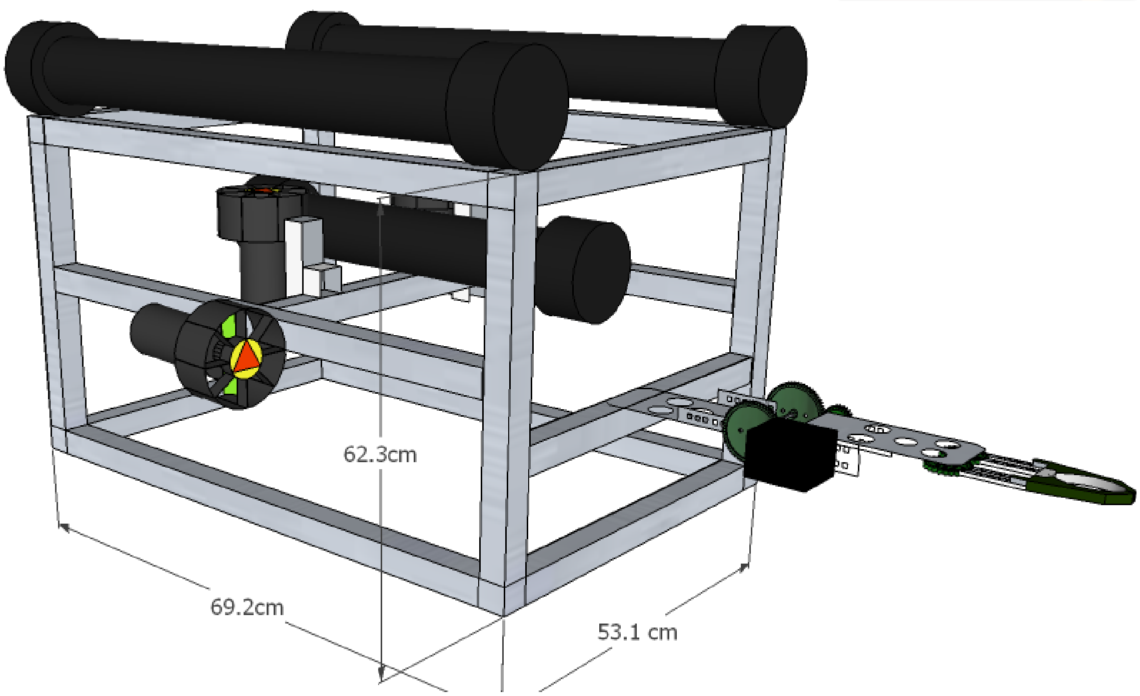
Tactical Research and Inspection Tool for Oceanic Navigation

AquaCard Inc.

Technical Report 2013

6/20/2013
Melvindale High School Robotics
Melvidale, Michigan
MATE International ROV Competition



Andrew Barron
Pilot
3rd year competing

Brandon Foster
Mechanical Engineer/Report
3rd year competing

John Felt
Electrical Engineer
3rd year competing

Nick Kean
CEO/Poster/Report
3rd year competing

"Innovate Today, Discover Tomorrow!"

Abstract

AquaCard Inc. has designed and constructed ROV *TRITON* to meet and exceed the requirements set forth by the 2013 MATE International ROV Competition. *TRITON* was constructed to move and remove various objects, as the competition is designed around the objective of ocean observing systems. ROVs are vital to the observation of the ocean. Now that meteorologists and scientists alike utilize the technology of ROVs to observe the ocean, ocean discoveries will dramatically increase in the following years. The particular mission set forth today includes tasks around a simulated Regional Scale Node (RSN) on the seafloor; this will simulate mapping the sea floor just like Ocean Observatories Initiative (OOI). Once the task of the RSN is completed the ROV will partake in the task of receiving a temperature every ninety seconds with a temperature probe. While waiting for a concise reading, the ROV can take part in replacing an Acoustic Doppler Current Profiler (ADCP) on a mid-water column mooring platform. Finally, the ROV must locate and exterminate biofouling organisms from the systems. The previously stated tasks will be accomplished with the use of the claw apparatus. *TRITON* will be able to complete the mission with a single dive, because the only attachment needed is the payload apparatus. It is a risk to use a new material that we had never worked with before; however our group decided to take on this obstacle and successfully constructed our ROV from durable aluminum. *TRITON* is fully functional and ready to take on the mission.

