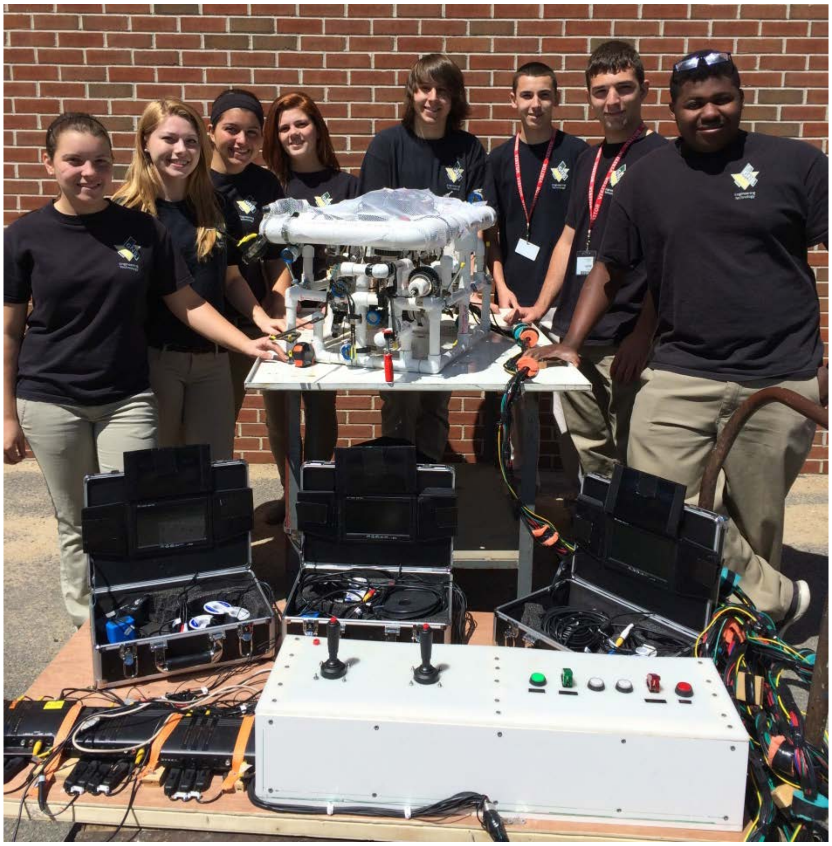
Triton Robotics Systems, Inc.

Greater New Bedford Vocational Technical High School
1121 Ashley, Boulevard, New Bedford, MA 02745



Neptune EOS

Team Members

Kyla LaPerriere	CEO- A/V Engineer
Kristen Botas	COO-Systems Engineer
Aaron Jesus	Pilot – Electrical Engineer
Nathan Gomes	Pilot – Electrical Engineer
Megan Young	Cameras- System Engineer
John Kitchen	Tether – Electrical Engineer
Katelynn Couto	Scoring-Mechanical Engineer
Isaiah Lopes	Co-Pilot-Electrical Engineer
Lance Stevens	Co-Pilot-Structural Engineer

Instructors/Mentors

Nelson Bernardo, Angela Basse, Thomas Canastra

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Abstract

As Engineers of Triton Robotics Systems, Inc. our business is to design and manufacture Remotely Operate Vehicles that can discover, explore and document shipwrecks. Our ROV, the *Neptune EOS*, is designed with specialized tools to retrieve items from the ocean floor, measure shipwrecks, and collect environmental data. With this data, ship designers can create safer and more efficient vessels.

The *Neptune EOS*, was completely designed and built by our engineers. Our guiding principal is: simple specialized tools are more reliable than complex multiuse tools. Starting with the custom frame design and ending with the intentional placement of 10 cameras, every aspect of our vehicle is carefully designed and thoroughly tested until we are certain it will work. The Engineers of Triton Robotics Systems, Inc. are dedicated to becoming the world's leading underwater recovery design and fabrication team.

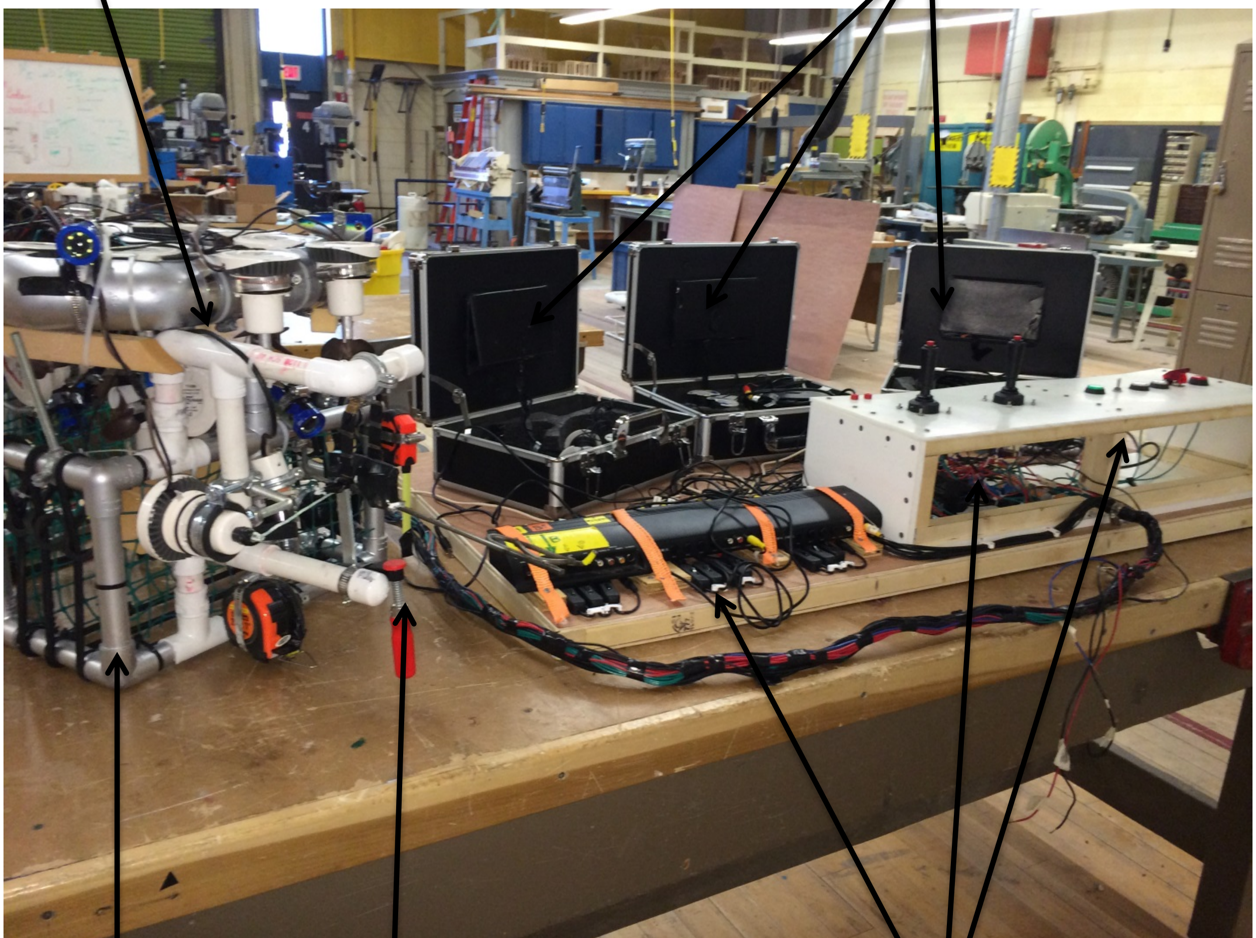
A typical work day is anything but typical. At Triton robotics we emphasize team work and creative problem solving. Daily morning meetings organize engineers into teams to solve our clients' specific problems. Engineers regroup by the end of the day to present possible solutions to each other for feedback.

