Technical Documentation

20-22 June 2024

Deep Sea Tactics
Governor's STEM Academy at Landstown High School
2001 Concert Drive
Virginia Beach, Virginia, USA

Mentors
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Luther Meyer

Chief Executive Officer
Robert Vasquez

Chief Marketing Officer
Alexander Nesbitt

Chief Design Officer
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Chief Engineering Officer
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LANDSTOWN HIGH SCHOOL
DEEP SEA TACTICS

ABSTRACT

Deep Sea Tactics is a marine technology organization specializing in developing and engineering underwater ROVs. **Technological Aquatic Discovery Device IVb (TADD IVb)** is an inspection-class remotely operated underwater vehicle (ROV) created as an entry for the 2024 MATE ROV Competition. Its unique thruster arrangement allows for motion with six degrees of freedom; the ROV's small volumetric footprint makes it a remarkably lightweight device with exceptional agility. Designed with modularity and expandability in mind, TADD IVb is a versatile, high-performing, yet cost-effective underwater solution. This year's improvements in the ROV and vertical profiling float represent five generations of continuous innovation within our organization. Beyond competing, Deep Sea Tactics is committed to sharing knowledge and inspiring future innovations, utilizing diverse talents to drive growth in engineering. With an unwavering commitment to progress, Deep Sea Tactics is confident that TADD IVb and its successors will help navigate a better tomorrow.

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Figure 1: The Deep Sea Tactics team taking a group photo on the school stairs.

OUR TEAM

Deep Sea Tactics is a marine technology organization and robotics team at Landstown High School specializing in ROVs. This underwater robotics division at Landstown High School is split into five subteams:

Marketing: Budgeting, social networking, and official documentation — business starts here.
Fabrication: Skilled engineers fabricate ROV and Float designs, overcoming technical and tooling challenges. Fabrication also has two sub-teams:

- **Design**: Talented designers use specialized CAD software and engineering principles to create foundational mechanical designs.
- **Electrical**: Circuitry, electricity, and intricate designs form the nerves of the ROV and float, forming its final structure.

Software: Diligent architects breathe life into the ROV, powering end-to-end communication between the pilot to the ROV and the float to the surface.

Deep Sea Tactics meets every Tuesday after school from 2:10 to 4:30 PM to work on unfinished tasks. Members are encouraged to research and develop any leftover tasks from the meeting asynchronously.

Project Management

Each team member comes from a different engineering, software, or marketing area that helped build our team to its current state.

NAME	GRADE	ROLE
Robert Vasquez	12	Chief **Executive** Officer
Jeremy Wallace	12	Chief **Fabrication** Officer Project Lead, Mini-ROVs (community outreach)
Caleb Allen	12	Chief **Electrical** Officer Project Lead, Float Design and Fabrication
Tara Bell	11	Chief **Design** Officer
Tristan Figueroa-Reid	12	Chief **Software** Officer
Alexander Nesbitt	10	Chief **Marketing** Officer
Zachary Stevens	11	Project Lead, Manipulator Engineering
Owen Amburgey	11	Project Lead, Manipulator Design
William Faircloth	12	Project Lead, UI/UX Design, Operator Experience

Figure 2: Deep Sea Tactics Leadership Team Members

Officers are in charge of overall organizational tasks, while project leads are in charge of a specific project or component. The team interacts through online tooling to work autonomously, utilizing Google Drive, Discord, Office 365, and other software packages to accelerate collaboration.

CORPORATE RESPONSIBILITY

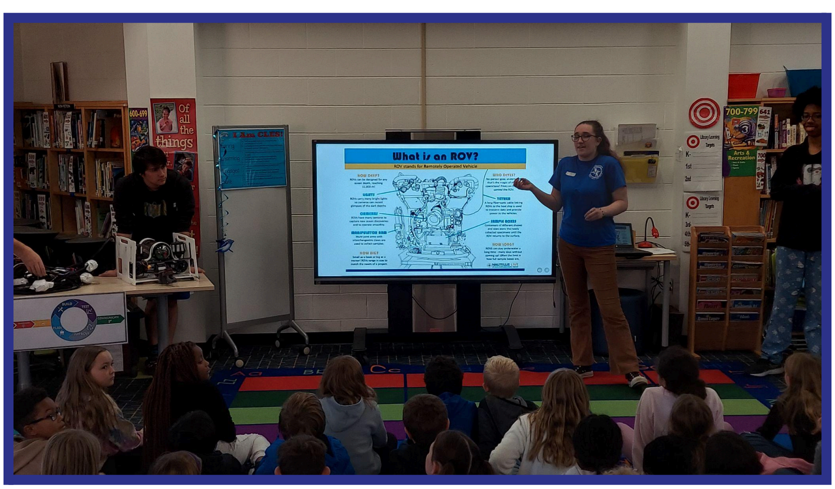
Deep Sea Tactics understands its commitment to its community. Given the incredible scale of talent given to it by its community members, our organization consistently gives back to the community through several outreach and education programs to inform the next generation of the opportunities they can grasp in STEM. Deep Sea Tactics hopes to affirm passion for learning and commitment to STEM with community outreach towards STEM-driven students.