A professional example for an OOI RSN Primary Node Installation off of the coast of Washington
Made by: interactiveoceans.washington.edu

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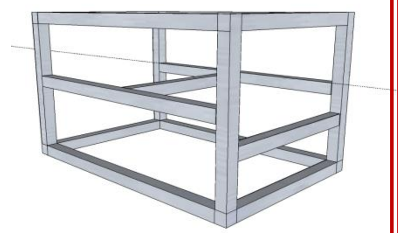
Design Rationale

Frame/Structure

TRITON's design is fully based around the versatility and durability that we have found to be essential in the overall operation of a ROV. We moved away from the flimsy and easily damageable PVC piping that we used to make the frames of our previous ROVs. Instead we used much sturdier and more reliable square aluminum tubing. This aluminum tubing offered much more strength to the ROV without adding extra weight, cost, or difficulty in building with our limited supply of machinery. The aluminum is also naturally resistant to corrosion and is safe for use in underwater applications. We used Esto connectors, which we screwed into through the frame to offer a sturdy hold between each of the pieces. This allowed for the frame to be both adjustable if needed and completely sturdy.

The shape of the ROV is meant to offer versatility in any application that we use it for. The basic square design leaves a lot of open space both inside the frame and on the outside for future attachments. This versatility has proven to be exceedingly vital in many of our previous designs as well as in *TRITON*. On many occasions we have faced a situation in which a quick attachment was needed to complete a mission. The versatile shape of the ROV has allowed for these quick fixes, which would be much harder to do on complex systems. The cross bars in the middle of the design offer both support and attachment points for the thrusters of the ROV. This



Student CAD of Frame

Working on the Frame

is one of the best examples of versatility and durability coming together in *TRITON*.

Cameras

The optical system onboard *TRITON* is composed of three separate cameras: one that is color and two that are black-and-white. The cameras are all on the front of the ROV and offer a wide variety of viewpoints for the pilot. The main forward facing camera is one of the two black-and-white ones. It offers a general driving view for basic maneuvering and control. The second black-and-white camera is used to scan the floor of the body of water or to view objects underneath the ROV. This camera is vital to completing missions in which you must remove objects from the floor or from areas far below the ROV. The single color camera gives the most important angle that the cameras offer. Tilted at around 45 degrees downward towards the claw, the color camera provides a both a navigational view and a functional view for the claw itself. Without this camera, one of the main components of our ROV's design would be hindered drastically. The other two cameras, however, are placed in a way that would offer a view that would still allow continued operation even with the failure of the color camera. Although it would not be quite as simple, the ROV could still complete the mission with this vital camera malfunctioning. We made sure that *TRITON* is prepared in case of any situation that could cause major problems with important systems onboard.

Color Camera

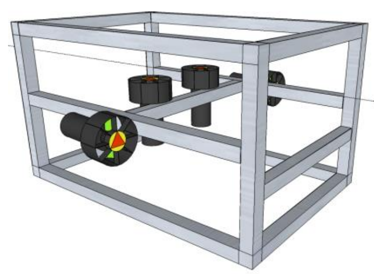
Black and White Camera

Thrusters

Since discovering the SeaBotix BTD-150 thrusters in 2010, the AquaCards have never wavered from their use. The BTD-150s provide a powerful thrust capacity while remaining relatively lightweight and small in size. Each thruster is capable of a max output of approximately 28.4 N, with an average continual output around 21.6 N. This force comes from a thruster that is only 17 cm long with a weight of 350 grams underwater. *TRITON* is equipped with four of these durable and well-suited thrusters; two for vertical adjustment and two for propulsion and control.

