Landstown High School

Virginia Beach, Virginia, United States

TADD II
Technical Documentation
MATE 2022 Competition

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Chief Fabrication Engineer
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Dom Varner

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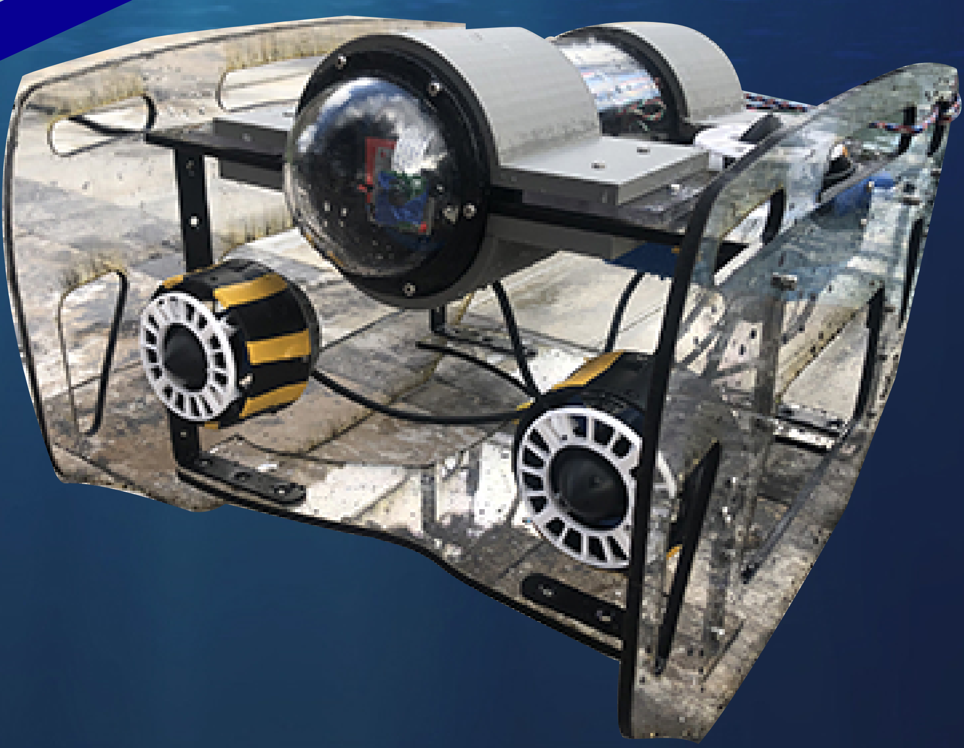
Labib Khan

Electrical
Dylan Sison



Abstract

Deep Sea Tactics' home city Virginia Beach is blessed with the Atlantic Ocean, where offshore wind farms are set up, and the Chesapeake Bay where more than 3,700 different species call home. Because the Chesapeake Bay watershed covers a large area, these species are endangered due to poor waste removal policies. Deep Sea Tactics is aiming to eliminate waste from the Chesapeake Bay and assist in wind farm operations. They have developed a solution and are proud to introduce the remotely operated vehicle (ROV) TADD II.

Founded in 2019, Landstown Governor's STEM Academy's Deep Sea Tactics has twelve dedicated employees with varying experience and knowledge in engineering, coding, business, marketing, and design. This year's organization used 3D modeling software to visualize the underwater Remotely Operated Vehicle (ROV) design. The main structure of the ROV is Polycarbonate which was laser cut based on the 3D model. The robotic arm was also designed using 3D modeling but printed using PLA (polylactic acid) filament with a MakerBot printer. The robotic arm allows the ROV to complete complex maritime tasks such as cutting an inter-array power cable or farming seagrass.

Figure 1: Deep Sea Tactics Team Picture

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Teamwork

Project Management

The team consists of four groups that work together to make a product that completes the tasks most efficiently. The four groups and their roles are:

- Fabrication - physically builds the product
- Design - uses computer modeling software to model different aspects of the product
- Electrical - designs and builds an electrical system
- Software - designs and programs software that will control the final product

Each member of the team comes from a different area of engineering, each member having a different level of experience in their area of expertise.

