AquaTech Innovations

Naperville North High School

Naperville, Illinois

Members:

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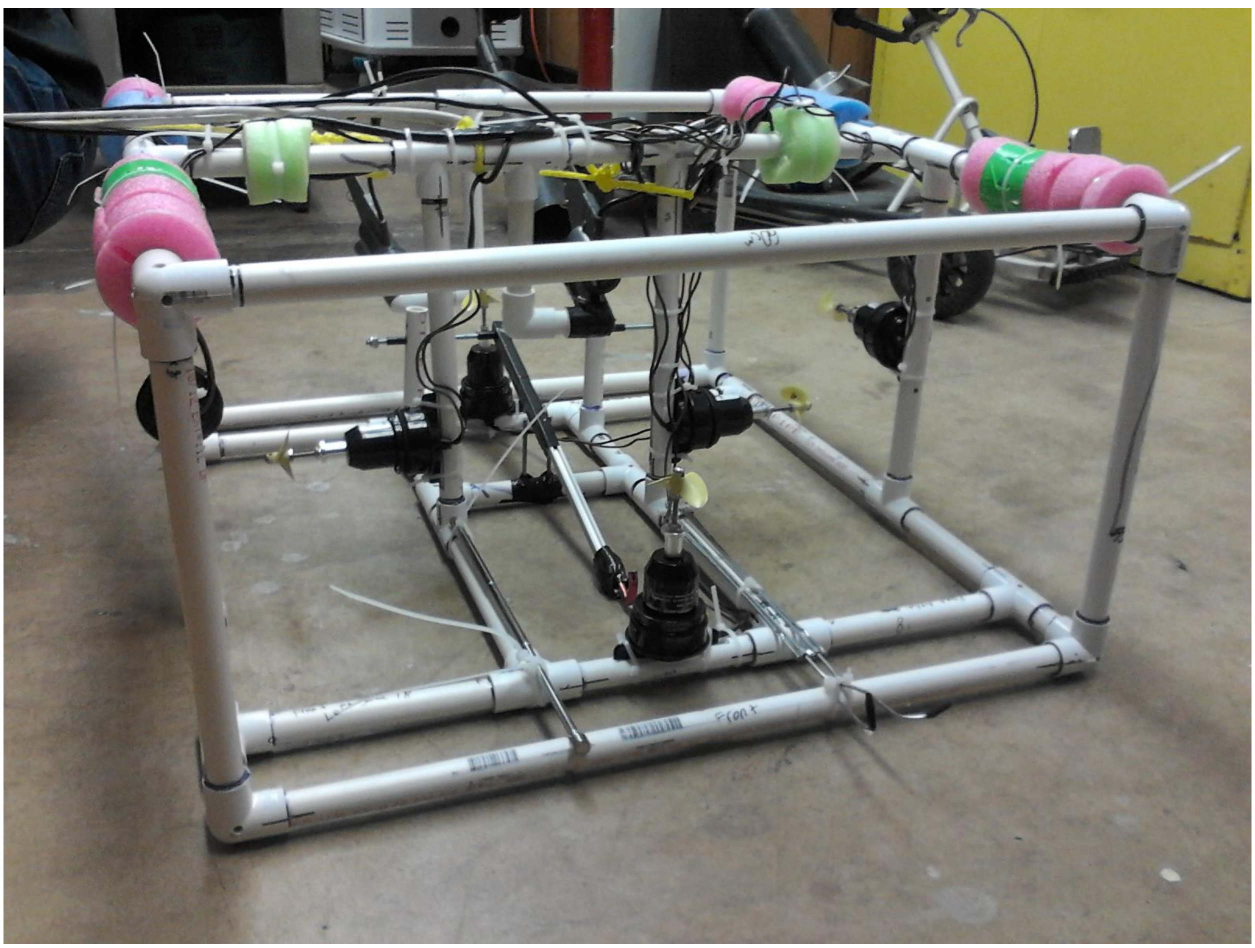
Mentored By:

Mark Rowzee	Physics Teacher / Robotics Coach



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Abstract

AquaTech Innovations aims to provide the most effective and efficient means for conducting research in depths that humans cannot reach via ROV. We continually seek to improve our products and services every proceeding year. Although we are a young company, our employees excel in their respective disciplines and come together to create the most maneuverable and highly functional machines at a low cost.

Our goal is to maximize machine quality and minimize cost. Due to our specialized roles and consistency in construction technique and safety checks, we are able to achieve this standard for our customers.

