11 (right panel), shown below).
This year, custom PCBs were designed to solder the motor controllers onto a compact board system (Figure 11 (right panel), shown below). Talos V uses two of these custom PCBs, stacked on top of each other to conserve space. These PCBs together hold a maximum of 8 motor controllers (4 each). These PCBs have double-sided lining and use copper strips to maximize electrical flow. Screw terminals were used to interface these boards onto a main board, effectively integrating all the wired connections into the circuit board. With this setup, a 50% space reduction was achieved, allowing for more accessible circuitry, while providing sufficient space for two additional motor controllers.

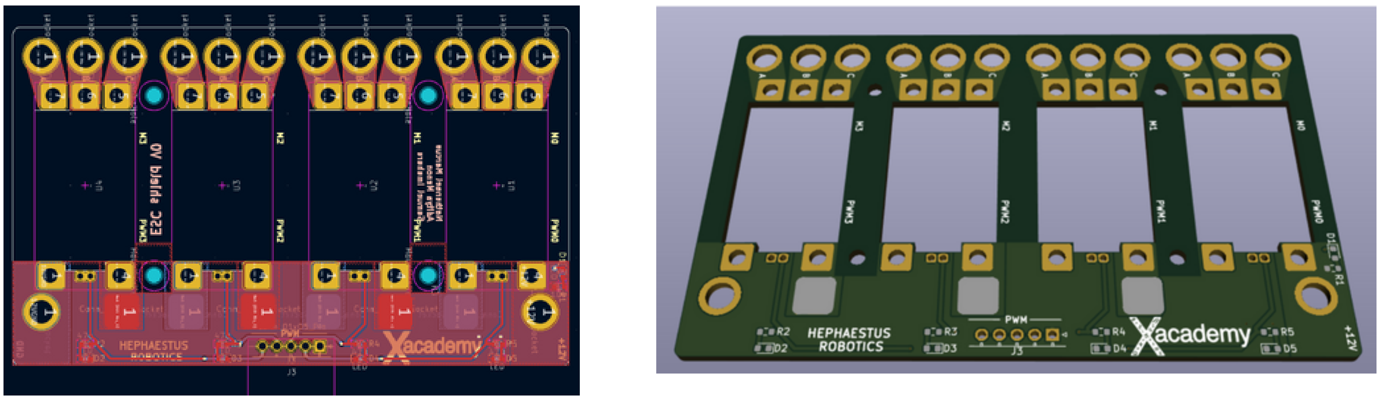


Figure 11: ESC Connector Board Footprint (left panel) and Custom PCB (right panel). Credit: Nathanael Marcus.

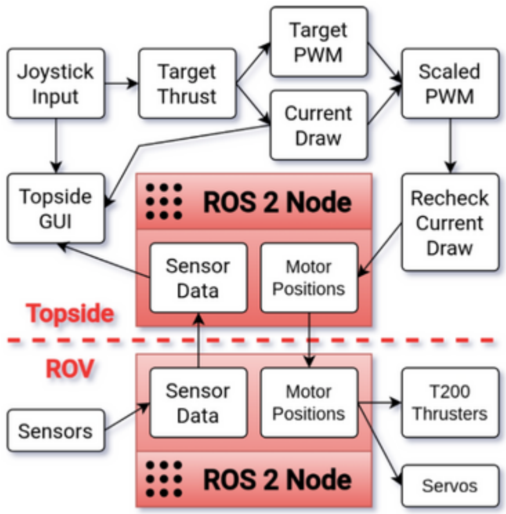
[3.2] ROV SOFTWARE

Hephaestus' top and bottom side software oversees all control functions, pilot operations, and ensures exceptional communication between the topside system and the ROV. The top side software runs on a BeeLink mini PC, while the bottom side software operates using two Raspberry Pi 4s. The topside is responsible for all major computations, while the bottom-side handles only essential tasks. Both systems run on Ubuntu 22.04.5 LTS (Jammy Jellyfish), chosen for its stability and compatibility with ROS 2, a critical framework for communication between the ROV and the topside. ROS2 offers efficient data communication and powerful control capabilities, making it an ideal choice for managing the ROV's systems during mission tasks.

The topside software processes input from the joysticks, keyboard, and sometimes mouse to calculate linear velocity, force, current usage, and PWM values that are sent to control the ROV. The main purpose of the topside software is to manage inputs and convert them into PWM signals for the ROV. The bottom side software's role is kept minimal, as all of the calculations are done on the topside to allow for advantages including portability, easier access to the software, and lower chance of the Raspberry Pi overheating. It receives PWM commands from the topside and sends them to the thrusters and motors, while sending sensor data and error messages back to the top-side system to inform the operator of the ROV's status. For safety, the bottom side software automatically stops all motors if the ROV loses connection for five seconds.

Figure 12: Topside setup. Credit: Rowan Delander.

The new code illustrates a significant improvement from last year's version. By offloading all complex calculations to the top-side, the ROV operates with a lower latency, improved accuracy, and better safety. Input from multiple sources is handled more efficiently, and gripper response time has dropped from over half of a second to under 30 milliseconds. A non-ROS version of the software has been developed for testing and simulation, allowing members to test and develop software more flexibly. This redesigned code allows for rapid changes with low risk, a significant improvement from the previous year.



Hephaestus uses GitHub as the team's central software repository, prioritizing documentation during development. To prevent accidental deletions or untracked modifications, Hephaestus follows strict version control. All software changes are managed through GitHub, preventing the loss of critical code. This allows for an organized workspace among the software team, improving accessibility and remote flexibility.

By using ROS 2 and optimizing the topside and bottom side software, Hephaestus Robotics has created a reliable software system that has precise control and rapid response time, enabling the company to perform effectively in timed mission events (Figure 13).

Figure 13: Graphical Representation of Data Processing and ROS 2 Node Communication. Credit: Arthur Guihaire

[3.2.1] CONTROL SYSTEM

To control the thrusters, a Pi Servo Hat Python library was integrated to send PWM values directly to the thrusters. The code for thruster control is more accurate as it communicates directly with the oscillator, allowing for very accurate PWM control. Last year's code assumed a linear relationship between joystick input and PWM, which made the thrust not correctly scale with the input.