- Daniel Tomov - lead the electrical team and the team. Worked on the electronics systems by designing and organizing the different components on the tray on the inside. Also responsible for the waterproof enclosure.
- Carter Elliott - designed the main body made of polycarbonate by using Adobe Illustrator and Blender. Also designed the claw and aided in the development of the arm.
- Christian Munoz - lead the building of the props that the team will use to prepare for the competition. Also helped the fabrication team and electrical team wherever needed.
- Tristan Figueroa-Reid - designed and programmed the control program for the topside computer. This program sends joystick commands to the robot in the water. This program also displays a graphical user interface to display joystick values and camera streams from the ROV.
- Dylan Sison - helped with the designing and building of the electronics systems
- Tara Bell - helped design the brackets that hold the electronics enclosure in the middle of the robot. Also helped in the building of the robot whenever needed.
- Dom Varner - designed the brackets that hold the electronics enclosure in the middle of the robot. Also helped in the building of the robot whenever needed.
- Elijah Fischer - mainly helped in the building of the tasks that the team will use to train for the competition. Also helped in the building of the robot and electrical system whenever needed.
- Labib Khan - Helped design the program that sends commands to the robot.
- Nicholas Reichard - designed, fabricated, and tested the robot arm
- Olivia Delarosa - helped the fabrication team build the robot

The team meets every Tuesday from 2:00 PM to 4:30 PM to work on the final product. During this time, the team works on any design, fabrication, programming, and building that needs to be completed. In addition to this, members are given assignments that continue the development of the robot. Members are encouraged to work on these at home because most of them require researching designs for the systems of the product.

Design Rationale

Engineering Design Rationale

Using their experience from last year, the team knew they needed a design that did not consist of PVC pipes. This is because PVC pipes are not strong enough to handle the power of the motors and are difficult to drill into accurately. This is why the team decided to take notes from other robot designs online. They ultimately decided to use a common box-like design because of its simplicity. Once a design was made in Blender, a 3D modeling and simulation program, it was decided that there should be holes in the sides and the bottom to allow for water flow. This edited model was then imported into Adobe Illustrator, which is used to create a diagram for a laser cutter that will cut polycarbonate, which was chosen because of its strength. The pieces were then made into a box-like design with 90-degree angle steel brackets.

Innovation

Additionally, to the availability of space on our ROV, incorporated into the design is an angled polycarbonate wing. This wing's purpose is to pitch the nose of the ROV up. At a 15% decline, the wing considers the frontal mass; which is the arm on the leading edge of the ROV. Thus, allowing the ROV to maintain leveled flight while in the water.

Systems Approach

The design for TADD II is rather simple so it can be robust but also modular to be easily maintainable. Occasional use of outsourced parts is necessary for mission-critical components so that replacements are readily available and easy to install. For the safety of our vehicle and employees, some standards include having electrical cables color-coded for different power buses: red for positives, black for ground/reference, white for logic signals, and yellow for switched/controlled power.

Vehicle Structure

The frame is made of polycarbonate, a material that can withstand the degrading properties of water. While it is relatively expensive, it is durable and easy to work with. The size of the robot is justified by the idea that any additional tools can be added to the large space beneath the electrical housing. An example of a use for this space would be a Mini-ROV that would inspect tighter spaces that the big one cannot get into. Another example would be housing a hydrophone that would collect profiles at different depths.

Vehicle Systems

In the creation of our ROV, we took great care in material and component design and construction. The sides and frame of the ROV were made of polycarbonate for its cost-effectiveness and its resistance to degradation in water. Polylactic acid was used as the 3D printer filament for the creation of braces to hold the acrylic enclosure containing the electronics. PLA was also used in the creation of the ROV arm.

Control/Electrical System

The electronics system was reused from the previous year, which prevented unnecessary spending costs and allowed us to be resource-efficient. The electrical system begins from the power source. The connection is split after the fuse to power the topside control unit (TCU) and the ROV. The TCU consists of a network router that routes information between three laptops and the ROV. The laptops are used for control, viewing the cameras, and doing some autonomous tasks.