Engineers on a typical day working on the *Neptune EOS.*

ROV Photos

3 Monitors with 10 camera views

Neptune EOS



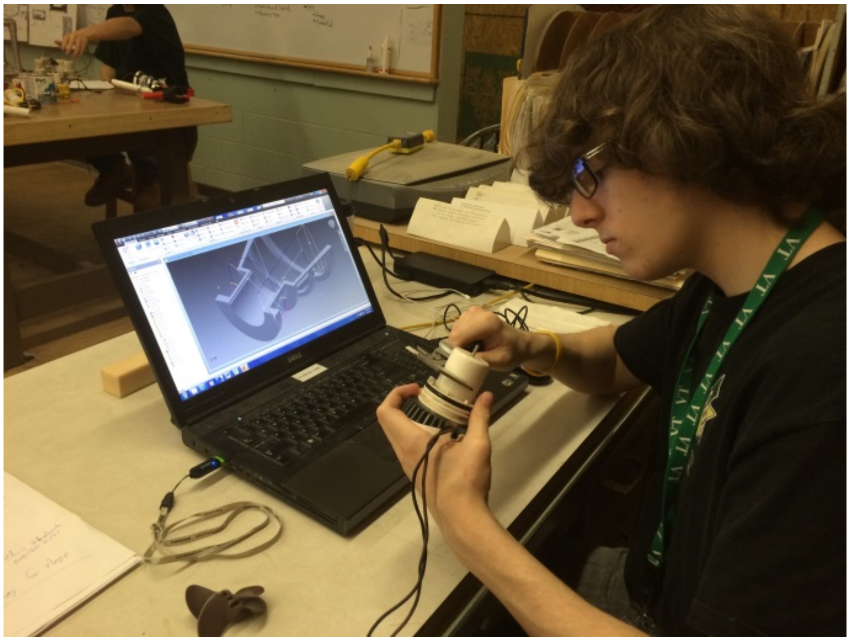
<u>Completed ROV</u>

Custom Built Control System
(Front cover removed to show wiring.)

Shop Built Bungee
Cord Bottle collector

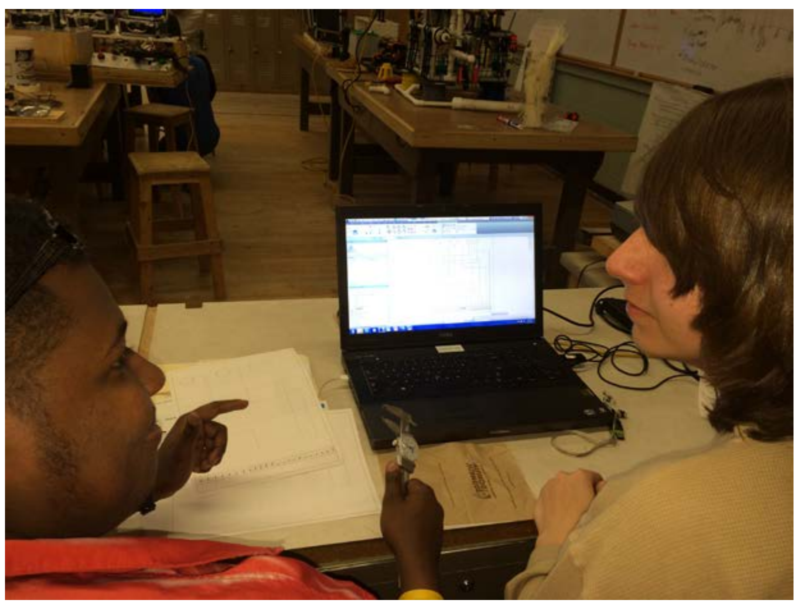
Specialized Plate Collector Tool

ROV Photos Continued



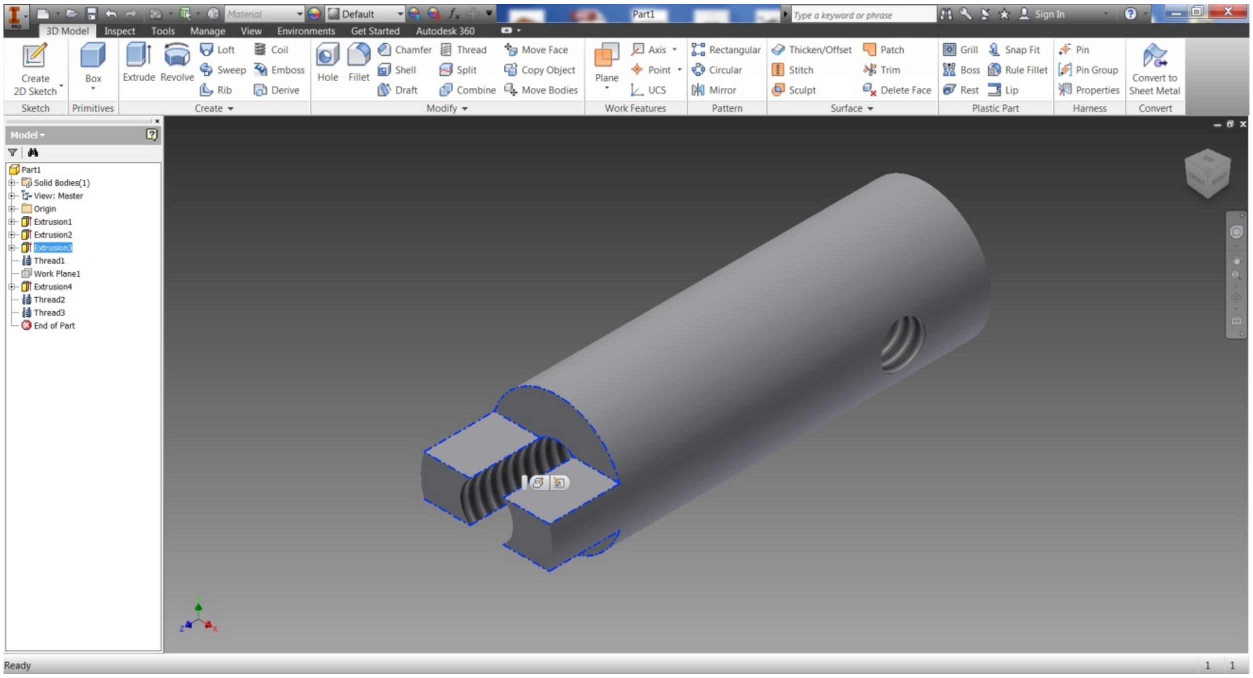
Our engineers work with the latest 3D modeling software and accurate measuring tools to design precision parts for the ROV.