The positioning of the thrusters is designed to offer the highest performance as well as the most efficient output when working together. By placing the vertical thrusters equidistant to each other and in the center of the ROV, the vertical motion of the ROV is ensured to be smooth up and down without any swaying or rocking that would throw off the precision needed to complete the missions. The propulsion thrusters are also placed in the center of the ROV in regards to both height and length. Placing them in the center of the length of the ROV is another way to keep it from rocking or swaying when moving. Keeping them in the center of the height allows the move forward and backward without additional vertical motion other than that controlled by the vertical thrusters themselves. This specific placement of the thrusters makes sure that the only movement of *TRITON* comes from the manipulation by the pilot.

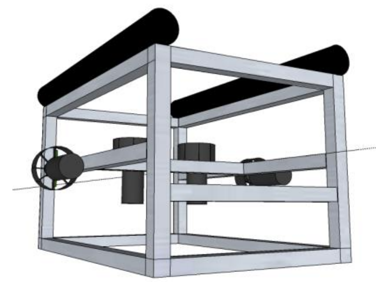
Sea-Botix BTD-150 thrusters



Student CAD of Frame with thrusters

Buoyancy

Three sealed PVC tubes offer all of the buoyancy control for *TRITON*. There are several small holes drilled into every component of *TRITON*'s frame to ensure that the water distribution inside is even and happens quickly. These holes exempt the frame from being a factor in the overall buoyancy of the ROV. The three tubes are cut to specific lengths to offer the correct volume of air that allows the design to remain almost completely neutrally buoyant underwater. This relatively neutral buoyancy allows for easy navigation of the ROV. The tubes are sealed with PVC cement and do not allow any leaking into the tanks that would throw off the overall buoyancy. Each tank is placed in a specific location to remain out of the flow created by the thrusters. In early designs the tubes were getting in the way of the propulsion and lowering performance. The current positioning allows for the thrusters to remain uninterrupted and the buoyancy tubes to still work effectively.



Student CAD of Frame with Buoyancy Tubes

Buoyancy Tubes of *TRITON*

Payload Device

One of the most important aspects of TRITON is its claw and wrist unit. This unit provides a mechanism for transportation, placement, and removal of various objects in a wide range of size and weight. It also controls many of the attachments used for the missions, such as the temperature probe used to take the temperature of the water at set time intervals. The wrist unit allows the claw to have vertical movement along with the clamping motion that it originally has. This vertical movement allows for versatility in the claw that many other ROVs do not have. This movement makes it possible to adjust the positioning of the claw and objects in its grasp without the more difficult movement of the entire ROV itself. It is this variance in design that sets TRITON's claw apart from those around it. With the added reinforcement to the claw this year, it is able to withstand much heavier loads and handle a much more efficient workload. The claw and wrist are the heart of the operation provided by our ROV and offer one of the best performances of any other system in their class.

Payload Device of *TRITON*

Control System

TRITON is equipped with a neutrally buoyant 18 m tether, which provides power to the thrusters, claw, and wrist as well as the feed from the three onboard cameras. The tether is comprised of six separate wires, bound tightly together to make sure that they do not interfere with the operation of the ROV itself. The length of the tether allows enough length to complete the missions with no restriction, but also is short enough to be easily transported.

Control Box of *TRITON*

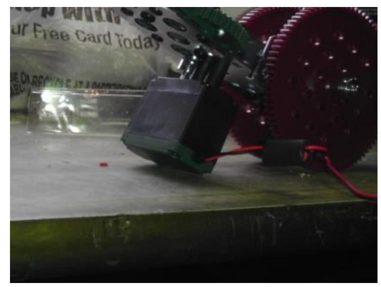
The tether runs from the ROV up to the personally wired control box. The electrical system was all done completely by our group alone and does not include any commercial wiring. Every connection within the box is soldered and heat shrink-wrapped to ensure that the wiring is safe to use for the pilot; this method of connecting the wires is used throughout the ROV and offers a safe and effective way to accomplish the wiring. The control panel is comprised of two separate boxes. The larger of the two controls the thrusters. It uses four momentary DPDT switches to control all navigational aspects of the ROV. The smaller box uses two of the same switches to control the opening and closing of the claw as well as the vertical motion of the wrist. These boxes are encased in a larger box to keep them organized. Each switch is also labeled so that, in case of emergency, any one member of the team could easily take over maneuvering the ROV. This box allows for a very simple, yet accurate controlling mechanism for the operation of *TRITON*.