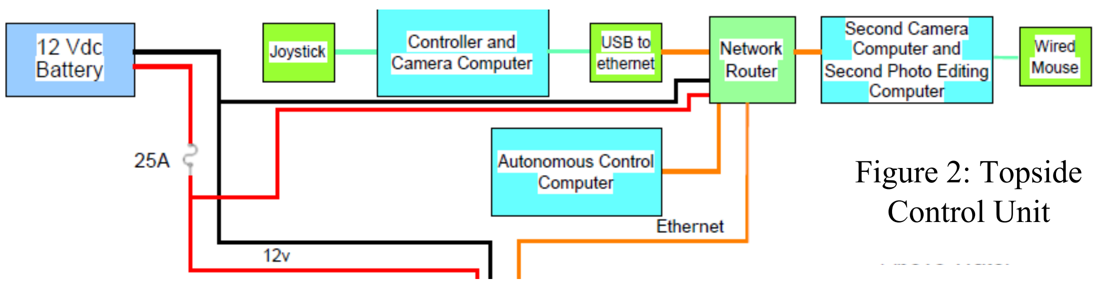


Figure 2: Topside Control Unit

The other side of the split goes into the tether, where the ethernet cable from the router also goes. Both go into the ROV where the ethernet goes directly into the Pi and the power goes into a terminal block to split the power to necessary components. Four Electronic Speed Controllers (ESCs) and a 12vdc to 5vdc regulator board receive this distributed power. The motors on the outside are connected to the ESCs with three wires, and the outside servos are connected to the Pi HAT also with three wires. The cameras on the inside are normal USB cameras that the Raspberry Pi uses to create a video stream. See Appendix A for a more detailed diagram.

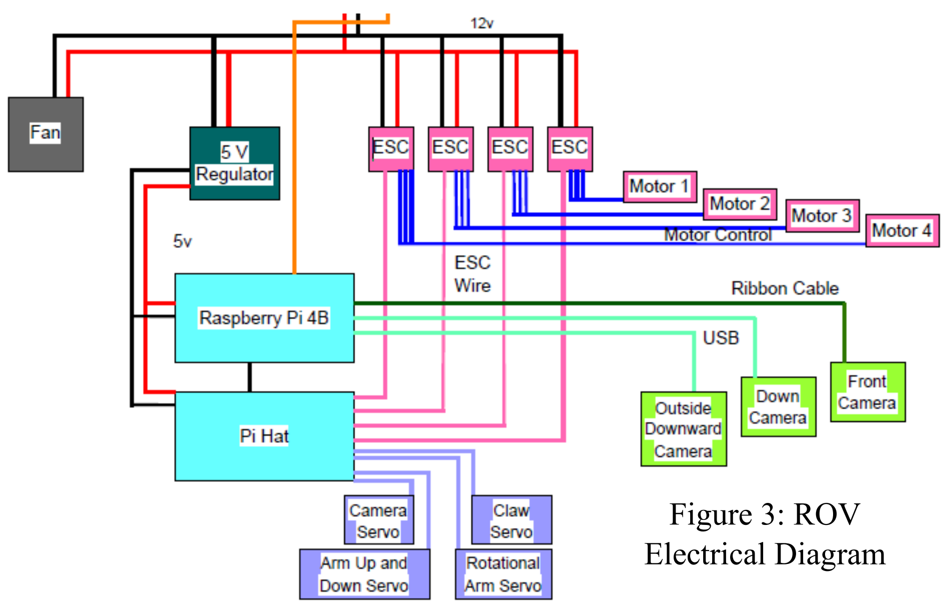


Figure 3: ROV Electrical Diagram

The topside control program runs using two Node.JS programs: the server and the client. The server (made with server-side TypeScript) reads the joystick inputs and sends them to the robot and the client, as well as handling any extra information the client may want to send back (such as automated tasks). The client (made with SvelteKit and client-side TypeScript to encourage component-driven development) is the web interface that displays the cameras of the robot and any additional information provided by the robot, as well as sending back data for automated tasks. The communication between the server, client, and the robot happens using various communication protocols like WebSockets and TCP (Transmission Control Protocol) under the communication library socket.io to make sure that the communication never gets dropped no matter what. To make sure the code on these two parts is robust, reactive libraries are used to make sure that data is sent whenever it changes and easily updates between all 3 involved parties, and TypeScript is used on both parts to enforce type safety and catch errors before they ever happen.