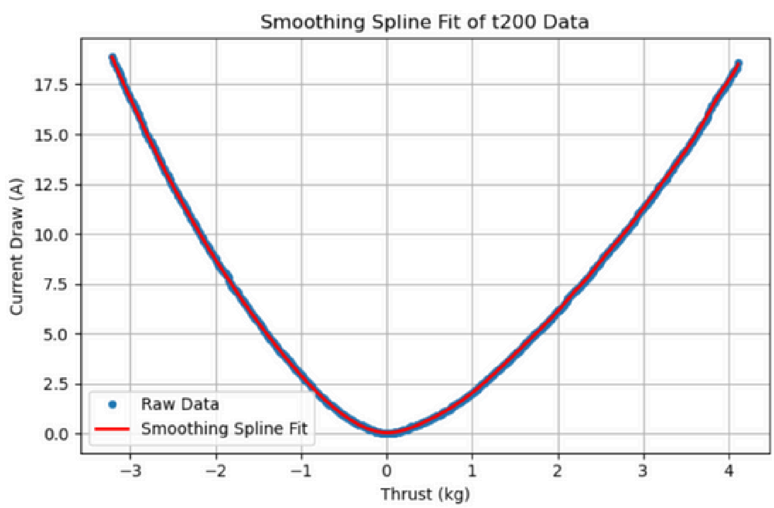


Figure 14: Synthetic Graph for Estimating Current Draw from Thrust for Individual Motors. Credit: Arthur Guihaire.

This year we implemented a non-linear scaling system based on data from Blue Robotics T200 thrust curves (Figure 14). New safety measures have been integrated into the code in order to limit power to the thrusters and to avoid power failures:

While calculating the PWM values to be sent to the motors, the thrust is scaled so that maximum thrust uses 18 amps (A). If the current still exceeds 18A, a binary search is used to scale the thrust so that it uses less than 18A. Extreme inputs are handled effectively as the software gives the maximum power to the motors without exceeding the 18A limit.

In addition, a "zero box" is included around the joystick's neutral position so that inputs very close to neutral will not run the thrusters. For computational efficiency, the current draw is first estimated using smoothing splines converting thrust directly to current draw (graph above).

The Talos V control system also features a depth hold algorithm. A button on a joystick is used to activate depth hold, and the ROV will stay at the current depth until a large vertical joystick input is detected or the button is pressed again. To implement the depth hold, a PID (Proportional Integral Derivative) control algorithm was used to dynamically control depth, using the data from the pressure sensor to calculate depth. The depth hold is very accurate; the ROV will not drift upwards or downwards more than 2 cm once stabilized, which makes it useful for completing tasks such as connecting the pCO_2 sensor to the buoy in task 1.2.

Steps Used to Translate Joystick Commands Into Thruster Movement:

1. Matrix multiplication is used to translate inputs into the target thrust vector. This is needed since the thrusters are oriented diagonally.
2. Thrust values are scaled by a predefined scale factor so that the maximum forward thrust uses the hardware's 18 amp limit.
3. Current draw is estimated using smoothing splines. If the current draw is too high, the thrust is scaled down with a binary search, re-estimating the current draw each iteration.
4. Data from Blue Robotics T200 thruster informational page used to calculate the PWM values needed for the target thrust values.
5. Verify that the final PWM values don't use more than 18 amps of current. If they do, they're all scaled down with a binary search.
6. Final PWM values are sent through ROS to the ROV Raspberry Pi, which sends the values to the motors directly.

[3.3] TETHER

Talos V uses a compact, durable tether system to manage the tether and ensure safe operation when maneuvering the ROV across varying mission scenarios (Figure 15). The tether is made up of two 12 gauge wires for power and one Blue Robotics Fathom ROV cable for Ethernet communication. Two pairs connect the onboard Ethernet switch to the topside router, and the Ethernet switch in turn is connected to the main Raspberry Pi and each Raspberry Pi Zero in the camera boxes. The other two pairs are unused.

9.5 mm diameter foam backer rod is used along the tether to provide uniform floatation, replacing the segmented pool noodle sections from the previous design. This change helps keep the tether afloat while reducing the likelihood of it catching on objects. These three components are wrapped in a flexible nylon sheath to protect the tether, keep the cables together, and allow purchase (i.e., shortening/lengthening) for the tether manager. A steel cable grip rated for 500 kg provides strain relief to the tether's connection to the ROV.

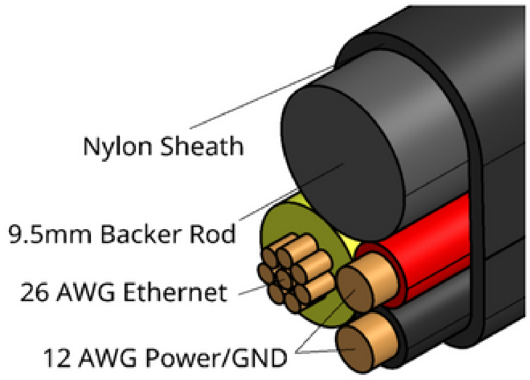


Figure 15: Tether Cross Section. Credit: Bennet Menzer

Penetrators on the bottom of both electronics chambers connect the tether to the ROV, supplying power and data. Detachable connectors are used between the ROV and tether, which allow the ROV and tether to be transported separately and reconnected easily. The Topside Control Station (TCS) has openings where the tether Ethernet enters and attaches to an ethernet switch, which in turn connects to the topside and scientist computers.

To protect both the ROV and members of the team, Talos V's tether is managed specifically so as to not damage the ROV, entangle the ROV, or cause a potential hazard during operation. Before launching the ROV, the tether is carefully coiled and any knots, tangles, or twists are removed before the launch. During operation, the main tether manager maintains an appropriate amount of slack to prevent the tether from getting in the way of operations or holding the ROV back. The assistant tether manager is responsible for ensuring that the tether is coiled neatly and watches to help the main tether manager. The pilot avoids rotating in one direction for too many revolutions, which could twist the tether. The team practices coordination between the pilot and the tether managers, ensuring that the tether stays manageable during the mission.

[3.4] PAYLOAD AND TOOLS

[3.4.1] DIGITAL CAMERA SYSTEM

The camera system for Talos V has been completely redesigned to solve space efficiency, weight, and power issues that were identified in Talos IV. The previous ROV (Talos IV), utilized three Pi cameras on Raspberry Pi Zeros, housed in bulky enclosures and wired back to the central Pi. Talos V's new onboard camera system utilizes four Deepwater Exploration exploreHD 3.0 cameras. Although the cost of these cameras is high ($300/pc) they offer significant advantages over our previous custom solution.

ExploreHD cameras provide a modular platform for seamlessly connecting up to seven units and deliver better low-light performance, while reducing weight, size, power consumption, and the waterproofing risks associated with custom enclosures. This ultimately simplifies the ROV design and improves its drivability, reliability, and reusability for future ROV iterations.

Talos V uses four of these exploreHD cameras, one forward facing camera for general navigation, one side mounted gripper camera for better depth perception, one camera for the water sampler, and one downward facing camera, which when combined with a standardized cube, the shipwreck can be measured to effectively address the mission requirements (Figure 16).