Oceana Airshow

Deep Sea Tactics visited the NAS Oceana Air Show in September 2023, where the team taught fifth graders about STEM and the Engineering Design Process. At this event, Deep Sea Tactics also got to talk with other companies like Dominion Energy and ask about what they do for work daily.

Elementary School Visits

CEO Robert Vasquez and Mr. Swartz had come up with the idea of visiting elementary schools to help newer team members with their knowledge of STEM and work on public speaking skills. Deep Sea Tactics visited eight local elementary schools in the Virginia Beach City Public Schools area, and various team members from every team went out. They presented about the MATE ROV competition, creating a condensed, simple-to-understand slideshow about the engineering design process, what an ROV is, and how they can join the MATE ROV Competition in the Scout or Navigator classes. Many elementary school students could also try piloting Mini-ROVs, a project led by Engineering, to invest them in the endless possibilities of underwater robotics.



POA&M (Plan of Objectives, Actions, and Milestones)

Milestone	Start Date	Task Name	Description	Money &/o Time Estimate	End Date	Status
1	06/26/23	TADD Design Planning	Initial ROV planning, research, and design.	25 hours	08/16/23	Complete
2	08/17/23	TADD Design Revision	ROV refinement and modeling	72 hours	11/26/23	Complete
3	08/27/23	Sponsor Research and Outreach	Researching & outreach to potential sponsors	15 hours	03/17/24	Complete
4	09/06/23	TADD IVb Revision 2 Assembly Design	Design the assembly process for TADD IVb Revision 2, including part positioning and research	16 hours	09/09/23	Complete
5	11/26/23	TADD Design Finalization	Amendments to the design to add and fulfill new ideas	7 hours	01/31/24	Complete
6	11/28/23	TADD Parts Procurement	Finding and organizing the purchase of needed parts for TADD IVb	$454 5 hours	04/23/24	Complete
7	12/13/26	TADD Float	Purchasing, 3D printing, and designing the electrical components of the ROV	75 hours	05/02/24	Complete
8	03/18/23	TADD Tether Construction	Fabrication of the power and information-transmitting underwater cable	50 hours	04/22/24	Complete
9	03/17/24	TADD IVb Competition Adjustments	All of the required modifications, additions, and code required for	114 hours	05/08/24	Complete

			competition			
10	5/18/24	TADD IVb Redesigning	Redesigned and reprinted TADD IVb	50 hours		

DESIGN RATIONALE

TADD IVb is an ROV intended to be used to compete in the Ranger class of the MATE ROV Competition. It was designed with both size and maneuverability in mind. While the design is intended to improve previous ROVs considerably, the team worked to retain a familiar look and structure.

The ROV's motors are tilted in a diamond shape at 30°, allowing for better sideways maneuverability without compromising speed.

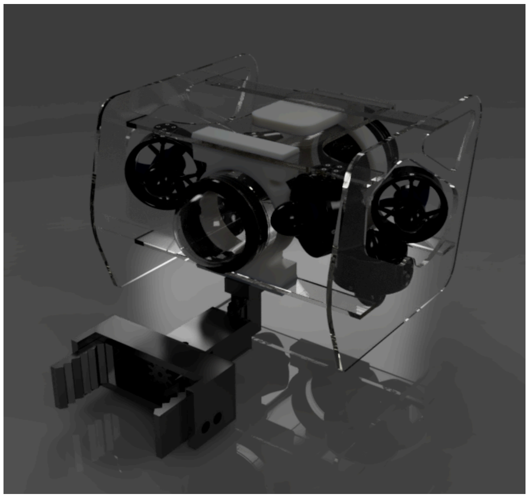
A manipulator carrier plate is attached to the inside of the bottom holes on the side panels of the ROV. This is intended to be a surface where the arm and other mission-specific components can be attached.

To fix many of the problems TADD IVb had, the team brainstormed an amended design, TADD IVb.

Progression and Innovation

The failures inspired TADD IVb's design and struggles that Deep Sea Tactics experienced in previous years and by what we learned. Our earlier ROV system was hydrodynamically unstable in the forward direction, making it difficult to maneuver in confined spaces. To address these issues, the team returned to polycarbonate, a lightweight yet durable material ideal for underwater applications. Using polycarbonate, the team created a smaller, more compact ROV that is easier to control and maneuver in tight spaces. In addition, the increased axis of propulsion allows our ROV to move more efficiently and quickly, giving us greater control and precision during underwater operations.

The design process began with a thorough analysis of the failures the team experienced with our earlier ROV system. The team found the need for a lighter, more compact design that would be easier to transport and deploy in the field. The team also recognized the importance of better controlling the ROV's movements, especially in challenging underwater environments. With these insights, the team developed a new ROV system using the latest materials science and propulsion technology advancements. The result is a competent and efficient underwater ROV system that meets the needs of various underwater applications, from scientific research to industrial inspections and more.



Systems Approach

TADD IVb is designed with continuous improvement and expansion in mind. All aspects of the ROV are intended to allow the addition of components to enhance performance for further MATE task completion.

TADD IVb is modeled in Autodesk Fusion. The software team uses this model to reference their simulation's thruster and center of gravity positions. Structural solid materials and a unique thruster arrangement are coupled with powerful software and electrical systems to maximize the performance of TADD IVb.