Soldering TRITON's connections

Safety Precaution sticker on thrusters

Safety

Customer and product care is AquaCard Inc. highest priority; the vehicle must exhibit how our company runs. With a disordered ROV it will only make our company look corrupt and downgrade ourselves with it. That is why while constructing *TRITON* safety was our main concern. The thrusters are SeaBotix BTD-150 which comes "safety-ready" to our standards. These thrusters come with metal motor guards, which cover the blade and direct water flow. In addition to those factors the SeaBotix BTD-150 also comes will mounts, placed on each side of the thrusters which gives the thrusters diversity to be mounted anywhere; on top of that it ensures that the thrusters will not fall off during operation. Electrical components are an enormous obstacle with building an underwater ROV. All electrical equipment must be completely soldered, heat shrunk or sealed with silicone sealant, and then finally electrical taped. To ensure electronic safety, AquaCard Inc. has included a 25-ampère fuse in line with all electronics. If the ROV draws excessive current, the fuse will blow, protecting the circuits from the short and anybody who could potentially be injured by such a catastrophic event. Even with those electrical precautions AquaCard Inc. makes sure that each wire will not interfere with another wire or the propellers. The frame of *TRITON* is connected with Esto connectors which have rounded edges so nobody is in risk while touching *TRITON* Safety is AquaCard's first priority and *TRITON* is a prime example!

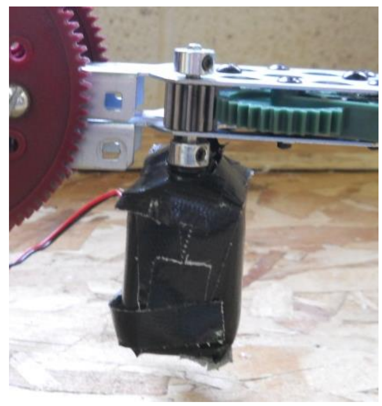


Waterproofed Servo Motor

Challenges

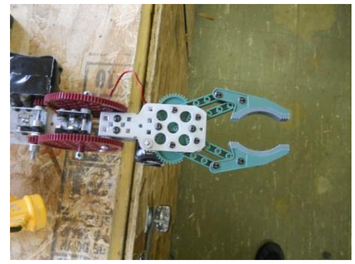
Every year the AquaCards team faces setbacks that could prove to be catastrophic to the operation of the ROV. In the past these problems have ranged from broken cameras to electrical failures and even a fractured frame. Not once, however, have we given up before the burden was fully resolved. This year, two major conflicts arose that could have meant disaster for our team and the competition.

The first of these two problems was the waterproofing of the servo motors that control *TRITON's* claw system. This is a problem that we have faced throughout our careers in MATE. We attempted to use countless methods of waterproofing, yet our success with them had been less than satisfactory. That is until this year, when we finally found a way to keep the water from destroying the system. The method that we were using most recently - a type of window sealant silicone around the openings of the system - had the highest success rate of any of our methods, but was still failing after around twenty dives with *TRITON*. This we attributed to the weakening of the silicone after being submerged for long periods of time. We continued to research waterproofing methods and happened to find two products that we had not found before; marine electronics grease and a different type of automotive silicone. We filled the empty cavity of the servo with the marine grease and then sealed the openings of the covering with the new silicone. The method worked flawlessly. It has provided a watertight seal to the system, which has now completed over thirty dives without any signs of water damage or failure.