Custom Designed Propeller Guards

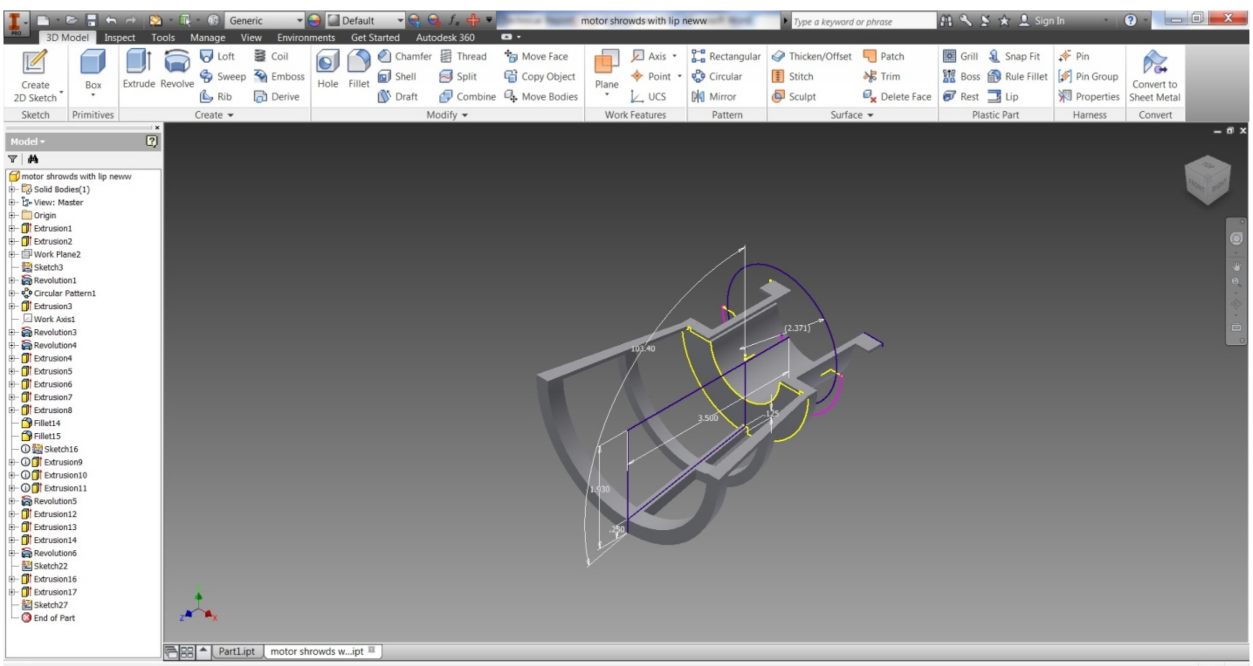


Creating the Systems Integration Diagram (SID)

ROV Photos Continued

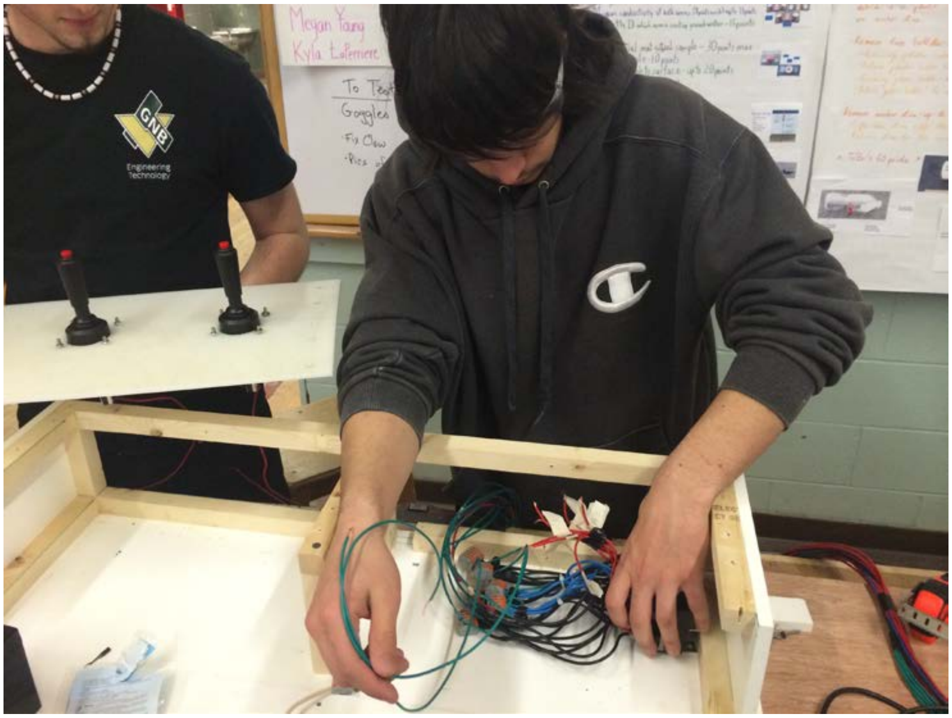


Custom Designed Propeller Shafts
(Designed and built in our shop.)



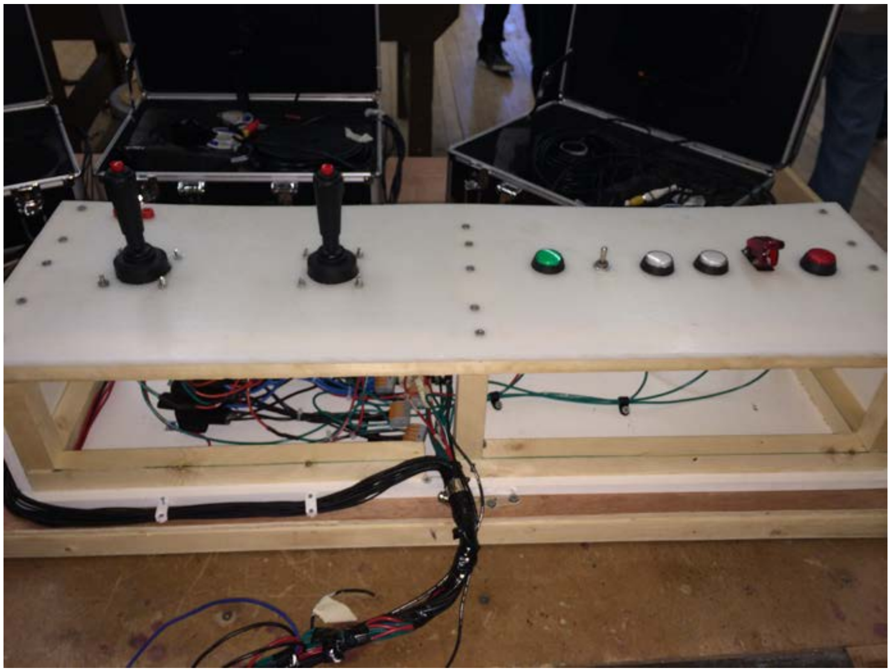
Custom Designed Propeller Guards
(Designed and built in our shop using Inventor and our 3D printer.)

