University of Rhode Island 2025 Tech Report: *Tardigrade*

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***Abstract*—The *Tardigrade* is an updated model of previous year's iterations which were more limited. This year we strive for not only additional task achievement but also a more reliable system that is easier to troubleshoot, adapt, and manipulate. To improve the capability of the system, we added a larger watertight enclosure to house the electronic system, as well as implementing a soft gripper, torpedo system, and dropper.**

I. Competition Strategy

A. General Strategy

Since *Tardigrade* attended RoboSub in 2024, we have decided to transfer many of our bulkhead penetrators from Blue Robotics to Blue Trail as it simplifies the removal and reorganization of the primary electrical systems. This change allows us to more easily access and diagnose problems as they occur. Additionally, we have shifted away from a more rudimentary self-designed kill-switch to a commercially available switch that provides a safer and more robust emergency cancel system. Another change that we have implemented this year is increasing the diameter of the electrical systems bottle. This creates more reliable and effective cable management as it keeps the data lines separate from high current systems that could interfere. The final and most substantial development that has occurred since our last competition is the implementation of a soft robotics manipulator, a CO2 powered torpedo, and a servo-based dropper. These additions allow us to complete more tasks than were previously possible. Our previous iteration only allowed the completion of tasks that were purely movement based. With this implementation, we will give our team the opportunity to complete so much more. Additionally, one of our biggest priorities in design is cost. With a tight budget, we are required to make every effort to minimize costs in development. All our funds come from sponsorships and fundraisers and fluctuate year by year. With our building funding under $7,000, the team must prioritize in-house custom work to keep costs low. Our main goal is to complete simpler and more structured tasks.

B. Course Strategy

Heading Out (Coin Flip): We will attempt the coin flip only once we are guaranteed to be qualified. The maneuver will use our onboard IMU and a rotation scan algorithm, supported by computer vision running on the Jetson.

Collecting Data: We aim to start strong by using distinct visual markers to identify the marine animal and ensure we pass through the correct side of the gate. This step will help confirm that both our vision system and heading control are functioning properly. Our focus is on executing a solid, clean gate pass.

Navigate the Channel: After passing through the gate, the AUV will use computer vision to detect the red pipes and navigate the slalom channel accordingly.

Ocean Cleanup: If time permits, we plan to proceed to the octagon. Using a hydraulically actuated soft gripper, object recognition, and a pump relay, Tardigrade will collect and identify designated objects for cleanup.

Return Home: We plan to attempt the return home task only if all prior tasks are completed successfully and systems are functioning reliably.

II. Design Strategy

A. Mechanical Systems

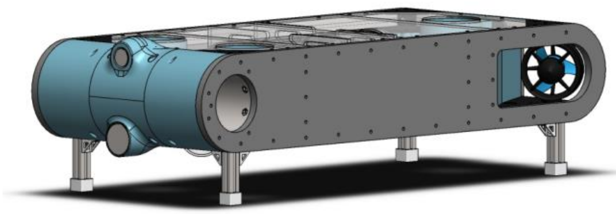


Fig 1. The full Tardigrade assembly (without task sub-assemblies).

This year, our primary focus was on increasing the *Tardigrade's* size to accommodate the addition of multiple subsystems required for completing the various tasks. The chassis was developed with these adaptabilities at time.

Materials: Since the frame of *Tardigrade* is almost entirely composed of 3D printed PETG components and 20mm T-slot rails, the system is easily manipulated and reorganized to allow for tidy and cost-effective adaptation to new developments.

Fig 2. A collection of our 3D printed parts (PETG)

3D Printing: To maintain a lightweight yet highly modular design, we heavily relied on FDM 3D printing for the construction of the Tardigrade's components. Nearly all custom parts are printed using yellow Overture PETG filament on a Bambu P1S printer. This approach allowed for rapid iteration, easy integration with other subsystems, and significant weight savings over traditional manufacturing methods. The extensive use of PETG offers a strong balance between durability and flexibility, ideal for underwater applications where mechanical stress and water resistance are critical.