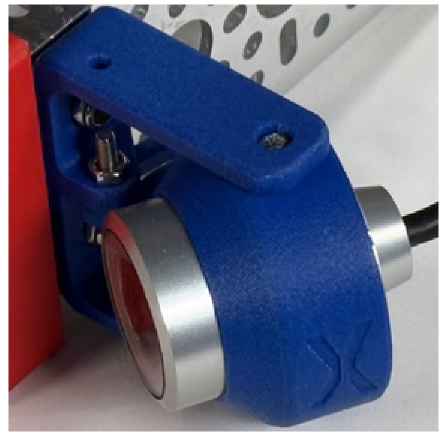


Figure 16: Explore HD Camera and Configuration. Credit: Blaise Benoit-Corey.

[3.4.2] 360 CAMERA SYSTEM

Figure 17: 360 Camera System. Credit: Blaise Benoit-Corey.

The 360 camera system is a stand-alone tool with a unique tether system. Hephaestus used the GoPro Max which is a commercial, off the shelf 360 camera that is water-proof, powered by a Lithium battery and can be controlled with a phone app over BlueTooth and WiFi. The camera takes excellent 360 photos but has run into two challenges. The competition rules disallow using Lithium batteries and the RF (Bluetooth and WiFi) doesn't work underwater. To create an innovative, inexpensive watertight enclosure and tether system for the camera, a combination of a 3" clear acrylic tube and a custom laser cut end-cap and PVC parts were used to house the camera. The enclosure has a 1" threaded PVC pipe at the bottom.

For the tether, a 1" flat fire hose was secured to the 1" threaded PVC pipe. The fire hose created an inexpensive way to put cables into the enclosure without having to use expensive, difficult to use penetrators. In the future, the team could pump air in the hose or add a fluid tube for pneumatic tools. Inside the fire hose, a power cable and a coax cable was installed. Directly transmitting 5V to the camera from the surface did not work, because of the voltage drop over long wires. So, 12V power was transmitted to the enclosure, where a 12V to 5V DC power converter with a USB-C connection was used to power the camera. This setup eliminated the need for a Lithium battery. To control the camera using the phone app over WiFi and Bluetooth, a coax cable was installed in the fire hose, with antennas attached on each end. The antennas and coax cable act as a passive RF extender, allowing reliable signal transmission. Ballast was added to the enclosure to make the entire system neutrally buoyant. This system provides a compact and efficient way to complete task 1.1.

[3.4.3] ACTUATION

To complete the various tasks required by the MATE RFP, the ROV must include systems for actuation. For this, Talos V continues to use waterproof servos for their various advantages compared to other systems, explained in Figure 18 below.

Factor	Force Output	System Complexity	Cost	Modularity
Waterproof Servos	Moderate	Low (simple electrical integration)	Low ($50-300 per actuator)	High
Pneumatic System	High	High (compressor, tubing, valves)	High (system wide cost $500-$1000+)	Low
Waterproof Linear Actuators	High	Moderate (power/control electronics)	Medium ($300-$600)	Medium

Figure 18: Underwater Actuator System Comparison

Pneumatic systems and linear actuators have an advantage in force output, particularly advantageous when the mission requires lifting heavy objects or requiring a large range of motion. However, MATE's requirements overwhelmingly require precision such as pulling a pin to deploy the hydrophone, or installing a two-pronged power connector for the pCO2 sensor. Thus, servos are the optimal actuator due to their low system complexity, high modularity (requiring only a PWM signal for control), and precise movement capabilities for delicate tasks, all while providing an acceptable amount of torque.

[3.4.4] ROTATING GRIPPER

Instead of designing an entirely new gripper, the team decided to go with the same general gripper design from Talos IV, which has the advantages associated with servos and had previously passed rigorous testing for reliability and efficacy. However, this year's gripper incorporates key innovations. VP of Engineering, Nate Hofmann, improved the gripper by upgrading the primary servo to a Blue Trail Engineering 2010-SER servo due to its waterproof enclosure, high torque, and top-notch build quality (Figure 19).

Additionally, Nate negotiated a 30% discount from Blue Trail Engineering, making it a cost-effective upgrade while still substantially improving performance. The design was modified to incorporate the upgraded servo and allow for additional rotational movement via a secondary servo. Furthermore, the waterproof enclosure allows for modularity and redundancy by fitting any standard size servo. This makes servo replacements easy for when technical issues arise.

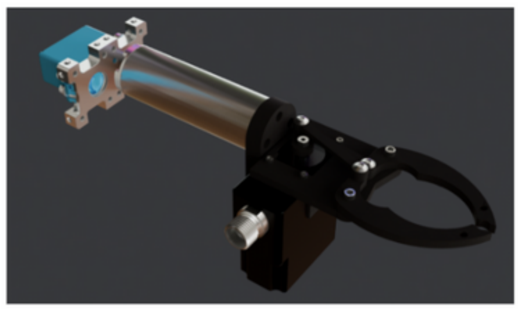


Figure 19: CAD Model of the Gripper. Credit: Nathan Hofmann

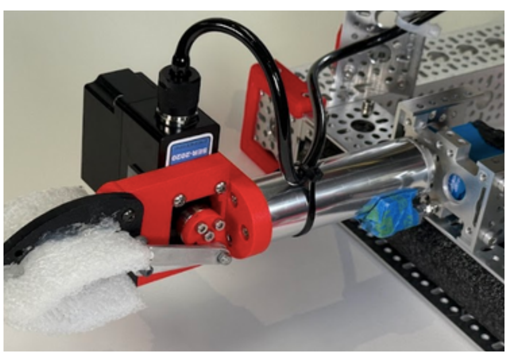


Figure 20: Final Gripper Design. Credit: Nathan Hofmann.

A GoBilda servo block is mounted on a Hitec HS-646WP servo which connects to a GoBilda tube. This fully metal system allows for a robust design that can easily support the weight of the gripper and payload while allowing the gripper to have easy rotation. Overall, the gripper reflects a strong build-oriented philosophy, where customizability and upgradability take priority. By combining programmable, off-the-shelf servos with a modular frame, our in-house solution offers far more adaptability and value than a prebuilt commercial gripper ever could.

[3.4.5] WATER SAMPLER

Talos V includes an integrated tool on the ROV to simultaneously collect a water sample and measure its pH in situ. The system's key requirements are: linear movement to puncture a plastic membrane, a pump to extract the sample, a sensor to determine the pH, and a bladder for storing the sample. For linear movement, a Hitec HS-646WP waterproof servo was integrated with a rack and pinion mechanism, delivering sufficient puncturing force while remaining compatible with the ROV's modular PWM control system. A 12V diaphragm pump extracts the sample and pumps it into a 150mL bladder that is easily detachable for quick sample retrieval.