Metal gear equipped within payload device

Completely damaged systems are the absolute worst failures that can happen to an operating ROV; this is especially true in the middle of competition. At the Great Lakes Regional competition in Alpena, Michigan, the AquaCards faced the worst failure of a system that has happened to date. The gear that mainly controls the claw apparatus on the front of *TRITON* snapped as we were testing the systems immediately before the beginning of our first round of missions. We replaced the gear for the next run with a metal gear that we had as extra, but another problem presented itself. As if one failure of the system was not enough. During the first minutes of the second attempt the spring in the system also snapped. This happened because the pressure of larger objects was becoming too much for the device. Each of these damages caused *TRITON's* claw system to work at about half of its full capacity. Luckily, in each situation our pilot was able to remain calm and complete the missions as best as he could without a fully functional claw, yet we knew we needed to improve the claw for the next competition. This we have done through the reinforcement of the claw itself and the addition of new attachments to help support the heavy payloads that it is required to carry. The reinforcement of the claw allows for it to withstand the pressures of heavier objects, allowing for less stress on the driving gears and spring. Along with this, the new attachments, such as the hook directly underneath the claw, allow for reduced stress on the system as well. They transfer the pressure from solely the claw to the much sturdier frame of *TRITON*, providing a much better distribution of stress throughout the system.



Broken Payload Device
(will not shut all the way)

Troubleshooting Process

#1
- Acknowlege the problem

#2
- Identify system causing the problem

#3
- Hypothesize the solution

#4
- Attempt solution (may need to repeat this step, if unsucessful)

#5
- Test the system and make sure there is no hesitation upon proceeding

#6
- Establish that problem is not existent and carry on

Lessons Learned

The AquaCards family has always been a small group of tightknit friends. From the very beginning we have had outstanding teamwork and dedication from each of the members on our team. However, over our three years as a team, we have had one problem that has really caused some troubles during competition and even just in practice. That is, a lack of clear communication amongst the members of the team. That is why one of our main goals this year was to improve our communication and get down a system where we could easily understand directions and work cooperatively during competition.

As we began our design of the ROV, we immediately started to work on the communication that we knew would be vital to success in the competition. From there on we saw improvements in efficiency and a lot less stress amongst the members of our group. We saw incredible improvements in the running of our missions as well. The speed at which we were getting the missions completed had increased exponentially, and it was not just from the new ROV. This enhancement of our team was most prevalent throughout the regional competition. In previous years, as one would watch our team compete, an excess of yelling, fighting, and blame could be seen being passed around as we were trying to complete the mission. This year, however, our team remained calm and collected as we competed. We could easily understand directions and there were a lot less mistakes being made due to our improved communication. Even when things went wrong, we were able to calm each other down and keep focused on the mission at hand. We picked each other up after tough situations and were able to keep going when it seemed our luck was out.

The lesson we learned most from our experience in MATE this year is very simple. Even if you were to have the best machine out there, if you do not communicate you will not get very far. Communication is key, as the old saying goes, and for us that was the most important lesson we could have learned. There is no class to teach this, or a book that you can study; it is a skill that must be acquired through the cooperation of a team and the dedication to improve.

Future Improvements

Although this is the last year of competition for this AquaCards team, there are a few things that we would improve if given the chance. Our team has always wanted to have an improved control system, but without proper funding we were always at a loss to do so. Given the opportunity to return, I believe this is where we would have focused on next. There are vast amounts of control systems that we could use. For all of our previous ROVs, as well as *TRITON*, we have used a simple box control with momentary DPDT switches. This system has allowed for a nice control of the unit, but has made it challenging to make fine, precise movements that would be nice for saving time in the missions. We focused a lot on the design and structure of the actual ROV this year, and did not get a chance to work on an improved system for control. Another improvement that we would make to a future ROV would be neater tether. The tether we currently use is a combination of three different wires along with the wires for the cameras. In the future we would try to find a wire that contains enough connections for every system onboard the ROV or cover these wires in a rope or other form of ordering technique. This would simply allow for easier spooling of the tether and a more convenient way to store the ROV. These improvements would allow for both a smoother operation and easier transportation of the device.