This year, we chose to prioritize FDM printing over resin-based methods primarily due to cost efficiency and increased access to printing resources, including dedicated lab equipment and a personal printer. In previous iterations, we experienced significant issues with resin-printed components, particularly during transport—many of our resin fairings cracked or fractured in shipping. By contrast, PETG prints have proven far more durable while remaining cost-effective for large-scale part production.

Our FDM setup has been optimized with guidance from Brian Leong, a mechanical engineer at VATN Systems who manages the 3D printing workflow for their AUVs. We print using a tented enclosure, with the P1S's top glass lifted to facilitate airflow and ensure consistent internal temperatures during operation. All PETG filament is dried at 80 °C for a minimum of 12 hours prior to use to prevent moisture-induced defects. For external structural components, we print at 95% infill to ensure maximum strength and reliability in demanding underwater environments.

Pressure Vessel Enclosures: Tardigrade contains 4 pressure vessels: one 5" Blue Robotics enclosure and three 3" Blue Robotics enclosures. Most connections are done using connectors made by Blue Trail Engineering as they have the advantage over our previous heavy usage of Blue Robotics penetrators of being able to be unplugged from the pressure vessel rather than having a bulkhead semi-permanently affixed to the robot

3. Hydraulics: A 3" Blue Robotics enclosure houses a peristaltic pump that is used as part of a "open cycle" hydraulics system, using the pool water as the working fluid. Currently, the only hydraulically actuated component in this iteration of *Tardigrade* is a soft robotics gripper based on work done on PneuNets type actuators [1]. Soft robotics is an active area of research in the marine robotics field, being used on research ROVs for the manipulation of delicate objects such as deep-sea organisms without causing excessive damage. While it is more difficult to implement than a servo-based system, it is more economical with the pump being the only significant cost. In the future, a valve manifold could expand the systems capabilities to other tasks, making the experience a good investment.

Additionally, we wanted to expand the *Tardigrade's* task completion capabilities and largely focused on developing the various sub-systems that did so.

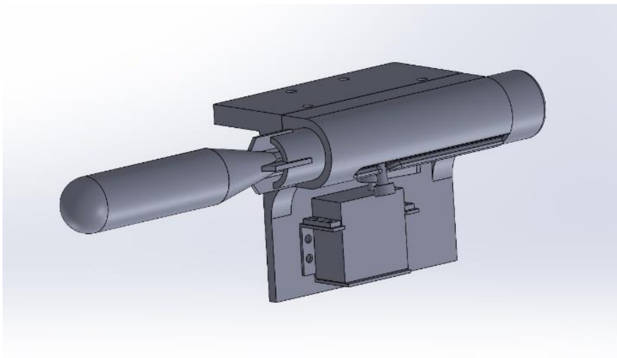


Fig. 2 Tardigrade's torpedo launcher system.

Torpedoes: This CO2-propelled torpedo launcher primarily uses 3D-printed components and operates via a bolt-action system. Each torpedo consists of two main shell parts that house a CO2 cartridge and can be weighed in the front for balance. When triggered by a waterproof servo, the bolt releases and drives a sharp screw into the cartridge, puncturing it and simultaneously breaking the friction hold in the key adapter to launch the torpedo. The released CO2 propels the torpedo forward underwater for about eight seconds. Internally, the launcher contains a spring-loaded striking mechanism assembled from the rear and secured with a 3D-printed threaded end cap.

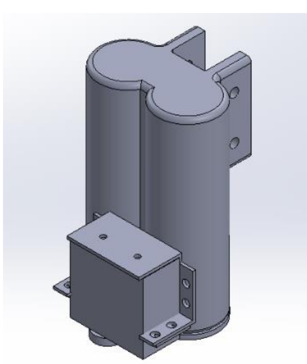


Fig. 3 Tardigrade's dropper sub-assembly.