Model Creation

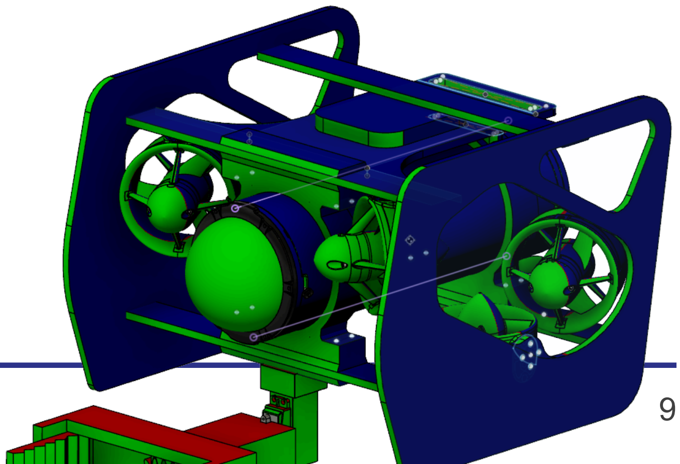
The original design (TADD IV) was made by Dylan Sison, however we encountered quite a few problems during testing and at the MATE ROV Ranger Regional Competition. This compelled us to make TADD IVb, the newest iteration of the TADD series. This new design fixes many of the issues we were having, and aligns the motor more towards the center of mass. The model was created using Fusion 360 and SolidWorks by Jeremy Wallace, Caleb Allen, and Kiel Nical.

Vehicle Structure

Deep Sea Tactics applied engineering polymers and corrosion-resistant metals to build a strong frame for TADD IVb. TADD IVb has a machined polycarbonate frame with stainless steel corner brackets and 3D-printed polylactic acid (PLA) mounting brackets for the waterproof enclosure. Critical components of the frame are solvent-welded with Caseway SC-325 Polycarbonate Cement to ensure structural stability even if multiple screws fail or are lost. All elements on TADD IVb are fastened with M3 machine screws to simplify maintenance operations; a common screw type cuts the different sizes of screws the team needs to have stocked in half.

Propulsion and Dynamics

Six Blue Robotics T200 thrusters provide propulsion for TADD IVb. Last year, they were reused because of their market-leading efficiency and cost-effectiveness. The thrusters are arranged complementary to the ROV's frame, providing six degrees of freedom.



TADD IVb gains its small form factor through 2 major design decisions. The tilted motors and precise placement of the thrusters closer to the enclosure in Fusion allow TADD IVb to be incredibly nimble in the water. Computational fluid dynamics (CFD) simulations were employed to ensure that TADD IVb remains hydrodynamically stable and efficient after the reduction in frontal surface area.

Vehicle Systems

In addition to its advanced propulsion systems, our ROV system features a rack and pinion parallel claw system that is capable of carrying objects that have a diameter of up to 5 inches. It is capable of rotating along its y-axis.

Electrical Systems and Controls

All electrical systems are powered through an Anderson Powerpole connector that plugs into the MATE-provided 12V power supply. 12V bus connections in the control box and onboard the ROV are made with Wago 221 series connectors to allow for quick troubleshooting and adjustment; compared to the prior year's solution of a bus bar, Wago connectors are also significantly more compact. The 12V bus travels into the surface control box and is wired to the tether, and a switch is in the control box that establishes a network between the ROVs and laptops to provide command and control. This network serves as the backbone connecting our software systems. An extensive sensor suite, including cameras and an inertial measurement unit interface with the ability to deliver telemetry data and information to the operator. Cameras are connected directly to the Raspberry Pi. Headers for servos, thrusters, and select sensors reside on a custom I/O hat PCB that connects to the Raspberry Pi 4 40-pin header.

Further information regarding the software linking TADD IVb's sensors and powering Command and Control can be found in the Software section.

Because the control box is mostly empty, it keeps spare tools and parts that may be used in a typical underwater robot launch, including extra fuses or an air pump to test for leaks.

Tether

TADD IVb's tether system represents a significant improvement in our design compared to prior years. TADD IVb's tether features sealed Bulgin Ethernet connections and Bulgin 900 Series Buccaneer IP68 waterproof power connectors. An 8/2 cable was selected to prevent voltage drop along the length of the tether. The tether has a foam backer rod attached continuously to ensure consistently distributed buoyancy. Wires pass through holes in the rear end of the main body tube; these are sealed using Blue Robotics Wetlink cable penetrators.

Vertical Profiling Float

The Vertical Profiling Float uses a buoyancy engine based primarily around Syringes drawing in or pushing out water from the pool to alter the float's volume. As its volume increases, the density decreases, causing the float to float once it has a density less than that of the water. The physical design involves a 4" diameter PVC tube and 2 PVC end caps, one fastened to the pipe while the other not. The end cap, which is not permanently affixed to the float, has a rubber cap behind it to hold weights and protect the electronics from leaking. The electronics involve two 9-volt batteries wired in parallel to increase the amperage output and a 5-volt regulator circuit. The servo is connected directly to the 9-volt input, while the Raspberry Pi Pico and Bar05 sensors are connected to the 5-volt output. The XBee Pro is connected to the 3.3-volt production of the Raspberry Pi Pico. Safety was a primary concern when designing the Vertical Profiling Float; the end caps are tightly fit, and one is permanently attached. Two rubber caps are inside the tube, at the bottom of the buoyancy engine, and inside the removable end cap to further protect the electronics.