ROV Photos Continued



Building and troubleshooting the control system.

Custom Manufactured Control System

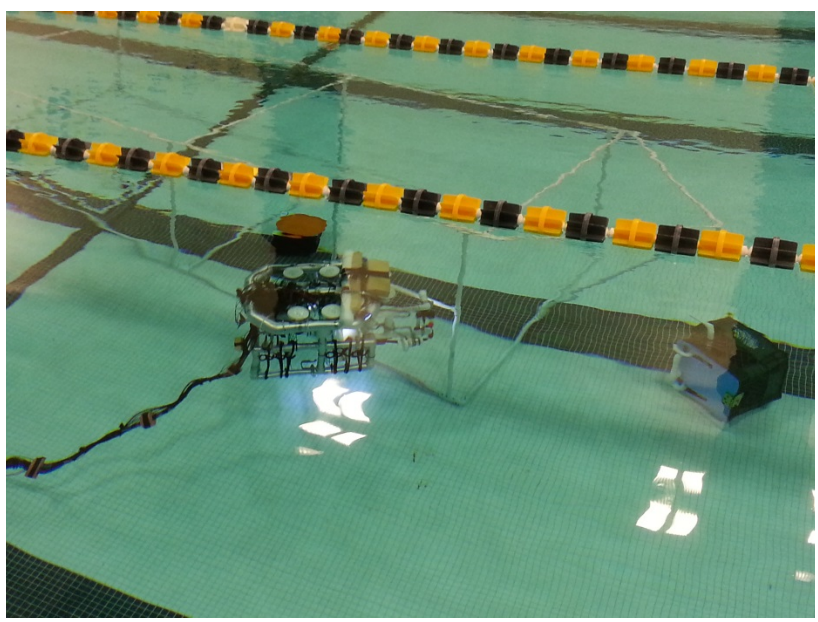


Completed Control System
(Utilizes pilot and co-pilot controls.)

ROV Photos Continued

Testing was both the most difficult and rewarding part of the process.

Testing at the YMCA Pool



Testing the completed *Neptune EOS*

(All props were built to fully test the vehicle with time constraints)

Design Rationale

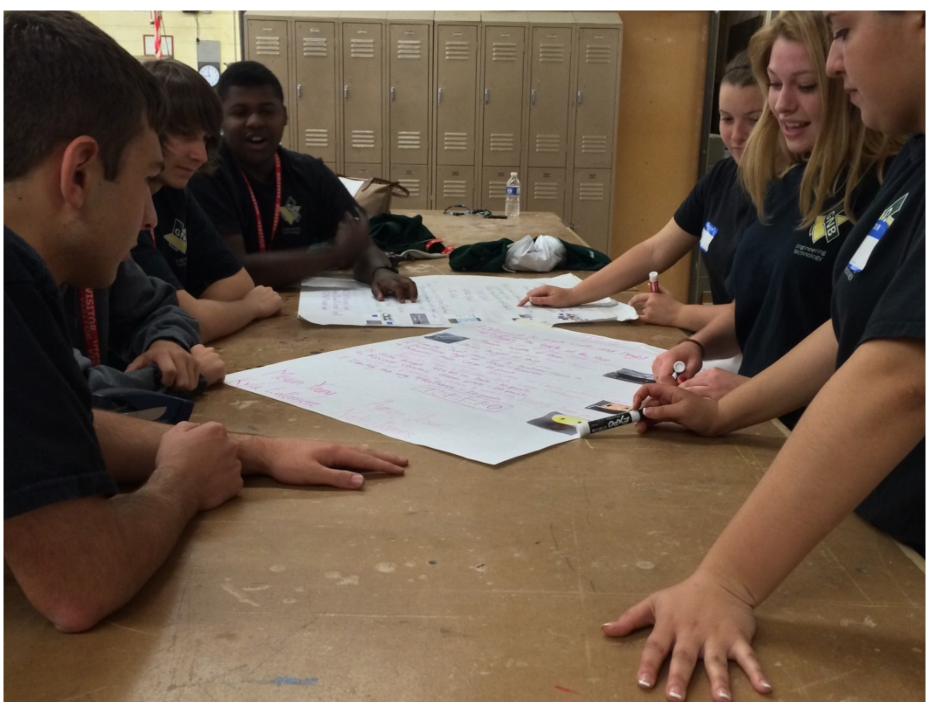
Engineering Design Process

Throughout the project we employed the engineering design process to achieve optimum results. We used the following steps to tackle every step of the project:

1. Define the problem
2. Research the problem and past solutions
3. Brainstorm ideas for possible solutions
4. Evaluate potential solutions
5. Choose a solution: design & refine
6. Built a testable version of proposed solution
7. Test and collect data
8. Review results: Solution achieved or back to step 1

We used morning team meetings to review the overall project status and identify problems to be addressed. The team was divided into groups of two or three members to develop solutions. For complicated problems, such as developing a bottle pick up tool, all teams worked on the same problem for a defined period of time. Then each team presented their solution to the group. This lead to vibrant brainstorming with lively discussions and more solutions to refine and test until the problem was solved.

We found this type of work to be our favorite part of the project and good team skills are essential to good results. To help build a strong team bond, we made time for activities like soccer games and guitar sing-alongs. The sense of belonging and trust is what allowed all team members to feel free to participate without concern for criticism. It is truly a team effort.



Team meeting and brainstorming session.

Design Rationale Continued

Frame

The Neptune EOS was designed and built with the mounting of motors, cameras and tools in mind. The ROV was built out of PVC pipe and fittings. We chose PVC as our material because it is buoyant, inexpensive, readily available and versatile. Our frame was designed to be more buoyant on top so the ROV would be stable. Our first designs in the Fall of 2013 were of 3” pvc on top and ½” pvc for the remainder of the frame. Testing revealed this frame design to be difficult to maneuver and transport. We dropped the ROV during testing and cracked the bottom of the frame.

Early frame design. Bulky, cracked during testing.

The final frame design was shaped like a cube so it would be more agile and rotate on its axis. Seventeen motors are mounted on the horizontal and vertical members of the frame for maximum stability and rotation. Additional frame members were added to provide necessary motor mounting locations in the places needed. The top portion of the ROV frame was reduced to 2” pvc, although smaller than the preliminary designs, it is still considerably larger than the ¾” pvc used for the lower part of the frame. Testing results were strong for both the maneuverability and stability of the ROV. Motors were mounted with two different methods based on distance from the frame. For motors located close to the frame we chose the double hose clamp technique because it is both light and strong. For motors mounted away from the frame we used a double split ring that uses threaded rod to mount the motor at any distance and angle required to achieve the optimum motor location.