Our final product ROV this year, SEAker Agility-6, is designed specifically to aid in observations at the ocean's base. The six bilge pump motors combined with the frame's bilateral symmetry make SEAker Agility-6 one of the most maneuverable machines available. It is able to quickly survey the entire observatory as well as ascend and descend with ease. What makes SEAker Agility-6 especially efficient at the tasks presented by the observatory are its three unique hooks: hanging, lateral, and vertical. In addition, SEAker Agility-6 is equipped with a drive camera as well as a work camera for optimal viewing of location while also being able to complete tasks. While the hooks and cameras are simple in design, their abilities are far from lacking. The three facings of the hooks and two available views of the camera allow SEAker Agility-6 to effortlessly operate all machinery at the observatory.

Safety

As safety was our top priority during the construction and operation of our ROV, we exercised great caution while building. During the building phase, we made sure to always use safety goggles. When gluing we made sure to always work outside or in well ventilated areas.. We only operated power tools and machining tools when under the close supervision of our engineering mentor, Mark Rowzee, and the only members who operated these tools were those who had prior training and experience.

When operating the ROV, we make sure to keep our power sources disconnected whenever the ROV is being handled. We only connect the power sources while the ROV ison deck when we needed to do a systems check of the electronic components, and this is only takes place after every team-member is made aware that a systems check is taking place and they need to keep their hands clear of the ROV.

Our ROV also contains many safety features. In addition to waterproofed electronics, our design also features a frame that completely encloses all six propellers. All sharp or pointy edges are fully wrapped in tape to ensure the safety of handlers and divers. Furthermore, our propylene tether rope is shorter than the electrical cables that are secured to it, so if our system were to fail in such a way that required us to remove it from the water using the tether, no tension is put on the electrical wires.

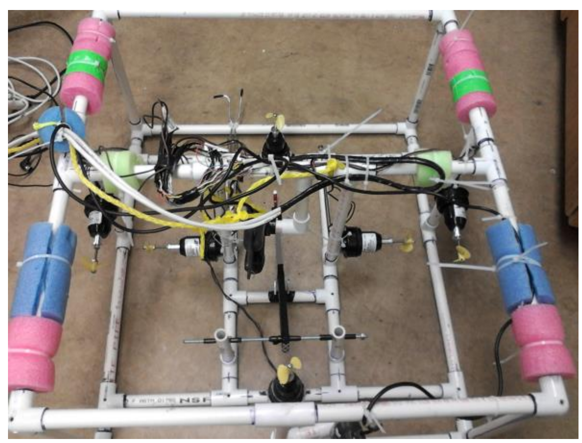
Design Rationale

Frame

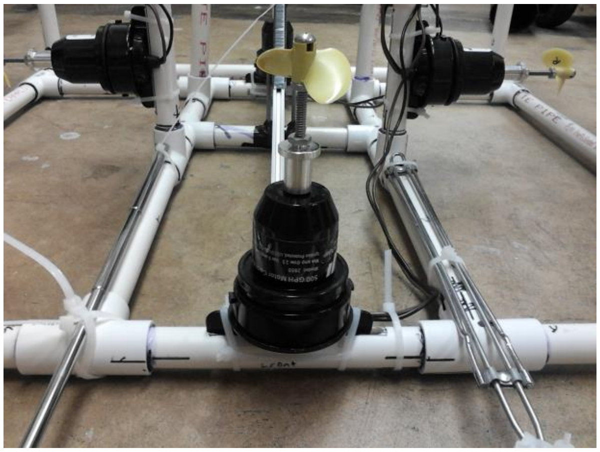
The design of our ROV was centered around several key aspects, including shape, modulation, and function. Ultimately the rectangular prism was the shape best equipped to address all of these points of interest. To prevent injury or damage, the motors were placed completely inside the frame perimeter, which was achieved due to the symmetrical shape and vacant area between structural members. That same openness in design provided for unobstructed views for our cameras to monitor the functions of the ROV. It also allowed for adjustable positioning of hooks and claws to complete various missions. We included a central cavity on the bottom of our frame to accommodate a hook attached to a swinging arm mounted from two pillars inside the frame. Ultimately this design was chosen for the many possibilities for component placement.