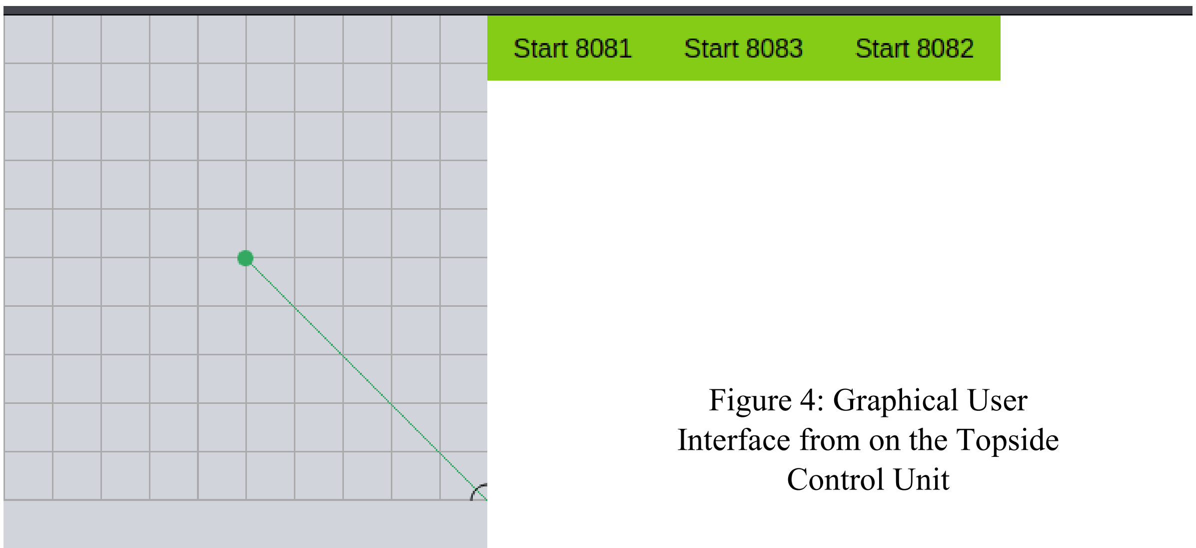


Figure 4: Graphical User Interface from on the Topside Control Unit

As already mentioned, the tether is made up of an ethernet cable and two wires for power. Both of these are wrapped in paracord to provide strain relief throughout the whole tether. This is to make sure that the robot will not pull on it and break the cable at either end. On top of the paracord, there is a sheathing that protects the cables. It also allows for easy wire management because the sheathing contains the individual wires preventing them from tangling. To manage the tether, several protocols have been defined. If the pilot feels that the robot is not moving, then they can call out asking for more tether. When the robot is coming back to the surface, the tether is neatly placed in a spiral by the other tether manager while the first one is taking the tether out of the water.

Propulsion

We reused our T-200 motors for their excellent reliability and performance. T-200s are brushless, water-cooled powerhouses and can run at high speeds for large amounts of time. Specifically, each motor has 2.9 kg of thrust. Each motor has its own Electronic Speed Controller

(ESC) which controls the motor's speed. BlueRobotics Basic ESCs were used to support high efficiency, low heat output design for our motors. The DC current throughout the motor wiring is turned into 3 electrical outputs, each stabilizing and controlling the speed of the motors. We also designed a mounting table for the ESC chips so that we could mount a fan on them to make sure they stayed at a reasonable temperature.

To protect wildlife and humans from the spinning propellers, we have redesigned, and 3D printed motor shrouds that attach to the front and back of the T-200 motors.