Final frame design, ¾” PVC members are strong and buoyant. The frame has multiple members added to provide mounting locations for motors, cameras and tools. The silver paint creates an aesthetic that matches the advanced ROV design.

Double hose clamp motor mount.

Design Rationale Continued

Specialized Plate Collector Tool

Each tool for the Neptune EOS was designed for their specific task. The gripper is a 6" clutch style bar clamp that clamps onto the plate and holds firmly. The clamp is mounted to a 3/4" PVC frame specially design to hold the clamp. The clamp is held open with a 1/8" cable tie that is 3" long. The cable tie is pulled out with water proof bilge pump motor that winds up a string and releases the upper part of the bar clamp, dropping it onto the plate and securing the disc for its return to the surface.

The first attempt at plate retrieval was a modified Vex claw that frequently froze up during testing. This led us to explore other options eventually reaching this solution.

Cable tie holds clamp open while operator maneuvers ROV into place. Motor pulls strings withdrawing tie on command.

Six inch bar clamp by Bessey, purchased at Lowes for about $6.

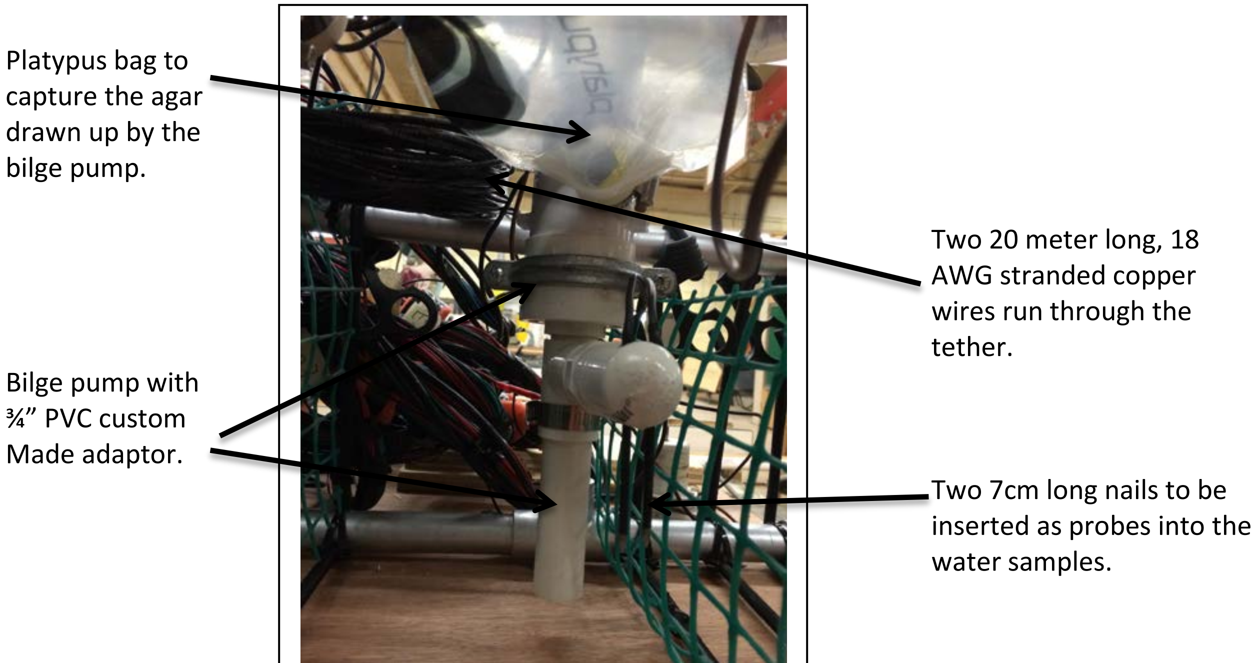
PVC frame designed to support collection tool firmly and protrudes forward of frame to allow operator to position clamp under plate without obstruction.

Plate Collector Tool

Design Rationale Continued

Conductivity Tester & Agar Collector

For testing conductivity of water, our company designed a tool using a multimeter, nails and wire. The multimeter is located on the surface and the two wires plug into the multimeter then travel fifty feet within the tether to the *Neptune EOS*. The tool on the ROV has two wires, each connected to a 7cm long nail, with the connections protected by heat shrink tubing. The nails are sealed in PVC pipe to prevent water from entering and altering the reading. The tool is placed on the bottom of the ROV so the operator can descend the ROV and insert the probes through the plastic covering and take a reading deep in the sinkhole. We actually designed the tool to measure the resistance of the water samples and compare the resistance readings to determine which sample is fresh water. The multimeter is set to measure resistance with an auto range function and the water with the most resistance will be the fresh water.



Conductivity Tester & Agar Collector

Collecting the agar was one of the most challenging aspects of the project. We designed several tools that failed in testing including modified test tubes, a mini claw and a custom auger bit. The final agar collector is a bilge pump outfitted with a ¾" PVC pipe that has been modified to fit in the inlet end. The pipe had to be machined in a lathe to reduce the exterior diameter by about 0.25 cm. The Platypus bag has 500 ml capacity, far more than the required minimum of 150 ml we need to collect. The two custom made tools have been combined in one location to allow a single camera to view both operations.