An Atlas Scientific lab-grade pH probe was selected to measure the pH of the sample while in situ, chosen for its high accuracy, full waterproofing, and integrated I2C communication, which resolves the signal interference issues common with many pH probes that require shielding.

Operationally, precise alignment is assisted by a downward-facing camera that helps the pilot line up the tool with the hole in the bucket. A funnel then guides the tool into place, allowing the pilot to drive forward without making fine adjustments. Once positioned, a servo lowers the syringe through the opening, and the pH is measured in situ. The sample is simultaneously drawn out using a pump and transferred into a quick-release bladder, enabling fast and convenient retrieval.

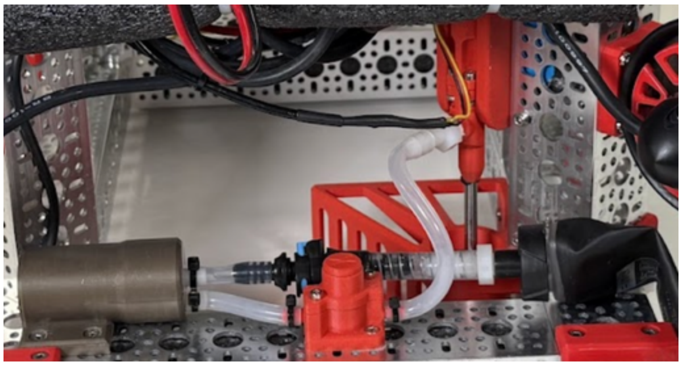


Figure 21: Water Sampler (Excluding pH Probe). Credit: Nathan Hofmann

[3.4.6] SHIPWRECK MEASUREMENT SYSTEM

A measurement system was designed to measure the length of the shipwreck in Task 1.1. Initially, we wanted to use lasers to cast red dots of a known distance onto the shipwreck, to be detected automatically by the software, but lasers would have been complicated as they require a power supply and additional safety precautions. Instead our system is to drop a 30x30x30 cm PVC cube near the shipwreck as a reference point. The cube was chosen because it is simple, cost-effective, and does not require power. To measure the length of the ship using the cube, the down-facing camera is used to take a picture containing the shipwreck and the cube. The scientist then runs a Python application which uses the cube's known dimensions to estimate the length of the ship. During testing, the error margins have ranged from 0.5cm to 3cm, which is within the 5cm required by MATE.

[3.4.7] MEDUSA JELLYFISH CAPTURE

To effectively collect a medusa jelly from mid-water, our team designed a custom tool that fulfills MATE's requirement to not apply any direct pressure on the jelly. The tool features an upside down bucket with a funneled top with vents that increases tolerance and manages turbulence during capture to ensure a gentler, more controlled entry for the jellyfish. A trap is incorporated into the design that allows the jelly to be captured passively and securely through a ratchet and pawl mechanism. To streamline operations, the tool is mounted on a custom quick-release mechanism with clevis pins, enabling the system to be detached immediately after capture and freeing the ROV for easier maneuvering.

Figure 22: Ratchet and Pawl Mechanism. Credit: Bennet Menzer.

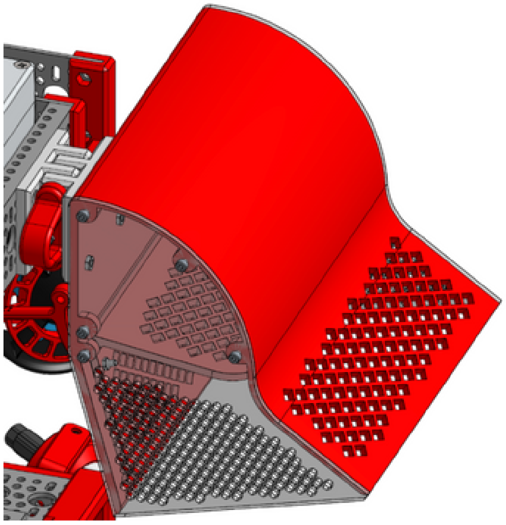


Figure 23: CAD Model of Medusa Capture System. Credit: Bennet Manzer.

4. BUILD VS BUY

Hephaestus Robotics follows the philosophy of trying to conserve resources whenever possible to reduce costs and minimize environmental impact. An easy-to-follow Build vs. Reuse vs. Bought table outlines our general process for optimizing cost while maintaining required ROV functionality (Figure 24). It should be noted that some upgrades were necessary this year to meet higher performance expectations outlined in the 2025 RFP. This year, some of the components from the previous year, such as the camera system and the electronics, did not meet this year's requirements.

The team decided to purchase new components for the ROV, which enhanced camera quality and improved the electronics enclosure that subsequently provided much more space for key components inside the ROV. On the other hand, we were able to reuse some of the components from last year's ROV. Reusing Talos IV's GoBilda frame saved money and assembly time, while thruster reuse ensured reliability for MATE depth requirements.

Component Name	Build		Reuse		Buy		End Decision
	Pros	Cons	Pros	Cons	Pros	Cons	
Cameras	Lower Cost, Customizable	Added Design Time	Low Cost	Bulky Enclosures	Compact, Modular, Expandable	Expensive	Buy
Electronics Enclosure	Low Cost, Custom Size / Shape	Difficult, unreliable, Lot of time to design and make	Low cost, time saved	Size not optimal for new components	Time saved, more reliable	Expensive	Buy
Pi Hat	Customizable, High Integration	Added design time, Added assembly and soldering time	Low cost, time saved	Not Updated, incompatible with the amount of components	Time saved, Less margin for error	Expensive, Less customizable, less integrated	Build
ROV Frame	Customizable	Expensive, Take a lot of Time, Unreliable	Cheap, Less Work Required	Possible Wear and Tear Issues	Reliable, Less Time Required	Expensive, Not as Customizable	Reuse
ESC Connector Board	Customizable, Space saving with integration	Takes More Time	Low Cost	May not fulfill this year's requirements	Saves Time, Easier to Obtain in Bulk	Higher Cost, Time to deliver	Buy
Thrusters	Cheaper, More Customizable Design	Take more time and experience	Cheaper, Can be used with current fram	Less efficient, Suffering from Wear and Tear	Does not require people to work on it	Expensive, Takes time to arrive	Reuse

Figure 24: Chart of Parts: Built vs. Reused vs. Bought. Credit: Nate Hofmann.