Motor Placement

Our design includes a 6 motor set-up, with each pair of motors performing specific and unique functions. The main driving motors are mounted orthogonally to vertical pillars at the edge of the frame. The motors are mounted slightly in front of the center such that the propellers will provide thrust at exactly the centerline. The radius from the center of the ROV to the motors is maximized to provide for a large torque around the center point provided by the thrust force of each motor, thus facilitating turning.



We learned from the 2012 MATE ROV competition that the ability to strafe would have been extremely beneficial for completing tasks. Having 2 motors dedicated to strafing allows the ROV to maneuver around objects without having to turn. This process allows us to always have the objects in our frame of view. The strafing motors are each mounted to vertical pillars on the centerline of the ROV, with each motor facing outward while still wholly contained within the frame. The low placement keeps these motors from interfering with our main driving motors and provide a stabilized distribution of forces. Both of these motors are controlled by only one switch as they would never need to operate independently.



The vertical motors are used to control the depth of our ROV, allowing it to quickly ascend to the ocean floor and ascend back to the surface. These motors are aligned lengthwise, with one in front and one in back. This allows for the ROV to pitch forward or backward when the motors are spun in opposite directions while still preserving symmetry and center of buoyancy. Additionally, we kept our center of balance high by mounting these motors to the bottom of the frame, to minimize the chance of the ROV flipping over while underwater.

Attachments

The design of the attachments was driven by examination of the specific details of the missions. It appeared to us that a large quantity of the tasks involved the general movement, manipulation, or transport of various objects, such as the SIA, the CTA, the OBS, the ADCP, and the hatches on the BIA and the water column mooring platform, as well as various pins that hold these objects in place or power sources that must be removed or replaced. This led to our decision to include several specialized hook attachments on the ROV.

The most prominent hook is attached to an arm that hangs below the ROV, but is free to swing upward into the ROV for positioning along the ocean floor. This hook distributes the weight of its load near the center of the ROV to maintain to center of balance even with its payload. This hook is intended for transporting the SIA, the OBS, the ADCP, and removing biofouling.

Also attached is a dual-hook to the front of our ROV. This was constructed by modifying a double pronged roasting skewer so that the prongs are oriented perpendicularly towards the left and upwards. The tip of each hook was thoroughly wrapped in electrical tape for safety, which additionally also provided a better gripping surface due to a higher coefficient of friction. These hooks are intended to manipulate small objects, such as the CTA, the OBS pin, the OBS cable connector, bulkhead connector, as well as opening and closing the hatches of the BIA and the water column mooring platform.

Camera Placement

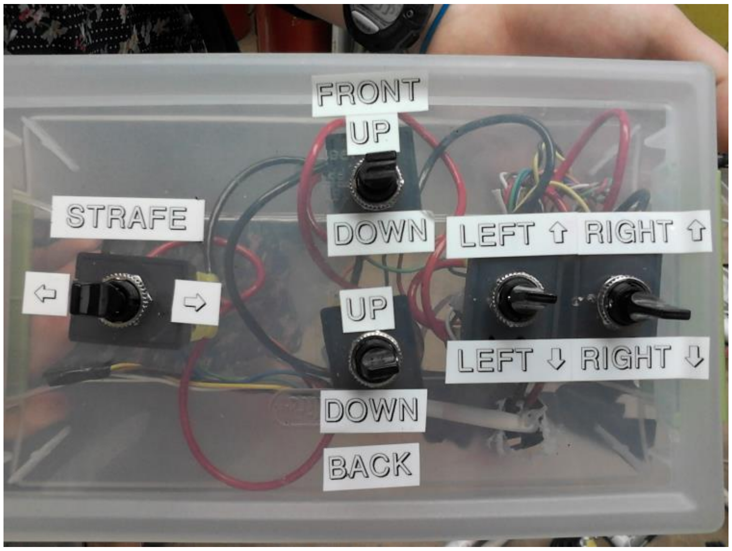
Our design relies on two cameras. The position of the primary camera was chosen to have a relatively clear frame of view that could be used for driving, surveying the area, and operation of the forward attachments. This camera was placed in the center of the ROV, facing forward and angled slightly downard so that the frame of view included our dual hook and magnet. Our secondary camera was placed at the back, offset to the right, and angled downward as its sole purpose was the manipulation of the hook-arm and its payload. We felt that it was necessarry to have a camera devoted to this purpose so that we did not have to compromise on visibility when driving and opperating the forward attachments.