Design Rationale Continued

Control System

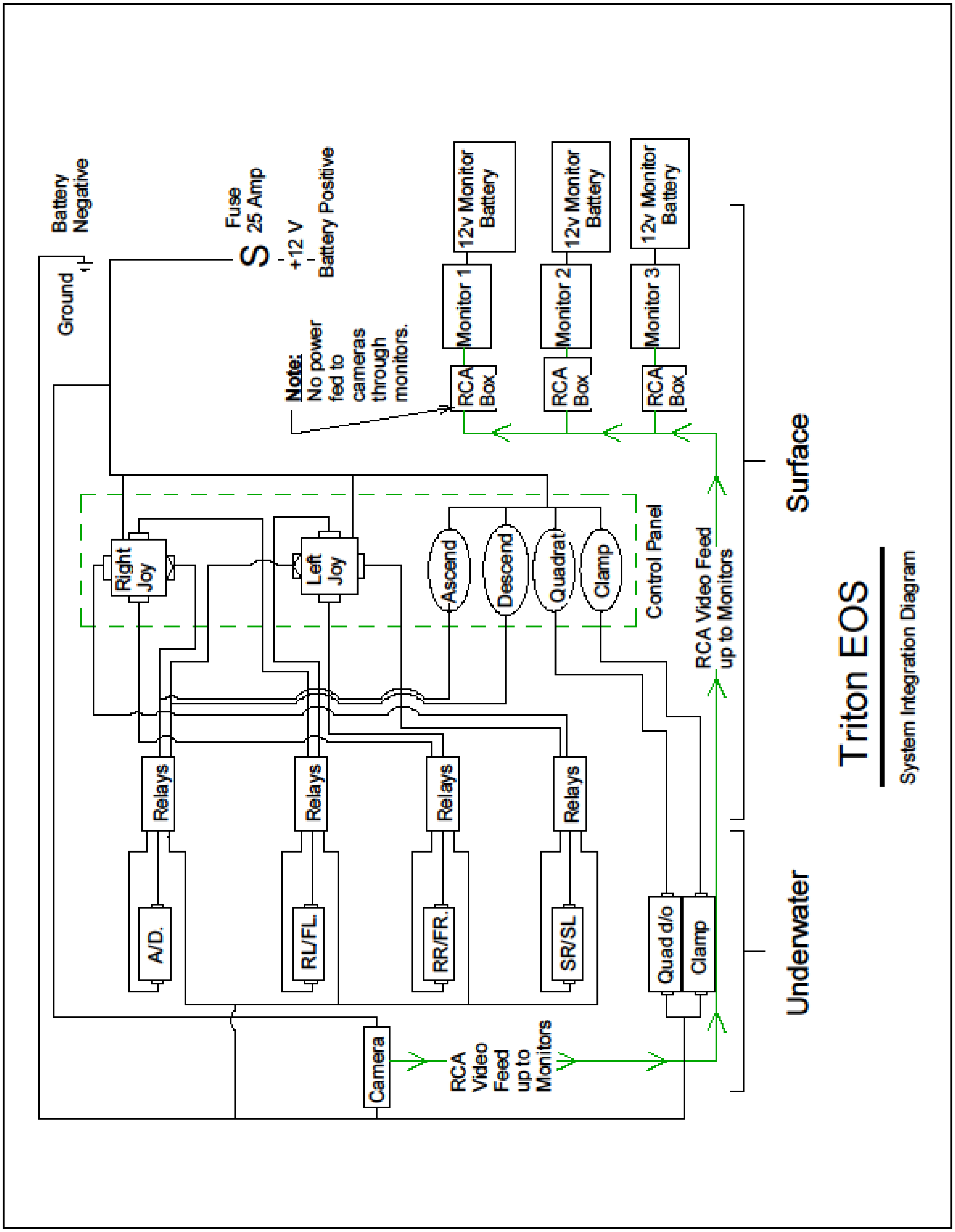
The control system for the Neptune EOS is comprised of two joysticks each with a pushbutton, a subpanel for co-pilot controls and a separate video monitoring systems with the ability to control 10 camera views across three monitors. The system was designed with analogue controls because of its reliability and ease of troubleshooting and on site repairs. For other projects we have used digital control systems and found the debugging process added precious time to our overall schedule. The analogue system proved reliable over repeated testing and when malfunctions occurred we had the tools on site to quickly diagnose and repair the problem. We do acknowledge this type of system requires a heavier tether and limits some control functions. However, we were able to overcome these challenges in our testing runs and ultimately concluded that the pros of an analogue outweighed the cons.

Neptune EOS Control System

Technical Skills

During the process of taking on this projects we acquired many technical skills including measuring with precise devices (including calipers and multimeters), designing with 3D software (Autodesk Inventor and Revit), and circuit design with Multi-sim. We also acquired practical manufacturing skills including accurately measuring and cutting materials, building boxes, pipes and small mechanical parts such as joysticks. Report writing skills, budget skills and scheduling were also learned and practiced throughout this process.

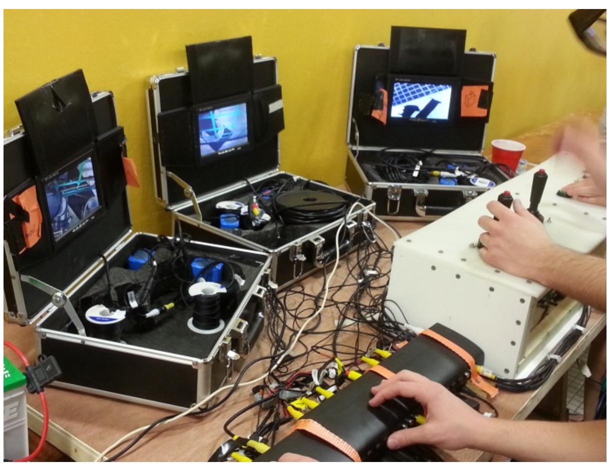
System Integration Diagram

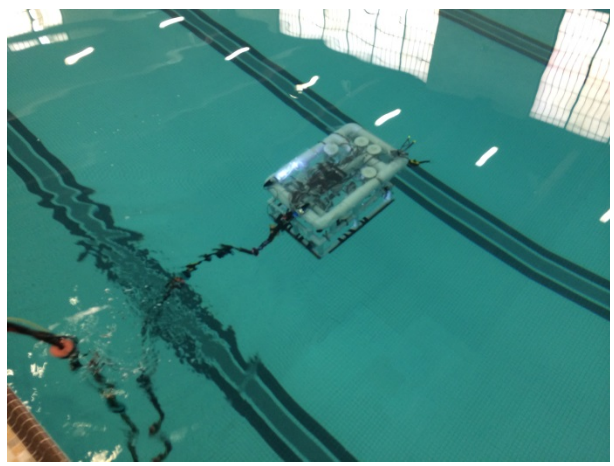


Troubleshooting

One of the steps we learned regarding the engineering design process was troubleshooting. We came to accept that at every round of testing we found items that needed to be improved. The question was always 'Why didn't it work exactly right?'. Troubleshooting is the process of answering this question. For electrical problems this usually involved using a multi-meter to perform some continuity tests to identify the opening in the circuit branch that powered a motor or ran a relay to change motor directions. In other cases this involved several layers following back the manufacturing process. Such as determining why propellers had fallen off the motors, usually due to too much vibration which is usually due to off center mounting, typically caused by stock not centered properly. We would use this information to return to step one in the design process then build it again, learning better design and manufacturing techniques along the way.

In the final stages we tested the whole ROV in simulated conditions. We built the mission props following the MATE guide available online. Brought the props to the YMCA and UMass Dartmouth swimming pools and tested the *Neptune EOS* under simulated conditions (including timing each task). We found areas for improvement every step of the way. Perhaps the most improved area of our performance is in our procedures for task completion. We realized that the most efficient way for us to complete the mission is not in the order listed as Tasks 1 through 3. Instead we group similar tasks together and find efficiency in fewer trips to the surface and completing tasks based on location. We minimize our time spent traveling from task to task by being flexible on the final order of operation for each run, allowing the pilot and co-pilot to take on tasks as efficiently as possible.





Testing revealed many areas for improvement.

(Task order procedures refined and tested many times.)

Vehicle Systems

We are very fortunate to have nearly all design and manufacturing capabilities required within our own building, therefore we use this advantage to build all possible components in house. Aside from stock materials (such as pipe and wire) we purchase only cameras, motors and switches. Every major system is designed and built by our company.