The electronics team decided to design and build its own ESC connector boards this year. Hephaestus' ESC connector board is used to connect the topside controls to the company's motor controllers on the ROV. The ESC connector boards were developed online by the electronics team and were shipped to the maker space for installation. Alongside the development of the ESC connector boards, the electronics team built their own Pi Hats. Hephaestus Robotics' customizable design allowed for the Pi Hat to be built specifically for the Talos V, a refinement that cost more time but allowed for more effective adaptability control for modifications. The team decided to build a new, smaller camera system in order to minimize space. This camera system is able to complete the photosphere and tasks while taking up little space. While last year's camera system worked sufficiently, it took up too much space to be viable, leading our efforts to focus on increasing space and efficiency. Though the cameras bought are more expensive, they are worthwhile as they offer better performance and align with the mission goals for this year. This year, the thruster system and frame materials from the previous year were reused. Talos IV's success with the Blue Robotics T200 thrusters and the GoBilda aluminum channels have proven to be reliable and well suited for this year's objectives. These choices support the goal of maximizing space on the frame for thrusters and mission tools, without compromising functionality.

5. SAFETY

[5.1] PHILOSOPHY

Personal safety is a top priority of Hephaestus Robotics. The team follows and expands upon the MATE ROV safety guidelines to ensure a safe working environment for both members and mentors. Each year, in order to establish the latest safety protocols, team members collaborate with mentors who have extensive knowledge and experience regarding workshop safety. This year, given the large number of new members, safety training was implemented at the beginning of the year, as it was important that members understood the safety guidelines and proper procedures. These practices protect personnel through required PPE such as safety glasses and closed toed shoes, hands on tool training, and supervision. They protect equipment through regular inspections and protocols for storage and usage of tools. Finally, they protect operations through following structured checklists (Appendix A and B) and being prepared for emergencies. Hephaestus's approach to safety ensures that personnel, equipment, and operations are protected throughout development.

[5.2] PROTOCOL

Every member of the Hephaestus Robotics team must wear the necessary safety equipment before engaging in any activity related to the ROV. This includes wearing safety glasses, tying long hair back, and wearing closed toed shoes. Furthermore, mentors and senior members of the team supervise safety protocols to ensure no accidents occur. Members must have adequate knowledge of the tools they handle before use, such as hand tools, soldering irons, power tools, and saws. Members must not work alone when handling tools: A trained senior member or mentor is always present when the workshop is being used. Devices used in the workshop are checked regularly for flaws or any signs of wear. Further, students are taught proper lifting techniques when moving heavy equipment to prevent strain injuries. In case of a fire, a CO_2 fire extinguisher is placed in the makerspace to put out electrical fires without damaging equipment.During operation, team members go through and follow a safety checklist (Appendix A and B), which covers visual inspection, communication, and electric system checks. While operating, roles are clearly assigned (pilot, tether manager, etc) and members announce each significant step such as contact with water or the start of thrusters. This prevents miscommunication, enabling a smooth process with no errors.

In order to maintain safety while doing tasks, the team ensures that each member on the deck is constantly aware of the pool. Roles like the prop manager are instructed to lie on their stomach while switching out props to make sure they do not fall in the pool. Talos V incorporates specific design features to reduce risks during tasks. For example, the syringe used in the DNA sample tool is fully retracted to ensure that no one is hurt by the sharp tip.

All thrusters and frame edges on Talos V are covered by guards to prevent contact with the blades and sharp edges while handling the ROV (Figure 25). The guards also help protect mission props and tether from damage during mission tasks. See Appendix A and B for a complete list of Safety Protocols.

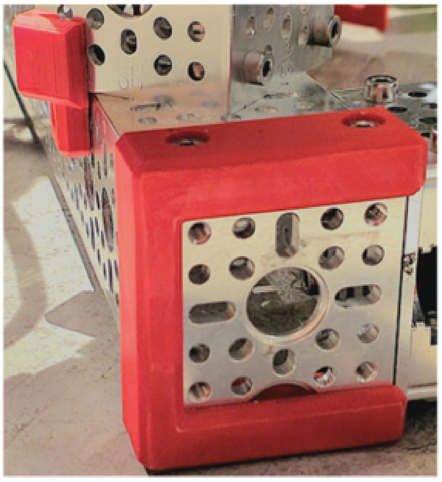


Figure 25. Guard on Edges of Frame to Ensure Safety (i.e., Sharp/Cutting Hazards). Credit: Nate Hofmann

6. CRITICAL ANALYSIS

[6.1] TESTING AND TROUBLESHOOTING

The team went through a series of refinements and iterations on the ROV, mostly on the mission tools, so it was essential that a rigorous testing protocol was developed to evaluate the progress. Testing allowed for immediate feedback on design changes and highlighted areas that needed to be improved or validated that certain components were on the right path. Testing became critical when the ROV transitioned from the bench to the pool. For main enclosures, a vacuum test was performed using a hand vacuum pump to 12 psi and waiting 15 minutes to ensure it held the pressure. A dunk test was also conducted in a water-filled 50-gallon trash bin to ensure we had proper watertight sealing. A trash bin was used to adjust buoyancy for both the ROV and the float. Once the ROV's watertight integrity was confirmed, the team performed numerous simulations of the RFP tasks in a swimming pool.

[6.2] TEST PILOTING SIMULATION

ROV Simulation is a 3D simulation developed by lead software engineer Rowan Delander in the Unity Game Engine, used to test and develop topside software and train pilots. The simulation is run on a separate computer from the topside controls software to fully test the topside's remote piloting capabilities. The simulation is controlled using the same software used to control the actual Talos V. The simulation can create virtual cameras and even broadcast the video streams over the network. Camera configurations describing the position, above and below surface field of view, resolution, and other information about the cameras can be switched between in real time while the simulation is running to prototype camera locations for the real ROV. Thrusters are simulated by applying force to different points on the ROV's model. ROV Simulation has systems to simulate weight distribution, buoyancy, drag, turbulence, and friction with sounding objects. The virtual ROV can interact with its environment, knocking over and picking up objects. The ROV simulation can run and simultaneously be viewed from a VR headset to provide a better sense of scale, distances, and prepare for future VR development.

The ROV simulation allows for the Topside software to be tested without needing access to the ROV and a pool. This is useful for both faster development and practice. To ensure accurate physics in the simulation, telemetry data was collected while driving the ROV in the pool. The simulation contains the props, to-scale, from this year's MATE ROV competition, which enables pilots to practice completing tasks without needing access to the ROV.