For next year, we hope to incorporate the following items:

Team Reflection

The past three years in the MATE competition have provided some of the most unique experiences that this tiny group of five students from the little city of Melvindale, Michigan will ever experience. If someone had told us that we would go to an international competition twice in our high school careers we would have laughed at them. Coming from such a small city, we could never have guessed that we would have such and incredible opportunity. Starting off as a group of four sophomores without even a pool at our own school, we dove into an entirely new concept for all of us. We learned how to construct, wire, and compete with this ROV that we had never heard of before. That first year we stood on top of the leaderboard at the regional competition for the entire day only to watch our score drop two places by the last two teams; out of internationals. However, this did not discourage us. The next year we added a team member, and our new group of five juniors took home first in the regional competition and flew to Florida for our first international journey. Eighth place with a third in the mission was not a bad finish, considering how different the international competition was from the regionals we were used to. Now we find ourselves here, our original group of four, now seniors ready to stand strong at the international competition and take home first place. As we mentor the new wave of AquaCards for the future, we must prove to them and ourselves that you can start anywhere and finish strong. *TRITON* is unlike anything we have built before and completely ready to stand up to the competition from around the world and hold its own against them. It is hard to describe just how important this experience has been on our lives. There is no telling what it will do for our school in the future, and what it will mean to all of us. We are all incredibly grateful to have made this journey.

Ambassadorship

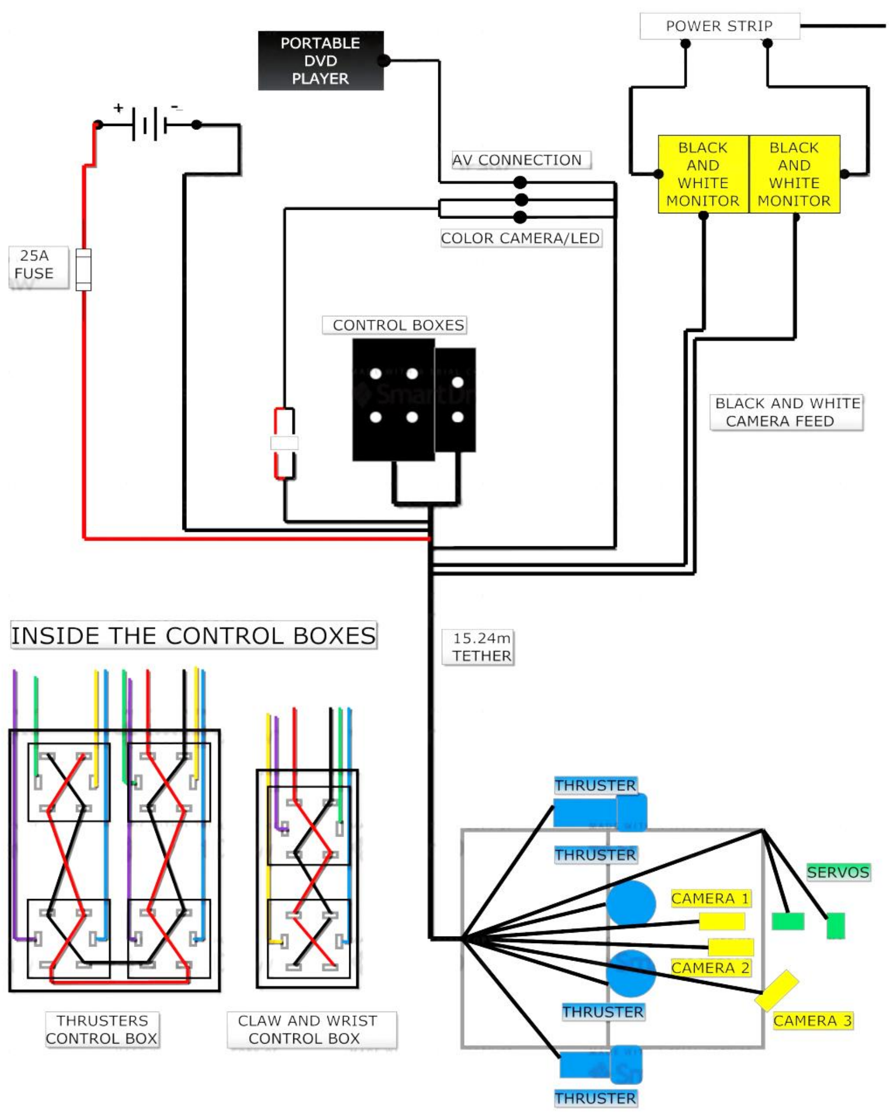
Ambassadorship is a great factor in our program. We want the younger generations to get involved early, so that they have the same opportunities. We recently went to Allendale Elementary School (the elementary in our school district) to get the young kids interested in our program. In addition to Allendale Elementary School we had a presentation at our own school, for eighth grade orientation. Surprisingly, most of the kids showed countless interest into the program. To us that was very inspiring to know that, no matter how old you are, you can show an interest in innovated designs. In addition to that school district we also showed ambassadorship within Oak Park Schools. The Oak Park Middle School is a local school who in which we share a pool with and they are there when we practice, since they are new to the program they have a lot of questions. We are more than content to aid them with any questions that they have. It is inspiring to know that you have helped a younger individual that has the same inspiration you have, to innovate and discover. Over the course of the winter we also visited another school, in which we presented at this one being Alpena Middle School. While up in Lake Huron searching for sunken ships we decided to pay a visit to a friendly competitor and collaborate with them to possibly assist them in their needs. All this may sound like a lot but we still want to do more for our community that is why we are creating a program this summer at our local pool. This program includes children doing activities to learn the basic concepts of an ROV, such as, filling a water bottle with vegetable oil and then attaching weights to understand buoyancy in fun, yet simple way. We hope to expand this program so we can get as many individuals in this ROV program as we can. The younger generations control their futures and receiving a head start is always astonishing.