System Integration Diagrams

Figure 3: ROV Electrical SID

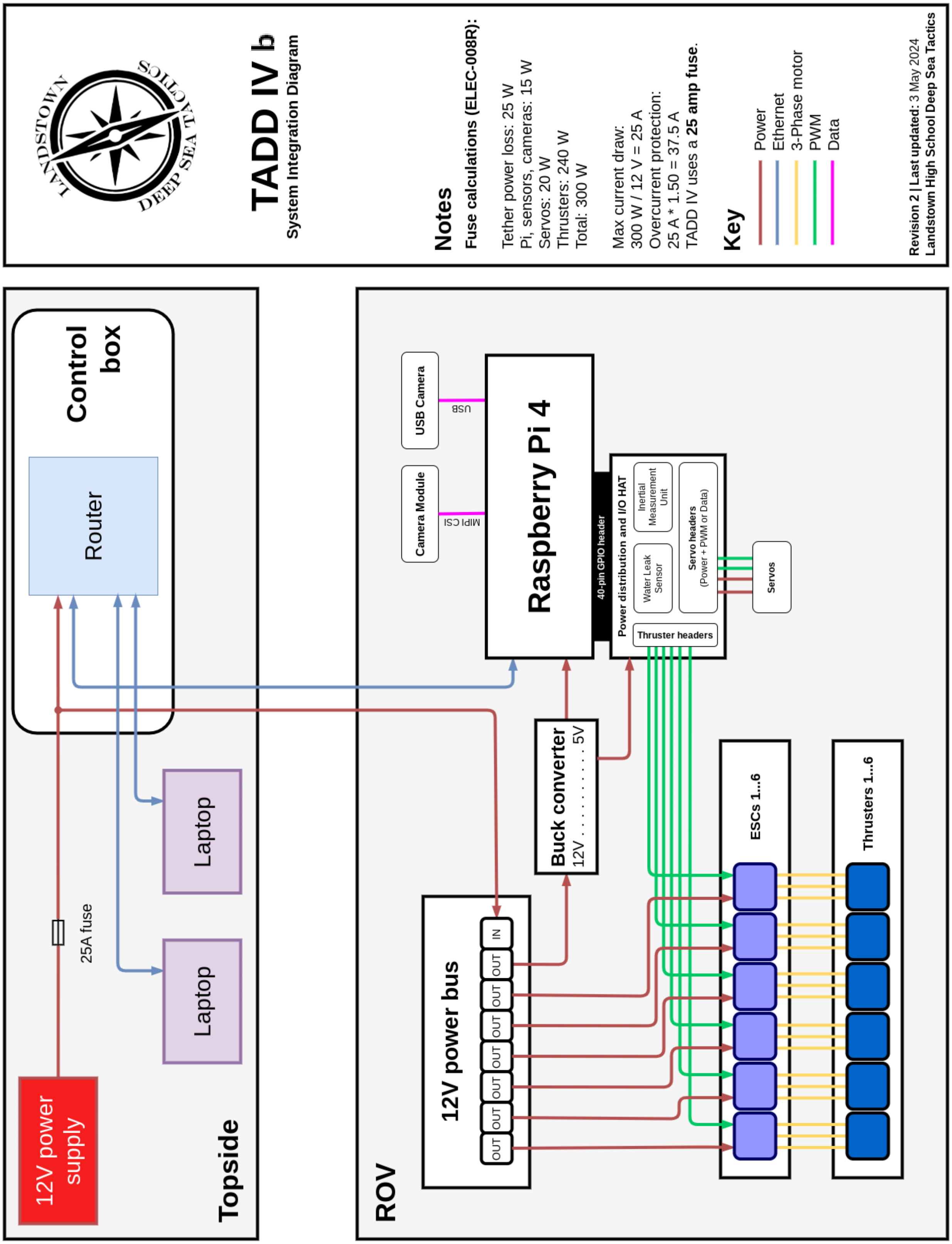
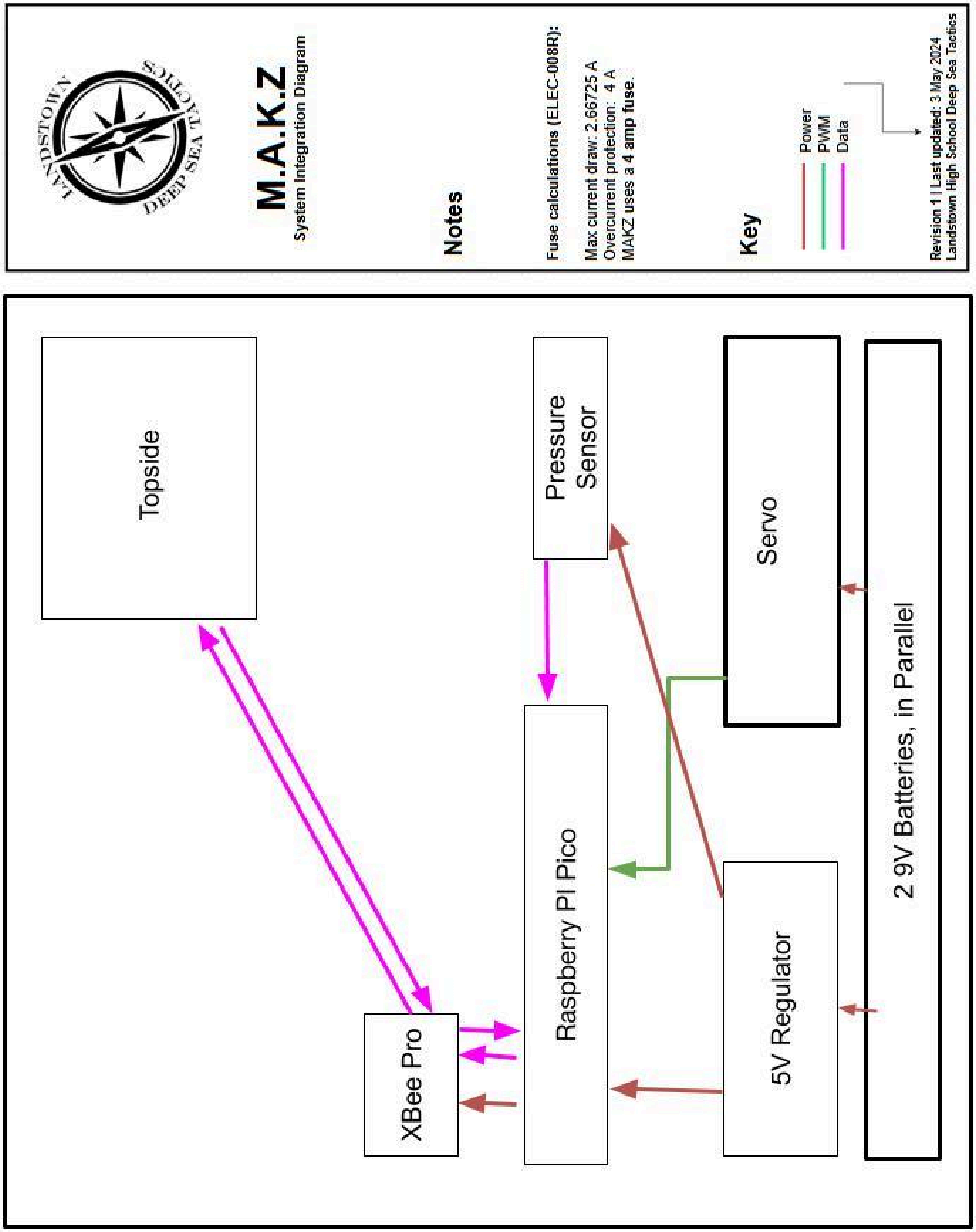