Buoyancy

Holes drilled in the frame of our ROV allowed it to quickly fill with water when submerged, and drain quickly when brought above the surface. This seemed much easier and more reliable than trying to keep it airtight, where small leaks could cause it to gradually fill with water over time, altering our buoyancy. We attached pool noodles to the frame and tether to counter the weight of the motors, and attachments. Most of the flotation is attached to the top of the ROV, positioned far apart to the left and right, running lengthwise to limit the ROV's ability to inadvertently roll to the side, while preserving the ability to pitch forward or backward.

We also included a substantial amount of flotation near the base of our tether to ensure that the tether does not descend within the frame of the ROV, where it could become entangled with the motors. This is a very important safety precaution because otherwise, the motors could potentially damage the wires and controls, or jerk the tether downward, potentially injuring the tether operator.

<u>Control Box</u>

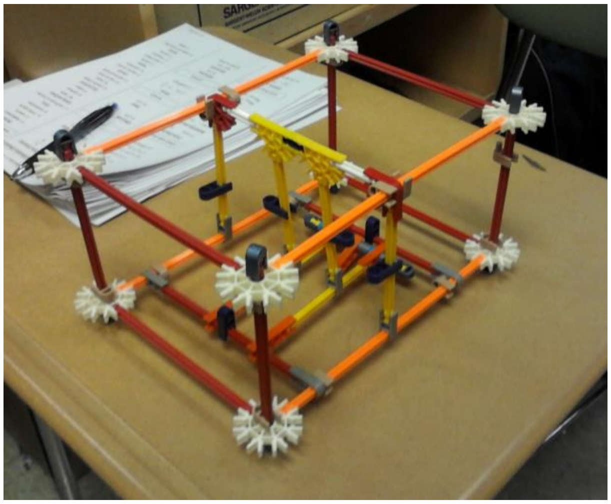


Our control box is constructed from a plastic storage bin. Because our ROV had six motors, we decided it would be easiest to design a control panel that could be operated by 1 pilot and 1 copilot. With the exception of the strafe motors, each motor was given its own independent switch that could spin the propeller in either direction. This gives us a great deal of control over our watercraft by allowing us turn in place or pitch forward or backward by spinning motors in opposite directions. The strafe motors, however, are each wired to one switch because there is no need for them to be independent of each other. Ultimately our ROV was designed to keep in mind safety, stability, and mission. Every component comes together to jointly address all the issues that compose this competition.

Challenges

Our first struggle was working together effectively with such a small, inexperienced team. Of our six current members, our design engineer was the only member who had prior experience from competing in the 2012 MATE Competition. Because of this, our preliminary meetings involved a great deal of research and learning about ROVs and the MATE competition. Additionally, having only six people put a lot of pressure on all of us as we each had to perform multiple roles. Everyone was involved with planning and construction in some way or another, but we often had to meet in small groups because it was very difficult to find times when everyone was free of conflict.

We quickly decided that we would need a completely finished well thought-out design before we began building the vehicle, so that we would not have to make modifications later to accommodate a radically new attachment or setup. This became frustrating at times; the planning process took several weeks, and during this time many of us felt that we were not progressing at the rate necessary to provide ample time for building and testing. The rationale behind the extended amount of time given to planning was because we had to find the best way to incorporate a hook that distributed the weight of its load over the center of the ROV while still allowing us to rest on the ocean floor, in addition to a six-motor setup and various other attachments. It became very hard for us to visualize everything without a three dimensional representation, and we were generally unsuccessful in conveying our ideas through sketches, which further hindered our ability to finalize a plan. Eventually, team member Konrad Hausman constructed a 3D model using K'Nex. This model was great for getting everybody onto the same page and then catalyzing collaboration, because we were then able to pass the model around and let everyone physically demonstrate their own suggestions.



The mission tasks also presented many multi-faceted challenges. Our biggest challenges actually led to our greatest innovations. We felt it was very important to be able to carry payloads underneath the ROV to keep the weight centered and allow for easy placement and retrieval of large payloads. We designed a hook arm that could hang below the ROV, but this created a new problem: A hook hanging below would prohibit us from resting flat on the ocean floor. We solved this by allowing the arm to swing, with a horizontal bar that would stop it from hanging down past a certain point and distributing the weight to the center of the ROV. Additionally, we opted to incorporate a second camera that would focus on this hook's payload so that we could have a primary camera with a relatively clear frame of view that could be used for navigation and operating the forward attachments.