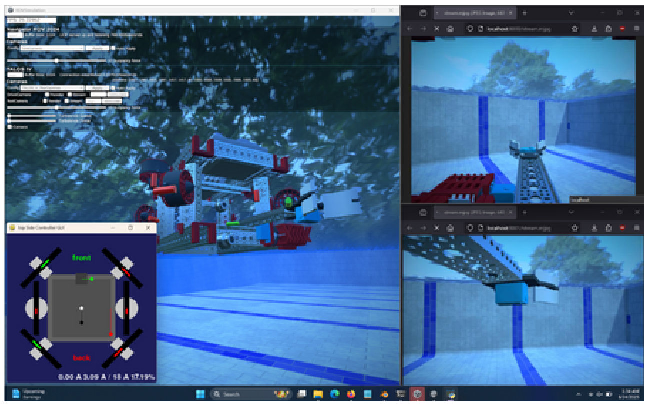
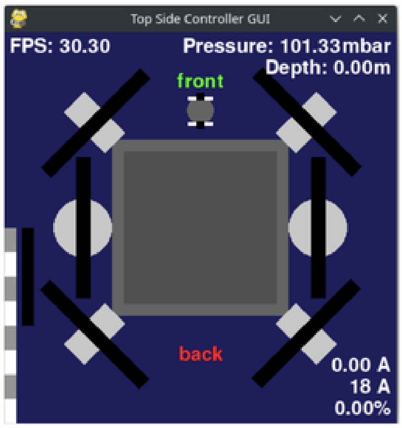


Figure 26: Screenshot of the ROV Simulation Controlled with the Actual Top-side Software Credit: Rowan Delander.

[6.3] TOPSIDE CONTROLLER GUI



The GUI used in the test piloting simulation is a 2D visualization of the ROV from above, applied throughout the testing and development of the software. This GUI (Figure 27) is part of the control software and uses PyGame, the same library used to get input from the controller.

Figure 27: Graphical User Interface (GUI) Credit: Rowan Delander

7. Budget and Cost Accounting

[7.1] BUDGETING

Hephaestus Robotics sourced components for Talos V based on evaluating the Talos IV features and the 2025 MATE ROV requirements to determine whether to buy, build, or reuse components. The budget was developed to organize the company's income and expenses planning to help the company in effectively and timely optimizing the affordability, sustainability, safety, serviceability, and reliability of each component. The main income source is a $10,000 grant from the Santa Cruz County Office of Education, to which the company added events for fundraising, sponsorships, and private donations to raise sufficient funds to cover the travel expenses for the 2025 Worlds Championship. The CFO examined previous years' spending to develop a 2025 budget, leaving a cushion to account for unforeseen expenses (see Appendix D).

[7.2] COST ACCOUNTING

The CFO tracked expenditures by having all team members complete weekly Bill of Materials request forms for any needed materials, with detailed justification for why new and not reused. It used these forms to ensure the preservation of all part receipts. Costs were then compiled from all the receipts into a sheet to keep track of expenditures and to help make decisions. For example, by re-using materials and parts from last year, we were able to allocate resources towards new cameras that can be reused in the next few years. Orders and costs were tracked in a Costs sheet (see Appendix D) to reflect the team's actual expenses and running balance. This helped the team to prevent the project's costs from going over budget as more parts are bought over the course of the ROV's development.

8. Acknowledgements and References

[8.1] ACKNOWLEDGEMENTS

Hephaestus Robotics benefited from the support of several generous individuals. Foremost, Hephaestus would like to thank Dr. Farris Sabbah, Jason Borgen, Dr. Heather Wyatt, Reynaldo Barrios, and Nick Ibarra at the Santa Cruz County Office of Education (COE) for their incredible support of the company. The COE has paid the rent of our 1,600 sq ft Maker Space for the team to innovate the ROV, in addition to providing the Watsonville location free of charge. This generosity is what made the current company possible. The team would like to thank Eric Brown, who has provided Hephaestus with access to the pool at San Lorenzo Valley High School, used for scrimmages and testing.

Hephaestus Robotics would also like to thank the following mentors for their guidance and support: Tim Sylvester, Barbara Meister, Tim Madsen, Lars Menzer, Geoff Tick, Curtis Galloway, Anoop Menon, Josh Corey, Parthesh Shastri, Simona Tick, and Kai Herbst. Their knowledge and experience was instrumental in making our success of this project into a reality. The team would like to thank Heberly Rosario for coordinating food donations, as well as to Woodstock Pizza for their sponsorship and free donation of pizza every quarter. The newest sponsor, Blue Zone Waters Westside, is graciously donating water supplies to the makerspace. Finally, Hephaestus Robotics would like to thank MATE for organizing this competition and giving the team a chance to apply our skills and learn through this experience.

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9. Appendices

Appendix A. Safety Checks

Appendix A.1: Operations and Safety Checklist

Pre-Power Checklist:

1. Conduct a visual check for any loose or damaged connections on the ROV
2. Verify tether is not damaged then ensure deck is tidy
3. Verify the electronics chamber is securely screwed on and conduct a vacuum test to confirm proper seal
4. Ensure Cat6 output of the tether is properly connected to the pilots computer
5. Verify the tether is attached to the strain relief and securely fastened to the ROV
6. After vacuuming, monitor the pressure: If it increases, follow these steps:

- ❏ Power down the ROV and remove from water
- ❏ Use soapy water to confirm the exact leak location
- ❏ Conduct a visual inspection to locate the leak
- ❏ Assess systems for damage and replace fault electronics
- ❏ Develop and execute a repair plan
- ❏ Document the leak's source, cause, and the corrective design changes

Powering Up

1. Ensure the pilot's computer is powered on
2. Confirm the tether is securely connected to the power supply
3. The pilot notifies the team when the system is ready.
4. The pilot tests the thrusters while warning the team to maintain a safe distance.
5. Ensure the gripper's rotation is set to 0° and that it is closed.
6. Adjust camera angle if necessary, and verify the video feed from the ROV's cameras.

ROV Launch:

1. Ensure two capable individuals are ready for tether management and lifting the ROV.
2. Confirm the strain relief is secure.
3. The tether managers keep the tether neatly coiled, avoiding any loose or tangled sections
4. Once the mission director initiates the plan, carefully lift and place the ROV into the pool.
5. Watch for bubbles—if any appear, immediately retrieve the ROV and check for leaks.