Figure 4: Float Electrical SID



SOFTWARE

General

To account for the ROV's non-axis-aligned thrusters, the Software team employed different techniques to create and rigorously test the ROV against many other conditions. A gradient descent algorithm was used to find the exact speeds to apply to each motor to make it move in specific directions. A stabilization algorithm incorporated accelerometer data to ensure the ROV remained stable and resistant to external forces.

The software team tracked all tasks in GitHub issues to ensure that all team members knew what to do whenever needed. Additionally, all the source code was available to foster collaboration within the general software community.

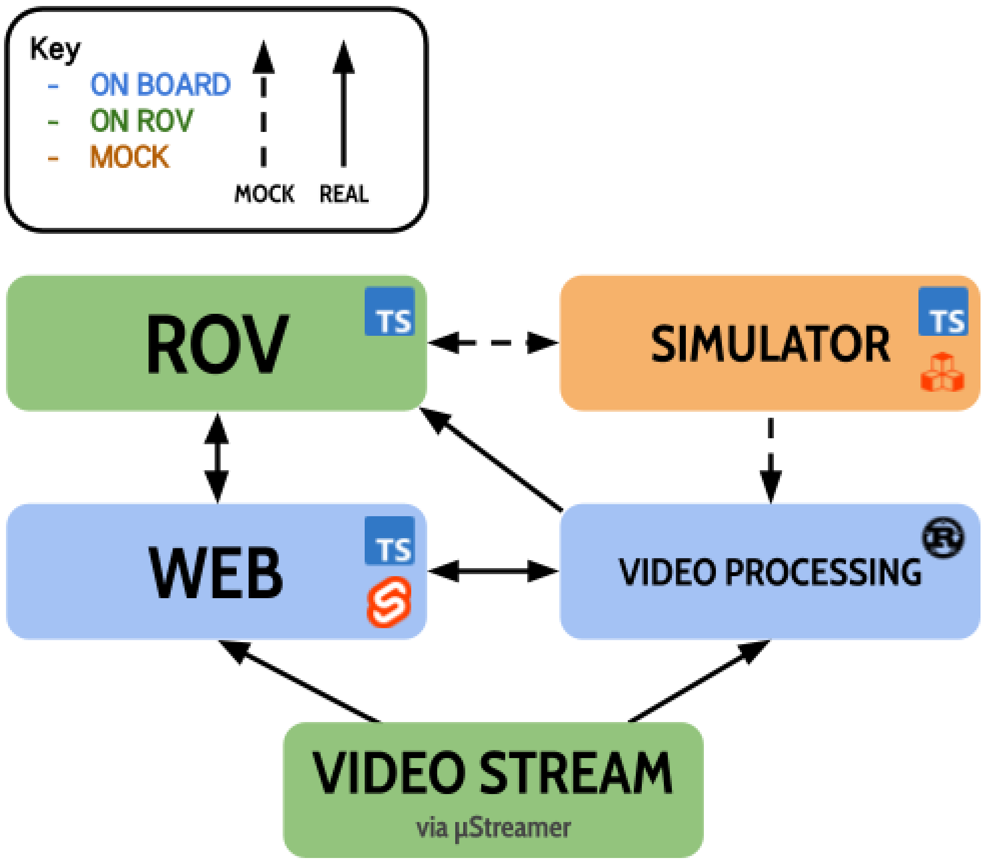


Figure 5: Software Architectural Diagram

To communicate between processes, the software team settled with tRPC, an overhead for WebSockets for inter-process communication between our Rust and TypeScript processes, and lossy motion JPEG streams with µStreamer for our video stream handling.

TypeScript and Svelte were chosen for the front end to assist in quick user interface building. The ROV and the simulation were also programmed in TypeScript to facilitate code sharing. The video processing library was built in Rust to ensure fast speeds and safety, guaranteeing success in our computer vision tasks. At any time, developers can switch between the real and mock modes, enabling testing, debugging, hot module reloading, and simulation.

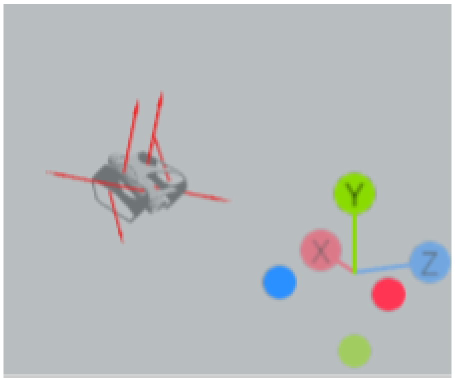
DevOps

To speed up collaboration, the software team used several tools to ease developer onboarding and communication:

- Git/GitHub: Promotes peer editing of the same codebase, allowing work from anywhere, anytime, with multiple people.
- Gitpod/GitHub Codespaces: Thanks to the GitHub Student Plan, many software engineers on this team could edit without installing manual tooling. Dev containers and contributing documentation were added to allow new contributors to join quickly.
- Continuous Integration: CI was added to the commit pipeline to allow errors to be checked without spinning up any development containers. The CI ran Nx and Cargo workspace tasks to build, check, and lint all of the various projects and subprojects within the repository.
- Nx/PNPM: Effective package and script management was implemented to facilitate booting up the repository, regardless of whether it is local or container-based development; starting the ROV is as simple as a single command. Nx-backed memoization is used for TypeScript type-checking and build processes to save time during development. Global package cache registries with PNPM were used to speed up installation and updating time across different repositories.
- Setup Scripts: Small scripting utilities were added to a separate repository to set up the Raspberry PI automatically. This allows for immediate and quick setup with a newly flashed SD card and allows for fallbacks during an SD card failure.