These motors were placed strategically with 2 motors towards the upper part of the craft facing upward. These provide for upwards thrust for ascending and pinpoint upward maneuvers. We also had 2 other motors in the front-facing forwards. These provide main forward and backward thrust and are placed so the ROV frame does not impede their effectiveness. We were unable to implement more motors into the design because they would use too much current when operating in the water.

Buoyancy/Ballast

Incorporated into the design is the main central electronic housing tube, which is airtight. This housing tube is placed centrically upon the ROV to provide leveled ballast upon the ROV. Additional forms of ballast incorporated into the design is the account for the ROV arm purposely making the ROV's (without the arm) trailing edge heavy to counteract the weight of the arm. The ROV also has four main air-captured flotations upon the four top corners and one on the trailing edge of the ROV helping main level flight without being too buoyant or not buoyant at all. Thus, allowing easier work upon the main directional control motors.

Payload and Tools

An in-house part we had to design, prototype, test, and implement ourselves was the ROV arm. The arm would enable us to implement modes of material transportation for the tasks. This includes things such as removing a ghost net, cutting a section of damaged inter-array power cable, deploying a hydrophone, and farming seagrass, to name a few. Our claw was designed to pivot up and down as well as rotate 180 degrees to allow for a broader range of motion.

Other tools on the robot are the three cameras. There is one camera in the front that can move up and down with the help of a servo. This allows the pilot to see the surface of the water and downwards at the arm. Two downwards facing cameras are mission-specific. One of them is towards the back and has no obstructions. This camera will be used to create a photomosaic and map a transect. While the other camera is obstructed by the body of the ROV, the body is clear, still providing visibility. This camera will serve as a backup.

Problem Solving

Problem-solving was a large part of the team's design process from the initial idea through to the final product. They used 3D modeling software such as Blender to communicate design ideas for the body of the ROV and a whiteboard to discuss the coding problems and the electrical system.

Safety

Content

Safety Feature	Description
Black and yellow hazard tape	The black and yellow hazard labels are taped around thrusters, providing a safe way to warn that there is danger and to 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 10mm and there are no sharp edges. They are also securely mounted in a way in which they will not interfere with the operation of the motors.
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.

Safety Procedures

Safety Procedures for construction
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
Eye protection and respirators/ masks worn when doing heavy sanding or filing with a machine
No open-toed shoes in the building area
Proper usage of machinery or tools

Stationary fan for circulation to rid of fumes from epoxy and when soldering
All work with dangerous or hazardous tools/materials is under proper adult supervision

Procedure	Check 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.	

The Landstown Deep Sea Tactics Safety Manager is responsible for reviewing this safety checklist with the rest of the team before workshop or pool competition activities. This checklist is an effective reminder to the entire team. By reviewing this safety checklist before each activity, the importance of safety at all times is established and reinforced.

Critical Analysis

Testing and Troubleshooting

For our ROV testing, the team was fortunate enough to be able to use a friend’s outdoor pool. This allowed the team to use the robot in the water and run diagnostics and train its capabilities. The team was able to test a total of three times before the regional competition. The first was to test for water leaks, the second was to test the capabilities of the arm, and the third was to begin training for the specific tasks. In the future, the whole team will train as if they are the competition. They will be timed and will be scored accordingly.

When there is a problem with the functionality of the system, the team would disconnect everything but the critical systems and check their functionality. This would often mean they would use a multimeter to measure the voltage in different areas of the system or check for continuity. If the issue is found, the team can efficiently fix it and depending on the severity, the team can replace each component in the electrical system.

Build vs. Buy, New vs. Used

The electronics tray, main body, arm, and electronics housing were all built by us. The custom electronics tray allowed us to only include what we needed to complete the tasks. One of the largest tasks was building the main body, since we wanted to redesign it. We used an in-house laser cutter to cut the polycarbonate sheets. Building the main body allowed us to make modifications like the angled polycarbonate wing that we added to help compensate for the weight of the arm. This would allow us to efficiently move from task to task in the water. Building the arm allowed us to make it the way we thought would be best to complete the tasks. This included the number of joints and axes that our arm would have on it. The electronics housing, which was used in the previous year, was custom built to encase the electronics tray and protect it from coming in contact with any water. This allows us to meet several safety requirements like no exposed wiring and no leaking. Overall, building the ROV by hand has many benefits.