Droppers: This dual-tube projectile dropper is primarily constructed from 3D-printed components and is designed for simplicity and modularity. Each vertical tube holds a single projectile, which is kept aligned by internal guide rails. A sliding retention plate, actuated by a waterproof servo mounted externally, holds the projectiles in place from below. To release a projectile, the servo rotates the plate to one side, allowing the first projectile to fall freely. When ready, the plate rotates in the opposite direction to release the second projectile. The entire dropper system attaches to a single X-rail on the robot's frame, allowing for straightforward installation and removal.

B. Electrical Systems

The Tardigrade electrical system is the heart of our AUV. Our team has opted to primarily use off-the-shelf components with some custom hardware where necessary. The bulk of the system is composed of three processors that reside in the "Computer Bottle".

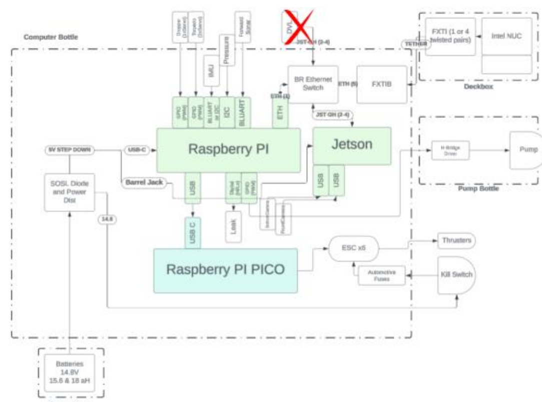


Fig 4. The full computer bottle schematic including power and communication.

Onboard Computers: Our Pi 4 runs on a headless Ubuntu 24.04 operating system and does everything non-vision related. To offload any heavy processing done on the camera side, we also have an NVIDIA Jetson Nano which takes care of our visual odometry, object detection, as well as camera streams for the surface controller. In addition, we utilize Raspberry Pi Pico as a microcontroller for our Electronic Speed Controllers (ESCs). The ESC stack is then used to control our 6 T200 thrusters that move the UUV.

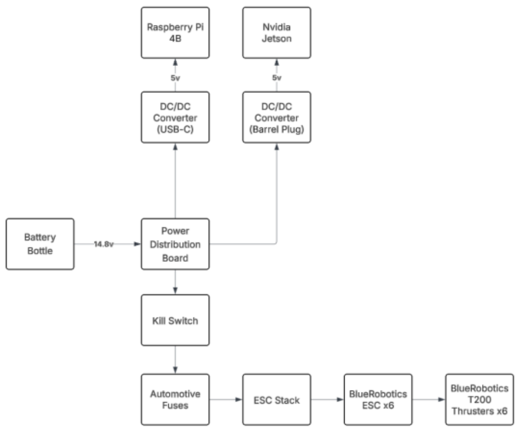
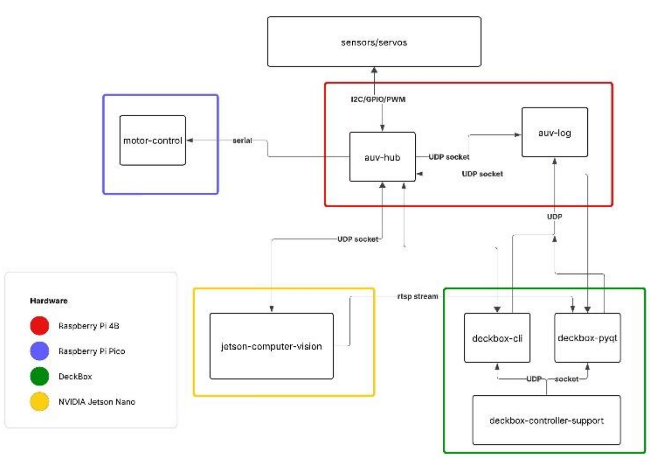


Fig 5. The power distribution system.