- Linter & formatter: Prettier and Cargo's in-built formatter was used to standardize all source files within the codebase to reduce potential merge conflicts, and eslint and Clippy were used to empower better code quality.

Simulation

To help test the ROV when it wasn't in the water, a full-scale simulation was made that employs the full scale of a physics engine into a convenient web-based simulation. Rapier was used as the physics engine, combined with the Threlte framework, a library combining the frontend tooling Svelte and Three.js to correctly render the simulation iteratively. Team members imported models directly from Fusion to assist in the simulation, creating realistic graphics for developers and pilots to test. A keyboard was used to substitute for the general Logitech controller to mock the



The simulation, depicting a rotation gizmo and the ROV.

controller, allowing for quick local development without any extraneous tooling.

Motors

Linear algebra was used to calculate the motor placements by using an empty control matrix and filling it with the contributions of the force and torque directions and orientations. The inverse of that matrix is what we use to calculate the force applied to each motor to make the ROV move in a specific direction.

Range manipulation was used to calculate the forces needed to move the ROV in a specific direction. The control above matrix was used to respect our amperage and voltage limits while utilizing our resources.

Controller

To connect to the controller, we used the Gamepad API. We adapted a standard unique interface that allows us to bind various controllers with different priorities and allows individual pilots to rebind the controller to their needs.

SAFETY

Team Member Safety

To ensure team member safety, team members are trained on and must follow a strict lab safety protocol. See APPENDIX B: LAB SAFETY PROCEDURES for more information.

Operational Safety

- mention safety checklist, appendix a
- job safety analysis

Safety Checklists

Appendix A and B contain procedures followed by our team in the construction, operation, and maintenance of the ROV to avoid exposing Deep Sea Tactics employees to harm.

Safety Features

- Locking connectors
- Wago 221
- Fuse

Safety Feature	Description
Black and yellow hazard tape	The black and yellow hazard labels are taped around thrusters, providing a safe way to warn of danger and avoid unnecessary injuries.
Fast-blown fuse	With the fast-blown fuse, the electrical current in the circuit is cut off to avoid electrical overload. It also avoids electrical shock caused by the exposure of wires to the conductive properties of water, avoiding full system failure.
Motor Guards	All holes are less than 12.5 mm (IP2X), and there are no sharp edges. They are also securely mounted so that they will not interfere with the motors' operation.
Trigger Button	Button 1 on the controller determines if the thrust motors will turn on. If it is not pressed, the ROV will not move.