Accounting

Budget

School Name	**Landstown High School**			**Reporting Period**
			From:	**9/21/2021**
Instructor/Sponsor	**Tyler Swartz**		**To:**	**5/26/2022**
Income				
Source				**Amount**
Landstown High School				$1,500.00
Expenses				
Category	**Type**	**Description/Examples**	**Projected Cost**	**Budgeted Value**
Hardware	Purchased	PLA, polycarbonate sheets, brackets	$500.00	$500.00
	Re-used	Stainless steel screws	$20.00	$0.00
Electronics	Re-used	T200 motors, Raspberry Pi, wires	$900.00	$0.00
	Purchased	Servos, USB adapters	$150.00	$150.00
Travel	Purchased	Round-trip airfare to Los Angeles, transportation	$10,000.00	$10,000.00
General	Purchased	Marketing material, transportation packaging	$500.00	$500.00
Tools	Purchased	Drill, pliers, soldering iron	$600.00	$600.00
			Total Income:	$1,500.00
			Total Expenses:	$12,670.00
			Total Expenses-Reuse/Donations	$10,830.00
			Total Fundraising needed	$9,330.00

Cost Accounting

School Name	**Landstown High School**			**Reporting Period**		
			From:	**9/21/2021**		
Instructor/Sponsor	**Tyler Swartz**		**To:**	**5/26/2022**		
Expenses						
Date	**Type**	**Category**	**Description/Examples**	**Sources/Notes**	**Amount**	**Running Balance**
11/19/2022	Donation	General	Cookie Dough Fundraiser	This fundraiser was for all clubs at school	$300.00	**300.00**
12/15/2021	Purchased	Fabrication Tools	Drill, pliers, soldering iron	Used to put robot together	$486.64	**(186.64)**
02/08/2022	Purchased	Fabrication Tools, hardware, and Electronics	Flex Seal, steel brackets, wires, paracord	Mostly for the body	$112.51	**(299.15)**
2/15/2022	Re-used	Electronics	T200 motors, Raspberry Pi, wires	Electronics is put together, all re-used parts	$1,022.00	**(1,321.15)**
3/1/2022	Purchased	Electronics	Servos	35kg servos for the arm	$147.96	**(1,469.11)**
3/10/2022	Purchased	Fabrication Tools	BlueRobotics socket wrench, Wetlink Penetrators	Tools to install penetrators on the back	$76.00	**(1,545.11)**
4/6/2022	Purchased	Props	PVC, rebar, spray paint	Props to test robot	$370.56	**(1,915.67)**
5/20/2022	Purchased	Travel	Round Trip Tickets to Los Angeles	For six team members and mentor	$10,000.00	**(11,915.67)**
					Total Raised	**300.00**
					Total Spent	**12,215.67**
					Final Balance	**(11,915.67)**

Acknowledgements

Dr. Johnson - Landstown High School Principal supported with a $1400 working budget.

Landstown High School - provided tools and a space to design and build the ROV.

Mr. Thornton - Salem Middle School Science Teacher who allowed the team to present team progress and discuss underwater robotics with other robotics students.

Ty Swartz - Team Mentor and sponsored $380 towards build.

Marine Advanced Technology Education - For the challenge and opportunity to compete.

Home Depot - For having all of the parts needed for obstacles.

Mrs. White - For constant support during the overall build.

Mrs. Fisher - For accounting and purchase order support.

Mrs. Jennifer - For allowing the team to use her pool to do testing and training.