Power Management: In our electronics bottle we have 2 power distribution boards (PDB). The 1st one connects to 2 dc/dc converters which then lead to the NVIDIA Jetson Orin and the Raspberry Pi 4b. The dc/dc being necessary as the controller is unable to take our full battery power. Our second PDB is connected to power through our kill switch. The reason this was done was so if the killswitch is engaged, it only kills the thrusters and not the rest of the system. We also use 2 fuses that are between the ESC stack and main power to prevent damage to the ESCs.

C. Software Systems



For this year, we decided to take a different approach all together. We opted to develop our own software providing greater learning experience to our growing, young software team.

Custom Software Suite: As opposed to ROS (Robotic Operating System) or other robotics middleware suites, our team chose to develop a custom system to pertain to our needs. This approach provides a minimal and flexible solution that is still powerful enough to complete tasks. Our software is a collection of programs written in C++ and Python that communicate with each other over UDP sockets. Each of Tardigrade's devices (sensors, thrusters, etc.) interface with our software via drivers, which are included at compile time ensuring optimal performance and reliability. All ports and addresses are also defined at compile time, ensuring maximum stability. Due to financial constraints, our AUV does not include a DVL, this limitation has presented the challenge of writing software to determine position and velocity reliably through other means.

Network Structure: Each component of, Tardigrade's computer systems communicates with each other over User Datagram Protocol (UDP) sockets, ensuring quick packet delivery without the overhead of Transmission Control Protocol's (TCP) handshake. Secure Shell (SSH) is utilized for debugging and remote access to our onboard processors.

Surface Setup (DeckBox): To minimize cost and reduce complexity, our team has opted for a simple surface control setup. We use a laptop, running a Linux-based desktop operating system (OS) as the primary interface to the AUV. A Logitech F710 wireless controller is used for manual control over the AUV when needed. This system is connected to the AUV using the Blue Robotics Fathom Tether Interface box.

Autonomy: Tardigrade is designed to operate autonomously using a combination of control algorithms and onboard sensor fusion. Motor inputs are regulated via PID controllers, providing stable and precise movement control. For dead reckoning, we plan to implement an Extended Kalman Filter (EKF) that fuses data from the IMU, depth sensor, and forward-facing sonar. To supplement this, we will use visual odometry through ORB-SLAM, running directly on the Jetson Nano. Pose estimates generated by ORB-SLAM [2] will be transmitted to the Raspberry Pi, where they will be integrated into the EKF for improved localization accuracy. As we do not currently have a Doppler Velocity Log (DVL), an optional downward-facing sonar can also be mounted to provide altitude data relative to the pool floor if found necessary.

III. Testing Strategy

Due to a limited timeline and issues with electrical manufacturing, the team has not been able to run underwater testing yet. The goal is to complete testing throughout the month leading up to the competition. During this period, we plan to undergo leak, safety, controls, autonomy, and maneuverability testing. We have also developed software to test the electrical systems of our AUV to help debug and ensure reliable operation.

For leak testing, we will use a vacuum pump as well as submerging weighted, watertight enclosures overnight to ensure there are no points of leakage.

To test electrical safety, we verify safe power distribution, continuity, and leak current tests to ensure all components are secure.

With controls testing, we will test the system to verify heading, depth, and speed regulation.

Autonomy testing will focus on validating waypoint navigation, mission execution, and fail-safe behaviors to ensure the AUV can operate independently and respond to unexpected conditions.

Maneuverability testing will evaluate the AUV's ability to navigate through various depths, complete turns and path tracking.

Acknowledgments

As with any team project, this could not have been done without the help of the many supporters our team has had along the way. This includes our sponsors, the University of Rhode Island College of Engineering, Navy STEM, Cadence, and SolidWorks, who have provided us with the funding and software necessary to make the robot and programming successful. We also would like to extend thanks to our support team of advisors. Our faculty advisor, Dr. Mingxi Zhou, and our graduate advisor Jason Noel provided valuable advice, and Dr. Stephen Licht who provided advice as well as sonar equipment, Nicole Larkin assisted with travel planning and logistics. Finally, we would like to thank RISE UP for their use of their facilities. We owe utmost gratitude to these supporters who have assisted with our progress. We would not have made it here without them.