We buy bilge pump motors because in our opinion it takes too long to build effective motors in house. We also see the cost of the motors, approximately $45 each as being reasonable for the quality and durability. The motors are so durable that we also are able to re-use some motors from year to year. The cameras and monitors follow the same logic for us. We did explore the possibility of using web-cam cameras for the camera system, however building a custom waterproof housing was difficult and time consuming. The USB extension cables were expensive and experience signal degradation creating more problems. For these reasons, we purchased our cameras and monitor systems and because they are durable we can reuse them for several years.

Safety

Safety has become an important part of our company's day to day procedures. Our philosophy is that all accidents are preventable. At Triton Robotics safety is everyone's job. All members have the authority to halt production or testing to assure safe practices. Proper personal protective equipment (PPE) is required for all tasks, from safety glasses in the shop, to welding masks and gloves for specific process. We use PPE for all tasks and look out for each other's wellbeing. The *Neptune EOS* is equipped with many safety features including propeller shrouds, a positive buoyancy system that rescues the ROV in case of failure and a main system fuse to help prevent injuries. One incident that occurred during manufacturing was the activation of a propeller while someone's hand was close enough to make contact. Fortunately, it only resulted in a minor injury which was quickly attended to with a band aid. However, it led to a stoppage of work for the day because we had to reevaluate our safety procedures. The final result was a new step in our shop procedures that the vehicle battery had to be stored behind the teacher desk at all times until specifically signed out for testing and then promptly returned. We use safety checklists as part of our safety procedures before all test runs. See appendix A.

Challenges

While working on this project we encountered many challenges that needed to be overcome. One technical challenge we took on was creating a robot that was both agile and stable underwater. We built several large, heavy robots that were very sturdy during testing but clunky and slow to drive around. Then we built some light robots that moved quickly but were easily thrown off balance. We finally ended up with a medium size frame design, shaped like a cube and mounted the motors near the center of gravity so the thrust from the propulsion would not sway the ROV during movements. Another issue we encountered was finding a location to test our robot. We do not have an onsite pool, so we made contact with local universities and the YMCA. We now regularly test our robots at both the New Bedford YMCA and the University of Massachusetts Dartmouth.

Lessons Learned

On a technical level we learned many aspects of wiring, measuring, planning and designing that typical class lessons cannot adequately cover. We used Inventor to model 3D parts and print them in our 3D printer. This experience closely represents real world manufacturing procedures. However, the better lessons were in regard to the overall approach to problem solving and the power of people working together. The tasks in the project were almost overwhelming, but once we starting working together we realized our goals were well within reach. We look forward to working in teams in our collegiate and professional endeavors.

Future Improvements

In the future we will design our control systems with digital controls. We want to lighten our robot by reducing the number of motors and the tether thickness. To accomplish this we will need greater control of the propulsion system with lower voltage communications. We have been working with Arduino systems for other projects and will incorporate that type of system into our next project. We will overcome the technical challenges of employing a digital system by educating ourselves on the process.

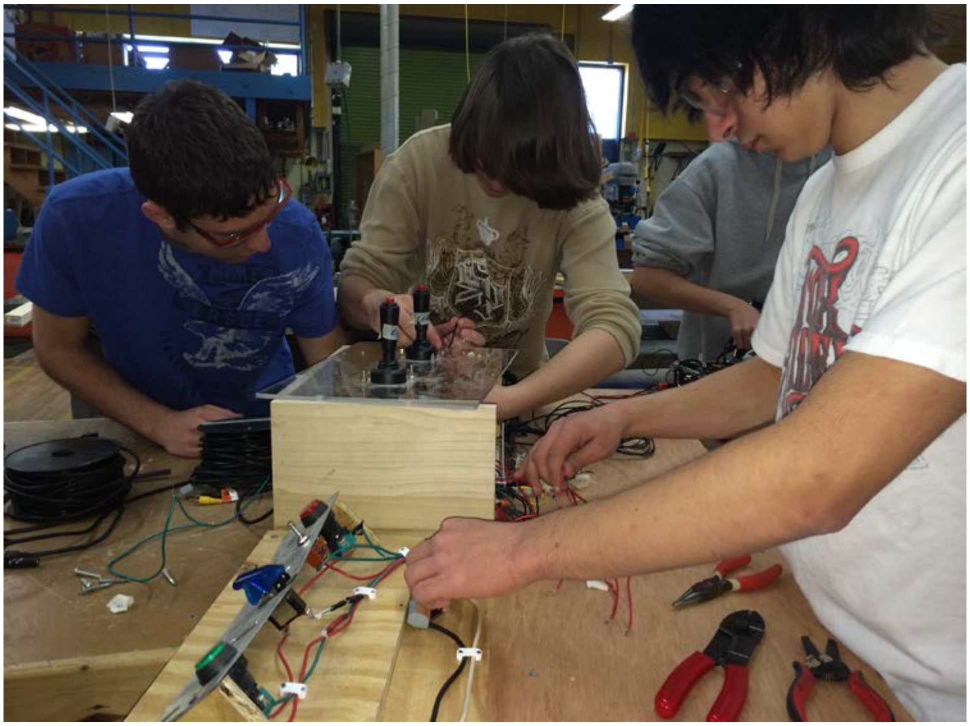
Reflections

As a team our most cherished accomplishment is how we came together over the course of the year to support each other in this process. We now know the value of teamwork and we look forward to working with each other again. Since the project started some of us have helped each other apply to college, apply for scholarships and get part-time jobs. We now see large tasks as possible if we break them down into smaller pieces, apply sound problem solving and work together.

Teamwork

Working together was not only the best way to complete this project it was the only way. We learned to help each other work quickly through the design process and move on to the next task. Morning meetings were held to review the updated list of tasks and teams were assigned to each task. Specific assignments with specific goals helped keep us on schedule. We used daily class presentations of our finished outcomes to motivate us to stay on task and not let the team down. We also created a schedule of the project and referred to it weekly to monitor our progress. See appendix B

Teamwork Continued



Team approach to problem solving.

Soccer was a common team building activity.

Teamwork Continued

Reviewing the technical report.
(We scored the technical report using the MATE score sheet.)

Celebrating the New England Regional 1st Place Result.