During a test of our ROV two weeks before the regional competition, we encountered an issue with our front camera not being able to send any video signal to our monitor. We examined the cable, monitor, and port but after careful inspection we determined that the issue was the camera itself – it had visibly filled with water and was ruined. Because having two cameras was crucial to our design, we had no choice but to purchase a new camera for roughly 187 USD. Not only was this by far our most expensive setback, it also limited vital practice time just weeks before the competition.

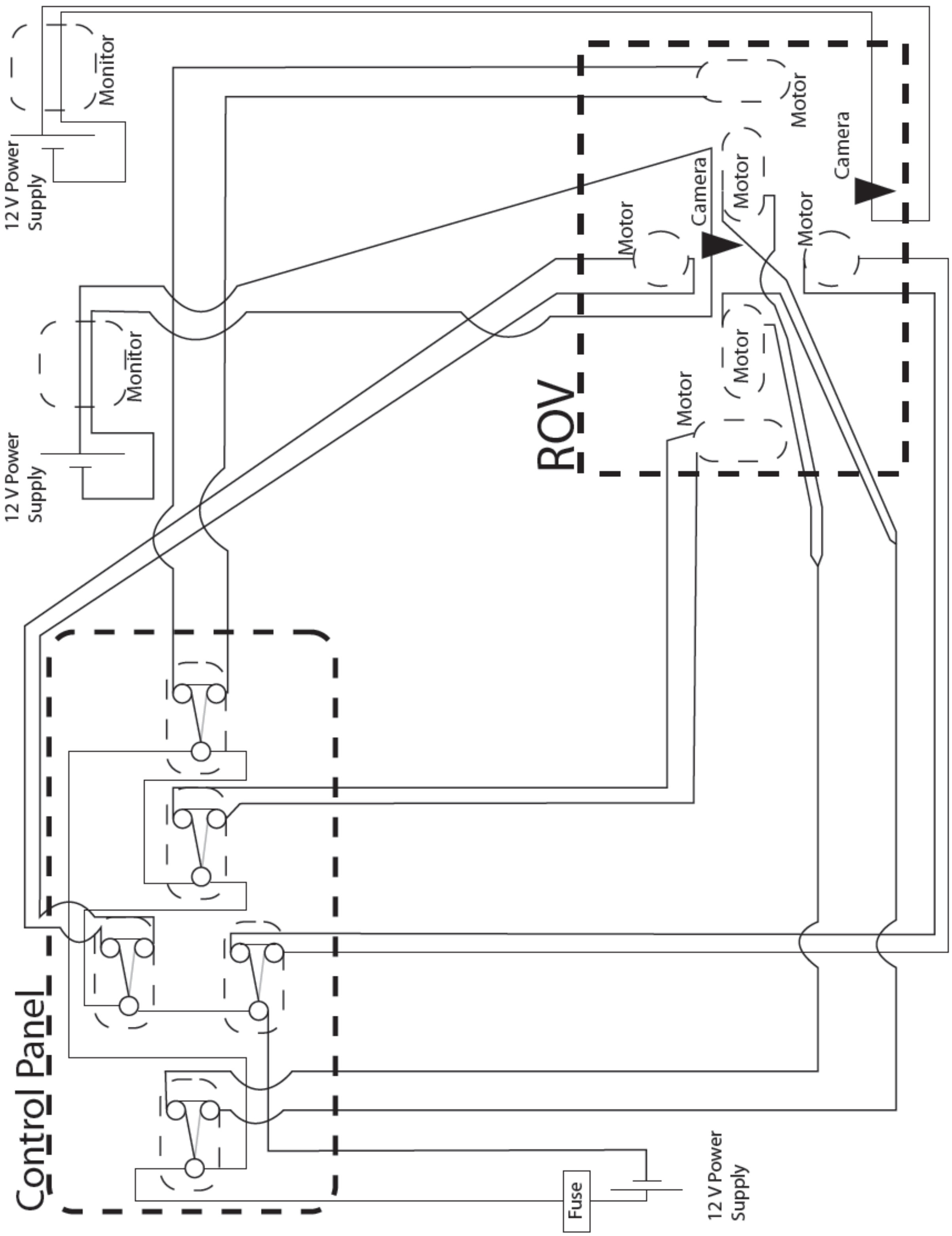
Skills / Lessons Learned

Throughout the process of building the ROV, we continually expanded our knowledge regarding ROVs through research online and with the help of associates who are experienced in this area. One piece of information that had the greatest impact on our design and process is that the center of buoyancy of an object is the centroid of its volume. We had expected the distribution of mass to affect the center of buoyancy which influenced our original design. This further taught us to be sure to research in advance of making final decisions.