References

https://www.bluerobotics.com

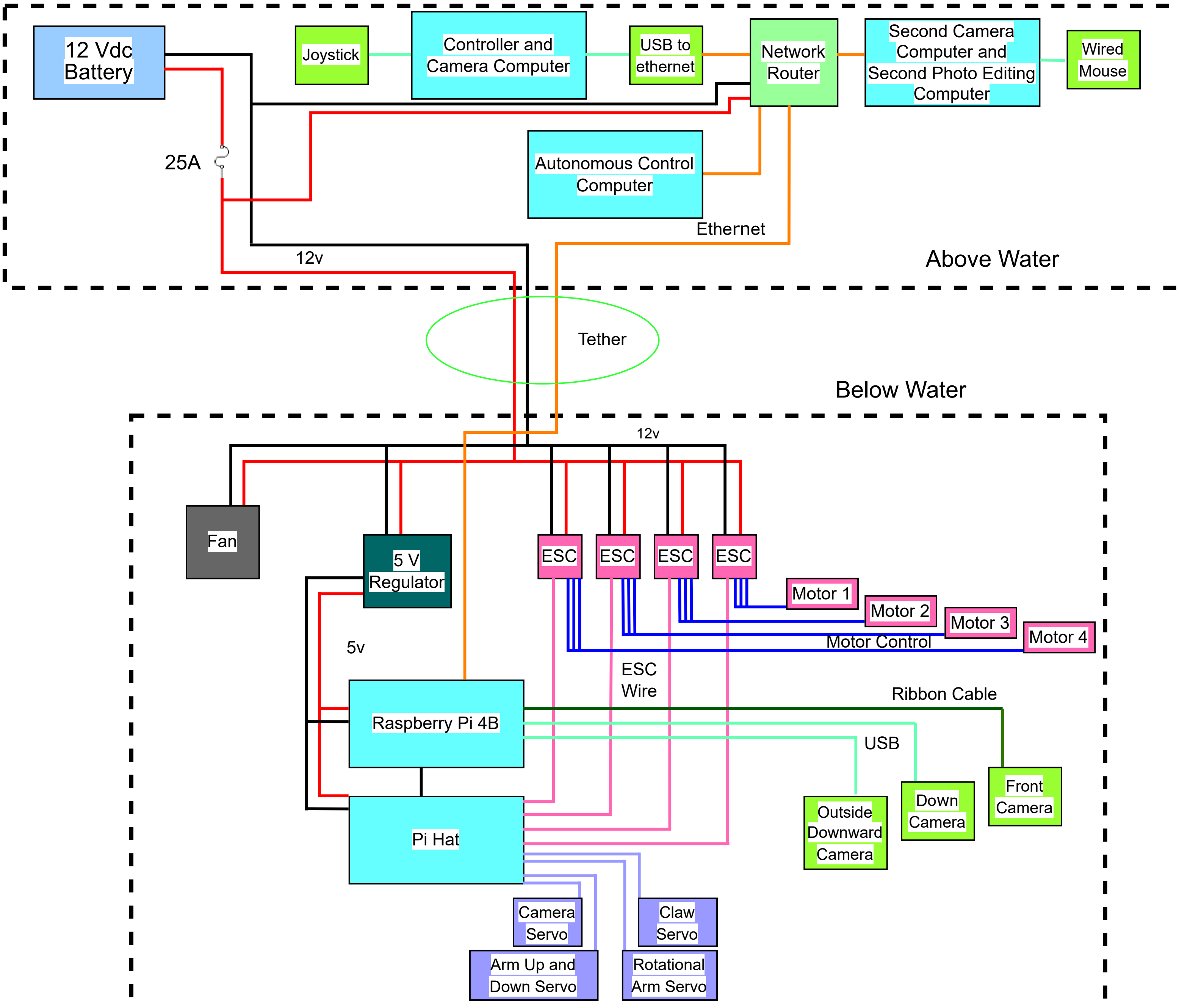
https://discuss.bluerobotics.com

https://materovcompetition.org

https://nodejs.org

https://svelte.dev

Appendix A - System Interconnection Diagram



Fuse Calculations

Motors: 5*4=20 amps
Raspberry Pi: 1 amp
Servos: 2*3=6 amps
Total: 27 amps
27*150%=40.5 amps
TADD uses a 25 **Amp Fuse**.

Legend

Ethernet
4 Conductor USB Wire
2 Conductor ESC Wire
Power (both 5v and 12v)
3 Conductor Servo Wire
3 Conductor Motor Wire
Raspberry Camera Ribbon Cable

Appendix B – Photos of TADD II