CRITICAL ANALYSIS

While our time available to test the ROV was limited, we made great efforts to test the components that we had assembled throughout the development process. Initial submersion tests were conducted without the onboard electronics tray installed to verify that the ROV's enclosure was structurally sound and maintained watertight integrity.

-Begin general processes earlier
-Methodical testing
-Advanced problem-solving
-Using CAD-based solutions to rudimentary problems

ACCOUNTING

Budget

We started the year with a fundraiser selling Christmas wreaths, raising $2700 after almost 72% team participation. We immediately put $2000 towards traveling to Kingsport, Tennessee, and $700 towards building the ROV and Buoyancy Module.

The team thought most parts, such as electronics and motors, would be reused from last year since they function. There were things the team expected to buy, such as two more motors and HDPE to build the frame out of. On the other hand, the team did not expect to need to purchase new equipment to make the ROV. A new laser lens and end mill bits had to be bought so the team could cut the ROV and GO-BGC Float parts.

Travel Expense Estimates

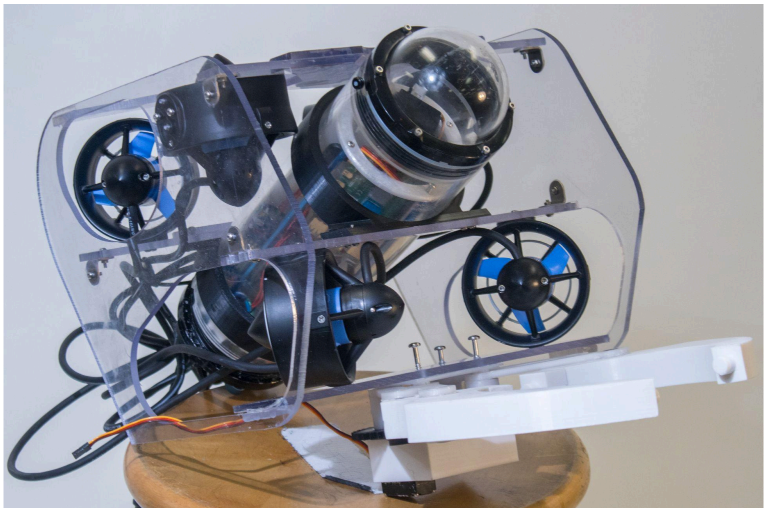
For the MATE ROV Mid-Atlantic Regional Competition, the team will travel to Villanova, Pennsylvania, and compete at Villanova University. The team will be traveling 6 hours away from Landstown High School. The team plans to take a bus to Villanova to transport students and equipment from Landstown High School. The team will book hotel rooms, and 10 will be grouped in pairs of 2 for the students. Two other hotel rooms will be provided for our mentors and the equipment, and any other adults with the team will be provided with their own room. Our overall cost for traveling to Villanova University is $85, which covers one night at Embassy Suites and pizza for dinner on the night of the team's arrival. The overall cost for our trip was $2038.

Cost Accounting: See Appendix C

ACKNOWLEDGEMENTS

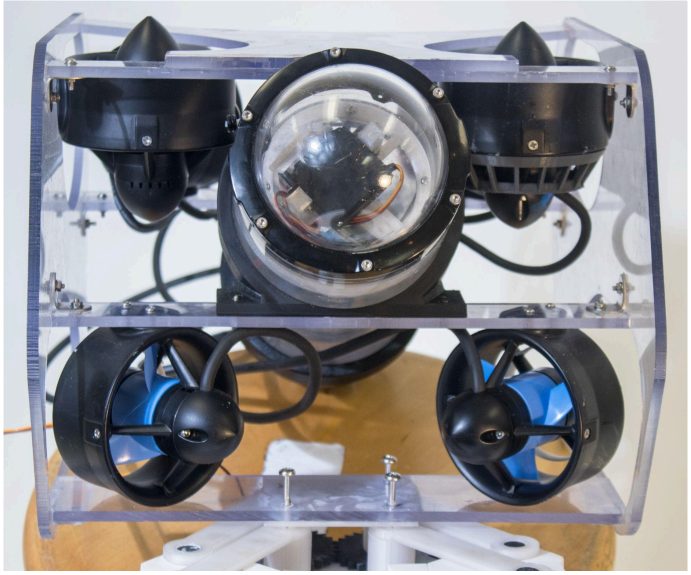
Ty Swartz — Main Team Supervisor and Mentor
Luther Meyer — Co-Mentor & Advisor
Dr. Johnson — LHS Principal
Jennifer Morris — Academy Coordinator, Governor’s STEM Academy at Landstown High School
Dr. Lockett — Director of Tech & Career Education, Department of Technology & Learning
Michael Turney Jr — Technology Education Teacher, Advanced Technology Center
Tom Siler — Technology Education Teacher, Governor’s STEM Academy at Landstown High School