Budget

Neptune EOS Available Funds

Type	Description	Amount
1	Funding Provided by School Department	
	GNBVT Engineering Technology Shop	$ 3,000.00
2	Financial Donations by Local Businesses	
	Bernardo Engineering	$ 500.00
3	Fundraisers	
	Soccer Game - Fund Raiser	$ 200.00
	Total Available Funds	$ 3,700.00

Expenditures

Item	Description	Quantity	Units	Unit - Price	Cost
1	Bilge Pump Motors - Purchased	11	each	$ 45.65	$502.15
2	PVC - Pipe 2"	2.2	meters	$ 1.35	$2.97
3	PVC - Pipe 3/4"	6.9	feet	$ 1.28	$8.83
4	PVC Fittings - 2"	11	each	$ 2.78	$30.58
5	PVC Fittings - 3/4"	36	each	$ 1.89	$68.04
6	Bungee chords	6	each	$ 5.99	$35.94
7	Cameras- New - Color with 6 LED lights	7	each	$ 109.99	$769.93
8	Switches - Various types	6	each	$ 2.35	$14.10
9	Joy sticks - analogue with push button	2	each	$ 19.40	$38.80
10	Wire - 18 AWG - Stranded Copper - 500' Rolls	6	each	$ 59.99	$359.94
11	Bessey pipe clamp	1	each	$ 5.99	$5.99
12	Misc - Screws, cable ties, electrical tape.	1	each	$ 150.00	$150.00
	Total				$1,987.27

Value of Re-Used Items

1	Bilge Pump Motors - Re-used - value listed	6	each	$ 45.65	$273.90
2	Monitors - Re-used- value listed	3	each	$ 189.00	$567.00
3	Cameras- Re-used- value listed	3	each	$ 89.99	$269.97
	Total				$1,110.87

Total Final Vehicle Value

1	Purchased Items	$1,987.27
2	Re-Used Items - Value	$1,110.87
	Total	$3,098.14

Final Accounting

1	Project Budget	$ 3,700.00
2	Project Expenses	($1,987.27)
	Net Balance - Funds to be applied towards travel expneses to Alpena, MI	$ 1,712.73

Note: No items nor services were donated for this project.

Budget Continued

Draft of Projected Costs

MATE ROV Trip to Alpena, MI

- June 24 - 29
-9 Students, 2 Teachers

Item	Description	Unit Cost	Units	Quantity	Total Cost	
	Traveling & Logistics					
1	Flights - PVD - Gaylord, MI	$ 689.00	seat	10	$ 6,890.00	
2	Lodging - Hampton Inn, Gaylord, MI	$ 775.00	room for 5 nights	6	$ 4,650.00	
3	Meals - Per Diem (Gov. Services Admin. Rate)	$ 83.00	pp/day	60	$ 4,980.00	
4	Rental Car - 2 Minivans	$ 723.00	per van	2	$ 1,446.00	
5	Incidentals - Room Cleaning tip, parking, gas, etc	$ 50.00	per day	6	$ 300.00	
6	Team T-Shirts	$ 30.00	each	20	$ 600.00	
7	Shipping	$ 140.00	each way	2	$ 280.00	
8	Transportation between school and airport	$ 150.00	bus	2	$ 300.00	
	Projected Cost for Traveling & Logistics					$ 19,446.00

Note: School district to provide all funding for travel. No fundraising required. No donations required.
Final cost to be determined.

Acknowledgements

We would like to thank our department head Mr. Steve Walker for his support of our project. We would like to thank Bernardo Engineering for financial support. We would also like to thank our regional contest coordinator Mr. Christopher Jakubiak for organizing the regional event and MATE for coordinating the ROV competitions. And we also appreciate the help of Mr. George Morrison for allowing us the use of the New Bedford YMCA pool.

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Appendix A

Safety Checklist

1.0 Documentation				
Checklist Items	**Yes**	**No**	**Not Required**	**Comments**
Electrical schematics & power distribution diagrams	☐	☐	☐	
Technical report	☐	☐	☐	
Main fuse shown in electrical schematics?	☐	☐	☐	
2.0 Physical				
Checklist Items	**Yes**	**No**	**Not Required**	**Comments**
All items attached to ROV are secure and will not fall off	☐	☐	☐	
Hazardous items are identified and protection provided	☐	☐	☐	
Propellers are enclosed inside the frame of the ROV or shrouded such that they will not make contact with items outside of the ROV	☐	☐	☐	
No sharp edges or elements of ROV design that could cause injury to personnel or damage to pool surface	☐	☐	☐	
3.0 Electrical				
Checklist Items	**Yes**	**No**	**Not Required**	**Comments**
Single attachment point to power source	☐	☐	☐	
¼” Ring terminals to connect to MATE power source. Fork terminals should not be used	☐	☐	☐	
25 amp single inline fuse or circuit breaker within 30cm of attachment point	☐	☐	☐	

No power conversion before ROV	☐	☐	☐	
No exposed copper or bare wire	☐	☐	☐	
No exposed motors	☐	☐	☐	
All wiring securely fastened and properly sealed	☐	☐	☐	
Tether is properly secured at surface control point and at ROV	☐	☐	☐	
Any splices in tether are properly sealed	☐	☐	☐	
Surface controls: All wiring and devices properly secured	☐	☐	☐	

.

Appendix B

Gantt Chart

Project Name: 2014 MATE ROV										Designer:			Aaron Jesus						Date: 12/14/2013					
	Cycle 9			Cycle 10			Cycle 11			Cycle 12			Cycle 13			Cycle 14			Cycle 15			Cycle 16		
	Dec 13 - Jan 6			Jan 7 - Jan 17			Jan 21 - Jan 31			Feb 3 - Feb 13			Feb 14 - Mar 5			Mar 6 - Mar 18			Mar 19 - Mar 31			April 1 - April 11		
Task	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
Mission Theme																								
Research Thunder Bay	xxx	xxx																						
Identify Mission Taks	xxx	xxx																						
Build Props		xxx	xxx	xxx																				
Competition																								
Form Teams																								
Identify Team Roles				xxx	xxx																			
Deliverables/Milestones			xxx	xxx	xxx																			
Concept Design																								
Proposed Sketches		xxx	xxx	xxx	xxx	xxx	xxx																	
Decision Matricies		xxx	xxx	xxx	xxx	xxx	xxx																	
Solution Selection		xxx	xxx	xxx	xxx	xxx	xxx																	
Preliminary Material List		xxx	xxx	xxx	xxx	xxx	xxx																	
Detailed Design																								
Component Drawings							xxx	xxx	xxx															
Assembly Drawings							xxx	xxx	xxx															
Material List							xxx	xxx	xxx															
Vendor Selection								xxx	xxx	xxx														
Sequence of Operation								xxx	xxx	xxx														
Material Acquisition																								
Order Raw Materials											xxx	xxx	xxx	xxx										
Order Components											xxx	xxx	xxx	xxx										
Receive Materials												xxx	xxx	xxx	xxx									
Prototype																								
Fabricate Machined Parts														xxx	xxx									
Complete Electrical Controls														xxx	xxx									
Assemble															xxx	xxx								
First Prototype Completed															xxx	xxx								
Safety																								
Secure all loose connections															xxx	xxx	xxx	xxx						
Finalize Insulation On Wires															xxx	xxx	xxx	xxx						
Mark Dangerous Areas															xxx	xxx	xxx	xxx						
Test and Evaluate																								
Generate Test Procedure																	xxx	xxx	xxx	xxx				
Test																	xxx	xxx	xxx	xxx				
Analyze Data																				xxx	xxx			
Refine Prototype																					xxx	xxx		
Test Refined Prototype																						xxx	xxx	
Final Prototype																						xxx	xxx	
Presentation																								
Presentation Rehearsal																								
Formal Presentation																								
Documentation																								
Technical Report																								
Company Spec Sheet																								
Engineering Notebook																								
Poster Display																								
Major Milestones																								
Scheduled Task	xxx																							
Completed Task	xxx																							
Dependent Task																								