In addition to learning much about the relationships between buoyancy, mass, and volume, we gained a lot of experience in electronic systems as we had very little previous knowledge of this subject. Thankfully, our physics teacher Mark Rowzee, was able to teach us how DPDT switches work. After teaching us, he stepped back to let us build and troubleshoot the electronics on our own, allowing us to further our working knowledge of electrical systems.

In both of these cases and most other challenges that we faced, whether it concerned meeting times or design, we had to learn to come together as a team in a way that none of us had ever done before. As the weeks passed, it was exciting for not only the members of the team, but other associates to see our team streamline our performance and work after seeing us struggle in the beginning. By the time the regional competition neared, we were a productive unit capable of delegating tasks and simultaneously work on many aspects of the ROV in order to reach our design and construction goals, as well as practice efficiently when we had time available in the water.

Electrical Schematic



Budget

The total cost of our ROV was $986.11 USD. Our donated materials are valued at $677.82 USD and our personal monetary contribution was approximately $308.29 USD.

AquaTech Innovations Engineering Budget						
Frame Materials						
Item	**Individual Cost**	**Qty**	**Cost**	**Donations**	**Estimated Cost**	**Variance**
PVC Pipe (1/2 inch x 10ft)	$1.19	3	$3.57			
PVC T-Joints	$0.46	20	$9.20			
PVC 90 degree Elbow Joints	$0.90	4		$3.60		
PVC 3-axis Joints	$1.15	4	$4.60			
Glue	$3.28	1		$3.28		
Primer	$2.07	1		$2.07		
			$17.37	**$8.95**	**$30.00**	**$12.63**
Electronics						
Item	**Individual Cost**	**Qty**	**Cost**	**Donations**	**Estimated Cost**	**Variance**
25-Amp Fuse (Tube Type)	$4.54	1		$4.54		
Plastic Storage Bin (control panel)	$4.00	1	$4.00			
Fuse Holder (20 A Heavy Duty in-line)	$1.97	1		$1.97		
18 AWG 8 Strand Carol Wire (300V, 50 ft)	$25.00	1		$25.00		
12V Power Supply	$59.99	1		$59.99		
12 AWG THHN red wire (20A, 10ft)	$35.00	1		$35.00		
12 AWG THHN black wire (20A, 10ft)	$35.00	1		$35.00		
Blue Splice Terminals, 16-14 AWG (100 pk)	$7.03	1		$7.03		
Blue Crimp Terminals, 16-14 AWG (100 pk)	$21.30	1		$21.30		
Yellow Crimp Terminals, 12-10 AWG (50 pk)	$27.48	1		$27.48		
Camera + Monitor	$187.99	1	$187.99			
Camera + Monitor	$149.99	1		$149.99		

DPDT Toggle Switches	$4.99	5		$24.95		
Cartridge Bilge Pump Motors	$24.99	6		$149.94		
Propellers	$2.89	6		$17.34		
Propeller adapters (SKU MAS3200)	$5.99	6		$35.94		
			$191.99	**$595.47**	**$10.00**	**($181.99)**
Tools						
Item	**Individual Cost**	**Qty**	**Cost**	**Donations**	**Estimated Cost**	**Variance**
PVC Cutter	$33.60	1		$33.60		
Wire Crimping/Cutting Tool	$30.70	1		$30.70		
Power Drill	$25.94	1	$25.94			
			$25.94	**$67.50**	**$75.00**	**$49.06**
Attachment Tools						
Item	**Individual Cost**	**Qty**	**Cost**	**Donations**	**Estimated Cost**	**Variance**
Zip Ties (box)	$5.78	1	$5.78			
Electrical Tape Roll	$2.94	1		$2.94		
			$5.78	**$2.94**	**$10.00**	**$4.22**
Rope						
Item	**Individual Cost**	**Qty**	**Cost**	**Donations**	**Estimated Cost**	**Variance**
Propylene Tether Rope (50 ft)	$3.89	1	$3.89			
			$3.89		**$20.00**	**$16.11**
Accessories						
Item	**Individual Cost**	**Qty**	**Cost**	**Donations**	**Estimated Cost**	**Variance**
Caribiner	$2.96	1		$2.96		
T-Slotted Alluminum Track (1" x 1" x 36")	$10.23	1	$10.23			
Pointer-Magnet	$6.99	1	$6.99			
Marshmallow Roaster	$7.10	1	$7.10			
Threaded Metal Rod (3ft)	$10.00	1	$10.00			
Temperature Probe	$29.00	1	$29.00			
			$63.32	**$2.96**	**$50.00**	**($13.32)**
Grand Total			**Cost**	**Donations**	**Estimated Cost**	**Variance**
			$308.29	**$677.82**	**$195.00**	**($113.29)**
TOTAL VALUE	**$986.11**					