Appendix A.2: Operations and Safety Checklist

ROV Retrieval:

1. Pilot notifies the team that the ROV is returning to the surface
2. At the surface, the pilot powers off the ROV while the tether team holds it in place.
3. The tether team adds or removes tools from the ROV as needed, wth instruction from the mission operations
4. If all missions are complete, the pilot powers off the ROV, and the tether managers retrieve it from the pool

Communication Lost

1. Check if the camera feeds are functioning
2. Verify all Ethernet cables are securely connected
3. Power off the ROV, wait 5 seconds, then restart
4. If the connection does not restore within 1 minute after power cycling, the tether team should pull the ROV to the surface for inspection
5. Check the fuse- if blown, inspect for leaks and verify waterproofing integrity
6. Begin troubleshooting to determine whether the issue is hardware or software related

ROV Failure:

1. Power off the ROV
2. Pull the ROV to the surface, remove from water, and unplug the vent plug from the leaking chamber
3. Carefully remove the electronics from the chamber and dry the area
4. Inspect the penetrator panel for the source of the leak
5. If a penetrator leak is found, patch is using a coaxial seal and electrical tape
6. Use a vacuum pump to verify integrity before redeploying

Appendix B. Workspace Safety Checks

General Personal Safety

1. Wear safety glasses while tools are in use
2. Tie back long hair securely
3. Wear close toed shoes when working with tools or building
4. No food or drinks near electronics

Tools and Equipment Usage

1. Receive approval from a mentor or senior member before using power tools
2. Only use tools you have been trained to operate
3. Ask for help if you want to learn how to use a certain tool
4. Check that all tools are in working condition (no loose parts, frayed cords, etc)
5. Keep fingers clear of blades and moving parts
6. Clamp materials down when cutting, drilling, or soldering

Workspace Behavior

1. No running in the workspace
2. Avoid distractions while using tools
3. Keep exits and aisles clear of clutter
4. Always return tools to their designed spots
5. Stay organized
6. Report any unsafe conditions to a mentor immediately

Emergency Preparation

1. Know the location of: First aid kit, fire extinguisher, exits
2. Report injuries or accidents to a mentor

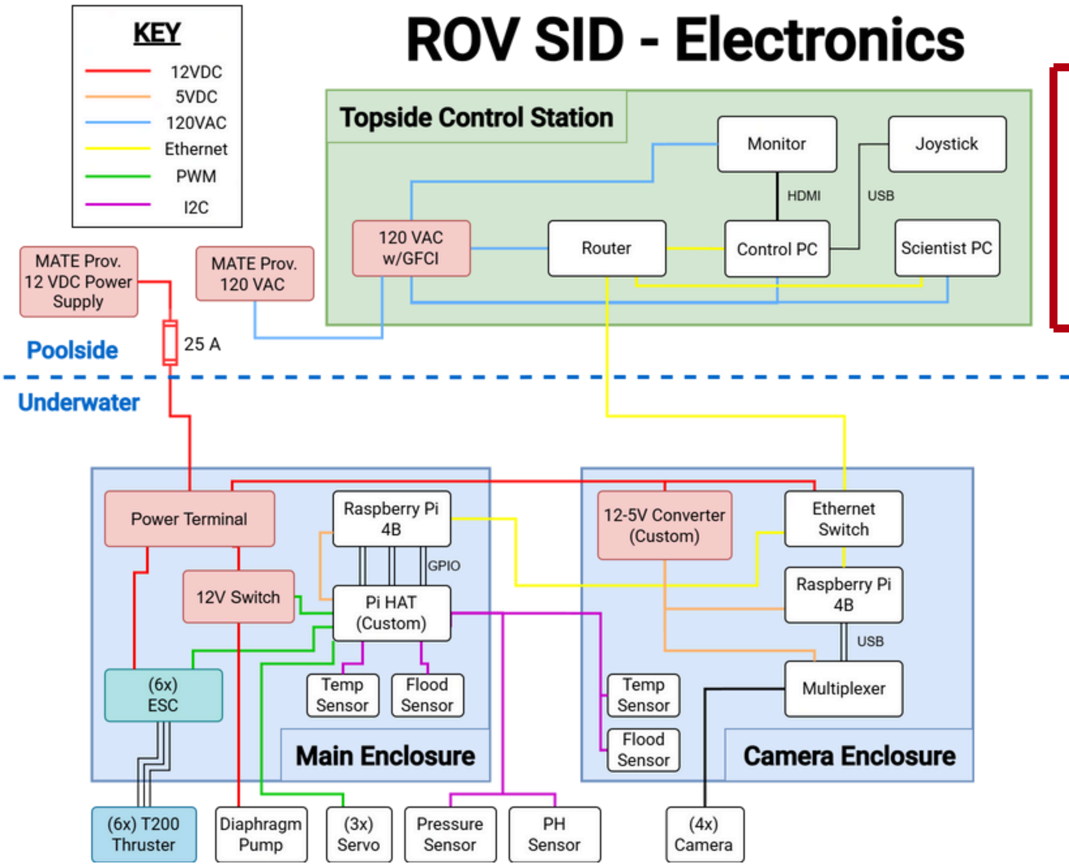
Appendix C: Budget

Budget				
Company Name:		**Hephaestus Robotics**		**Reporting Period:**
			From:	9/30/24
Sponsor:		X Academy, Santa Cruz CA	**To:**	6/16/25
***Income** (income at start of project)*				
Source				**Amount**
Santa Cruz County Office of Education grant				$10,000
Expenses				
Category	**Type**	**Description/ Example**	**Projected Cost**	**Budgeted Value**
Hardware	Purchase	Tube & flanges, pipe fittings, bladders, junction boxes, penetrators, misc hardware	$500	$500
	Re-use	Frame, Tether, Gripper kit, topside case	$1,100	$0
	Donated	Tripod	$50	$0
Electronics	Purchase	Motor driver, Servo, PCBs, fuses, battery, screw terminals, misc connectors	$200	$200
	Re-use	Raspberry Pi, ethernet switch, converters, cables, servos	$400	$0
	Donated	Laptop, Monitor, and RC Controller, Tablet, Surge protector	$1,000	$0
Propulsion	Purchase	Pumps	$100	$100
	Re-use	Thrusters	$1,400	$0
Sensors	Purchase	Cameras, probes	$1,500	$1,500
	Re-used	Pressure & temperature sensors	$100	$0
	Donated		$0	$0
General	Purchase	Pool Props and Pool Rental	$1,100	$1,100
General	Purchase	Regional Competition Registration Fee, Travel	$350	$350
General	Purchase	Worlds Competition travel, accommodations for full team	$55,000	$55,000
			Total Income:	$10,000
		Total Purchase Expenses (without travel):		$3,400
		Travel Expenses:		$55,000
		Total Expenses Re-use /Donations:		$4,050
		Total Funds Needed:		$45,000