Acknowledgements

We will now like to take some time to acknowledge some of the people who helped us during this ROV experience. The following people I would also like to thank: all the volunteers who in which volunteered their time to help with the competitions, Sara Waters for hosting the Great Lakes Regional Competition, Oak Park Public Schools for allowing us to use their pool, Melvindale High School for supporting us, Mr. Thomas for mentoring us, and all the parents who have supported us. In addition to those we will like to thank our donation providers: Melvindale Teachers, Melvindale Hardware, and Weast Financial Group. To these people we generously thank and we couldn't of done it without you. To the MATE Center we show our gratitude to you for providing us with this great opportunity. MATE Center makes dreams come true, at least ours. Thank you to all listed.

Electrical Wiring

Electrical wiring is a vital key for full operation. Below you will see our electrical schematic of our ROV, *TRITON*. This ROV consists of momentary DPDT switches with a simple yet, successful design. You will see that we do indeed have two control boxes: one for the claw and wrist operation and the other for the thrusters operation. We can either use a portable DVD player for our viewing or any TV or monitors with AV cables. The black and red wires you see within our boxes are to transport the electricity, while the colored wires are used to send the current to that specific system depending on which way the polarity switches are turned. We use a 12V battery box, as well as a 25A fuse to ensure safety upon the system's current.



Budget and Expenses

Item	***Quantity***	***Cost Per Unit***	***Total Cost***
ROV CONSTRUCTION			
Aluminum 6ft Square Tubing	5	$14.24	$71.20
Esto Connections	14	$1.50	$92.20
Seabotix BTD-150	4	$500	$2,092.20
Vex Robotic Arm	1	$54	$2,146.20
Submersible Black and White Camera	2	$79	$2,304.20
Submersible Color Camera	1	$99	$2,403.20
1.5" PVC Tubing	2	$4.32	$2,411.84
2" PVC Tubing	1	$5.42	$2,417.26
#36 Hose Clamps	6	$1.29	$2,425
Stainless Steel Tek Screws	1	$3.49	$2,428.49
Stainless Split Lock Washers	1	$2.33	$2,430.82
CONTROL SYSTEMS			
12V Battery	1	$43	$43.00
Project Box	2	$6.55	$56.10
25A AGC Fuse	2	$1.59	$59.28
4mm Male Banana Plugs	1	$3.19	$62.47
MISCELLANEOUS			
Electrical Tape	2	$1.99	$3.98
Solder	1	$5.64	$9.62
		Total	$2,502.91

TRAVEL			
Air Travel	5	$106	$531
Hotel Rooms (two each night)	6	$175	$1581

DONATIONS			
Weast Financial Group			+$2,000
Melvindale Federation of Local Teachers			+$500
Melvindale Hardware			+$50
		Grand Total	-1533.91

**The excess of the cost will be either handled by donations within the next 4 weeks or will be spread upon the group members