Future Improvements

There are several aspects to our current design that could be modified to be more successful in future competitions. Perhaps the most common adjustment that could be made is regarding the structure and security of several of the attachments. Tape is currently the connection mechanism for the rear camera and the bottom hook. Rather than tape, a mechanical connection via clamp or bolt and nut would be a much more secure way to attach these accessory components. As the PVC frame is easy to drill through, attachments could feed through the frame. More secure components would provide for more repeatable results and reliable camera streaming.

The placement of the cameras, although usually beneficial, posed problems for specific missions. While picking up the SIA, the view of the camera is obscured. This makes depositing it into the BIA a blind task. This issue could be fixed by cutting into the frame and moving the camera backwards to expand the range of visibility, which would improve accuracy on most of the missions.

In our attempts to waterproof all of our systems, the wires became disorganized and unevenly distributed. To provide for a cleaner, more organized appearance, the wires could be unraveled and rewound with corresponding wires in locations closer to their actual components rather than wherever they fit within the ROV.

The organization and presentation of our tether is also lacking. Currently all of the wires and the rope are held together via zip-ties, which could be a potential safety hazard as the cut ties are sharp. To remedy this, we could coat the tether in a plastic sheath that ran the entire length of the tether. All the wires would then be held together in an efficient, safe way.

Finally, the control layout, while effective, is slightly confusing. The control switches send Boolean signals from the position of the switch to the motors on the ROV. The current layout of the switches is rather ambiguous in terms of what motor is connected to what switch. By redesigning this control board, the pilot and copilot could have better insight as to which direction they are steering the ROV.

Reflections

This competition has been a great opportunity for me to learn more about engineering and technology. My experience with the 2012 competition was a strong factor that influenced my decision to pursue mechanical engineering. What I love most about this project is the collaboration. Because we were able to incorporate each member's best ideas, our ROV turned out far better than it would have if one of us had tried designing it alone. This project has helped me grow as a leader, designer, and innovator, and I'm thrilled to be going to the International Competition in June! *(Isaac Heine)*

I certainly have worked with groups and as a team before, however this project was an entirely new experience. I really learned to be patient with team members as they explained their rationale for a design or learned how to use a new power tool. In the past, I have gone into groups with the expectation to win competitions and get awards, but due to the fact that most of our team has no experience in anything we did, this project demonstrated how important it is for actual learning to take place. Patience, teaching, and research were a major part of our company's growing and will continue to be of the utmost importance as we move forward. *(Julie Ozols)*

This team, being as small as it is, really brought us all close together to the point that we can interpret each other quite well and know each other's strengths and weaknesses. Our team as a whole managed to create a very promising looking ROV with minimal amounts of man power and prior experience. I managed to find areas in the process that I found to fit my skill set and I helped the team excel in these areas. Every member of the team brought forth their own unique skill set that contributed to the success of our build. *(Dylan Coupe)*

Personally, I really enjoyed this competition; so much so, that next year not only will I be part of leading the team, but will be reaching out to junior high schools to help them build their own. I think the best part about all of this was that I didn't have to know physics and calculus in order to build our ROV, it really helped to show me that engineering can be fun, and isn't all math and science. If anything, I think the accomplishments that I achieved through this are the relationships, not only to my team, but to the teachers involved with the program. We all had an enjoyable experience with this competition, and are going to have many fun stories to tell from it. *(Stuart Houston)*

References

We used the help of our Physics teachers, Mr. Mark Rowzee and Mr. Geoffrey Schmidt as professional overseers to guide our project.

Acknowledgments

We would like to thank all of the following for their help and support on our ROV and the competition: MATE Center, Shedd Aquarium, UIC, Mark Rowzee Geoffrey Schmit, Mohsin Azmat, Nathan Lindquist, David Degenhardt, Naperville North High School, the NNHS swim team, and each of our families. Thank you!