Appendix D: Cost Accounting

Project Costs							
Company Name:				Hephaestus Robotics	Reporting Period:		
				From:	9/30/24		
Sponsor:	X Academy, Santa Cruz CA			To:	5/18/25		
Funds							
Date	Type	Category	Expense	Description	Sources/ Notes	Amount	Running Balance
10/6/2024	Re-used	Hardware	ROV Frame	goBilda Frame, Rubber Bumbers, 3D Printed Frame parts	Servo City, Blue Robotics	$ (592)	$ (592)
10/6/2024	Re-used	Hardware	ROV/Topside	Tether (incl. strain releif), pressure relief valve, gripper kit, topside pelican case		$ (490)	$ (1,082)
10/6/2024	Donated	Hardware		Tripod	X Academy	$ (45)	$ (1,127)
10/6/2024	Re-used	Electronics	ROV Electronics	Raspberry Pi 4Bs, ethernet switch, step-down converters, ESCs, cables, Hitec servos	CanaKit	$ (376)	$ (1,503)
10/6/2024	Donated	Electronics	Computers	HP Laptop, Tablet, Monitor	X Academy	$ (800)	$ (2,303)
10/6/2024	Donated	Electronics	Computer accessories	USB peripherals, surge protector, and RC Controller	X Academy	$ (198)	$ (2,501)
10/6/2024	Re-used	Propulsion	Thrusters	T200 Thrusters	Blue Robotics	$ (1,380)	$ (3,881)
11/17/2024	Re-used	Sensors	Float Sensors	Pressure & temperature sensors	Blue Robotics	$ (189)	$ (4,070)
12/8/2024	Purchased	Hardware	ROV / Float	Blue Robotics 4" tube & flanges, pipe fittings, bladders, misc hardware (screws, nuts, washers, etc).		$ (298)	$ (4,368)
12/8/2024	Purchased	Electronics	ROV / Float	H-Bridge motor driver, BTE Servo, custom PCBs, fuses, NiMh battery, screw terminals, USB multiplexer, misc connectors		$ (198)	$ (4,566)
12/12/2025	Cash	General	Fundraiser	Fundraiser with Woodstock Pizza	Used for general vehicle construction	$ 278	$ (4,288)
2/9/2025	Purchased	Propulsion	Float	Peristaltic & diaphram pumps	Hyuduo	$ (75)	$ (4,512)
2/9/2025	Purchased	Sensors	Cameras	ExploreHD cameras	4 x ExploreHD cameras from Deepwater Exploration	$ (1,200)	$ (5,712)
2/9/2025	Purchased	Sensors	Probe	pH probe	Altas Scientific	$ (85)	$ (5,797)
3/9/2015	Purchased	General	Fee	Registration	Regional Competition Registration Fee	$ (250)	$ (6,047)
3/16/2025	Purchase	Sensors	Cameras	GoPro 360 camera		$ (300)	$ (6,347)
4/1/2025	Purchase	Hardware	Pool	Pool Props and Pool Rental		$ (1,100)	$ (7,447)
4/26/2025	Purchased	General	Travel	Mileage	Santa Cruz to Watsonville, 15 miles x 2 ways x 5 cars x $0.56 IRS milage rate	$ (84)	$ (6,431)
5/15/2025	Cash	General	Cash Donation	Cash donated by the Santa Cruz Rotari Club	Used for general vehicle construction	$ 273	$ (7,174)
5/18/2025	Purchased	General	Travel	Air travel, accommodations	Delta Airline $723.00 per person x 21 people, Holiday Inn Express $970 per person x 26 people, rental car, luggage fees	$ (55,000)	$ (61,431)
6/7/25	Cash	Donation	Fundraiser	Fundraiser, match donations	Scheduled: Fundraising to cover travel expenses	$ 55,000	
					Expenses		
					Purchased		$ 3,655
					Donated		$ 1,043
					Re-used		$ 3,027
					Total Expenses (without Travel)		**$ 7,725**
					Cash Flow		
					Cash In		$ 10,773
					Cash Outlay		$ (3,655)
					Final Cash Balance		**$ 7,118**

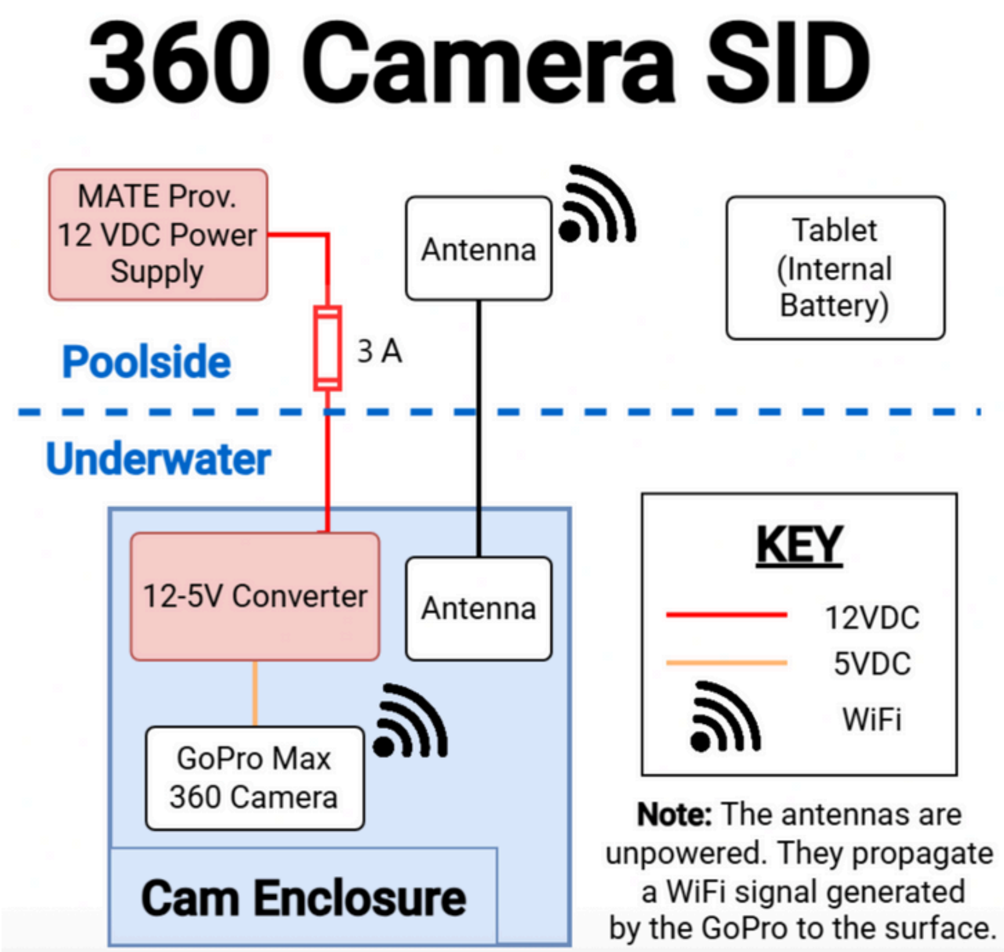
Appendix E: System Integration Diagram (SID)



ROV Full Load Amps

Device Full Load Amps (FLA) in water = 2.150 A

Fuse size selected = 3 A



360 Camera Full Load Amps

Device Full Load Amps (FLA) in water = 2.150 A

Fuse size selected based upon FLA = 3 A