IV. References

[1] *R. F. Shepherd et al. "Multigait soft robot" Proceedings of the National Academy of Sciences, vol. 108 no. 51, pp. 20400-20403, Nov. 2011, doi: https://doi.org/10.1073/pnas.111*

[2] *M. Ferrera, J. Moras, P. Trouvé-Peloux, and V. Creuze, "Real-Time Monocular Visual Odometry for Turbid and Dynamic Underwater Environments," Sensors, vol. 19, no. 3, p. 687, Feb. 2019, doi: https://doi.org/10.3390/s19030687.*

APPENDIX

Component	Vendor	Model/Type	Specs	Cost (if new)	Source
Front Camera	DeepWater Exploration	ExploreHD 3.0	400m ~82 FOV	$300	Purchased
Top Camera			180 FOV		Purchased
Thrusters	Blue Robotics	T200 Thrusters	Brushless Motor	$1320	Purchased
Battery Charger	Blue Robotics	H6 PRO Lithium Charger	10A charger with balancer	$200	Purchased
Batteries	Blue Robotics	14.8v 15.6Ah & 18Ah	15.6Ah and 18Ah	$760	Purchased
Echosounders	Blue Robotics	Ping-1D Echosounder	Single-Beam Sonar	$700	Donated (Professor Stephen Licht)
Raspberry Pi	Raspberry Pi	Raspberry Pi 4B	RP2040 CPU 4gb RAM	$65	Purchased
Nvidia Jetson	Nvidia	Jetson Nano	4GB RAM	$180	Purchased
IMU	Adafruit	BNO055	9-DOF Fusion	$40	Purchased
Pressure Sensor	Blue Robotics	Bar30	2mm Resolution	$85	Purchased
Leak Sensor	Blue Robotics	SOS Leak Sensor		$35	Purchased
ESC	Blue Robotics	Basic ESCs	Speed Control	$240	Purchased
ESC Stack	Custom		3 ESCs per Board	N/A	Donated (Professor Mingxi Zhou)
Computer Bottle	Blue Robotics	Locking Series	5” inner diameter	$200	Purchased
Battery Bottle	Blue Robotics	Locking Series	3” inner diameter	$150	Purchased

Pump Bottle	Blue Robotics	Locking Series	3” inner diameter	$150	Purchased
Pump					Purchased
Bulkhead Connectors & Cables	Blue Trail	Cobalt Series	Dry-Mate	$1250	Purchased
Computer Vision	Yolo				Custom
Software	C++	“Tardigrade System Software”			Custom
Soft Gripper	Custom	N/A		N/A	Custom
Deckbox	N/A			N/A	Custom
Tether Control Board	Blue Robotics			$265	Purchased
Mini Network Switch	Blue Robotics	Ethernet Switch		$175	Purchased
Buck Converters					Purchased
H-Bridge Driver	N/A	50A H-Bridge Motor Driver	15v, 50A rating	$15	Purchased
Frame	Xometry / Various Others	N/A	Aluminum X-Rails HDPE Sides	$200	Custom
3D Printer Filament	Overture	PETG	~3kg for fairings	$90	Purchased

Total: $6500

Community Outreach Activities:

URI Hydrobotics aims to build close relationships with our on campus and off campus communities. We do our best to connect with local robotics clubs once a semester or more, to give educational presentations about our AUV, what our different sub-teams do, and how students can become more involved. This past year we visited North Kingstown High School, to provide feedback on their FIRST Tech Challenge presentation and robot, while our team members shared their experience with Tardigrade and provided technical advice. We have also hosted the Aluminum Eyas, a FIRST Lego League robotics club from Pawcatuck, CT, at our robotics lab. A club alumn connected them with us, and we provided feedback on their design, as the theme for the competition this year was ocean exploration. The Aluminium Eyas went on to win the CT state championship and compete at the world championship in Houston, Texas.