PHOTOS OF TADD IV & TADD IVB



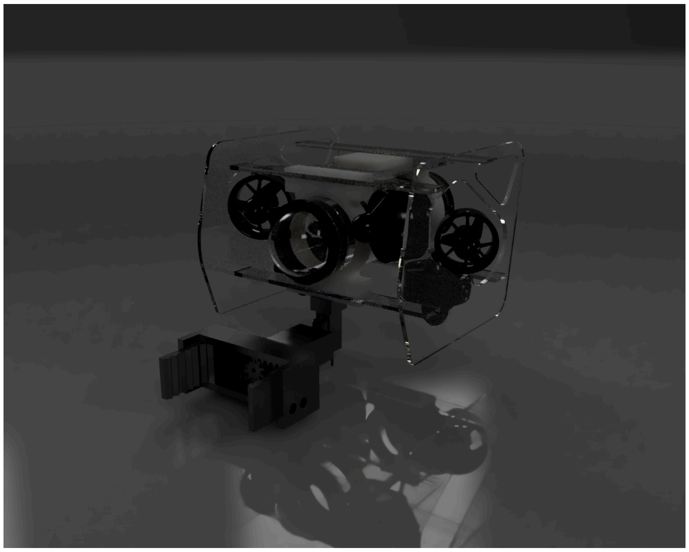
Right Side View of TADD IV

Photo by Deep Sea Tactics



Front view of TADD IV

Photo by Deep Sea Tactics



Left Side View TADD IVb

Photo by Deep Sea Tactics

APPENDIX A: SAFETY CHECKLIST

Procedure	Mark
Pre-Power Checks	
All crewmembers are wearing safety gear	
Power is disconnected before conducting a safety check	
Check the fuse is not blown	
All mechanical structures fastened securely	
Motor guards are fastened securely and clear of obstructions	
All sharp edges covered, and cap nuts installed	
Shafts and manipulators clear of obstructions	
Video gear clear of obstructions	
Cables tied down and electrical connections are waterproofed	
Check all seals are installed correctly	
Check electronics enclosure end caps are fastened correctly	
Check operating environment is clear of obstacles	
Call out “Safe”	
Pre-Water Checks	
Connect the tether to the control station and power the system	
Check the video system	
Check motor and sensor systems	
One crewmember and the tether man lower the ROV in the water	
Call out “In Water”	
In-Water Checks	
Call out “Pilot in Command”	
Recovery Checks	
Check ROV is at the surface, facing away from the pool wall	
Power down the system and call out “Crew in Command”	
Two crewmembers and the tether man lift the ROV from the water onto land.	
Safety officer signature.	

APPENDIX B: LAB SAFETY PROCEDURE

Lab Safety Procedures
All sharp edges are carefully filed down and smoothed to avoid possible injuries
Long hair tied back when testing the motors, gluing, or soldering materials, and working with power tools
Use eye protection and respirators/masks when sanding or filing with a machine
No open-toed shoes in the building area
Proper usage of machinery or tools
Fan for circulation or fume extractor to remove fumes from epoxy and when soldering
All work with dangerous or hazardous tools/materials is under proper adult supervision

APPENDIX C: COST ACCOUNTING

Expenses

Item Quantity	Item Description	Unit Cost	Item Total	Running Total
2	Clear Polycarbonate Lexan Sheet - 1/4" (24" x 36")	$ 44.49	$ 88.98	$ 88.98
1	Frost King C22CP Caulk Saver Bulk Contractor Pack, 1/2-inch Diameter x 250' Long, Grey	$ 17.09	$ 17.09	$ 106.07
1	20 pcs WAGO 221-2401 inline splice connector	$ 13.85	$ 13.85	$ 119.92
1	SD Card	$ 7.25	$ 7.25	$ 127.17
1	Servo	$ 31.99	$ 31.99	$ 159.16
1	Energizer Alkaline Power 9 Volt Batteries (8 Pack)	$ 26.98	$ 26.98	$ 186.14
2	WetLink Compression Gland Penetrator for Subsea Electrical Cables	$ 12.00	$ 24.00	$ 210.14
1	Bar02 Ultra High Resolution 10m Depth/Pressure Sensor	$ 75.00	$ 75.00	$ 285.14
50	8/2 SOOW Black Portable Power Cable 600V Non-UL	$ 2.65	$ 132.50	$417.64
1	14/2 round boat cable	$ 1.14	$ 1.14	$418.78
1	Energizer MAX 9V Batteries 8 Pack 9 Volt Alkaline Batteries	$ 20.98	$ 20.98	$439.76
1	Caseway SC-325 Polycarbonate Cement (1/4 Pint (4 oz.))	$ 1.00	$ 1.00	$ 440.76
1	60PCS L Bracket Corner Brace, Stainless Steel L Brackets, Metal Corner Bracket, Small Right-Angle Bracket, with 120PCS Screws	$ 5.99	$ 5.99	$446.75
2	Phoenix Contact PTFIX distribution block black 12 position	$ 3.80	$ 7.60	$454.35

We spent a total of $454.35 on ROV and Float parts this year.

Reused

Reused	Price
6 Blue Robotics T200 thrusters	$1200
Blue Robotics 4" Waterproof Enclosure	$425
Raspberry Pi 4	$55
6 Blue Robotics Basic ESCs	$228
2 Pressure Relief Valves	$56
MicroSD Card	$7

Income Sources

We earned income from support through fundraisers and donations. In total, the team earned $1,508.53.