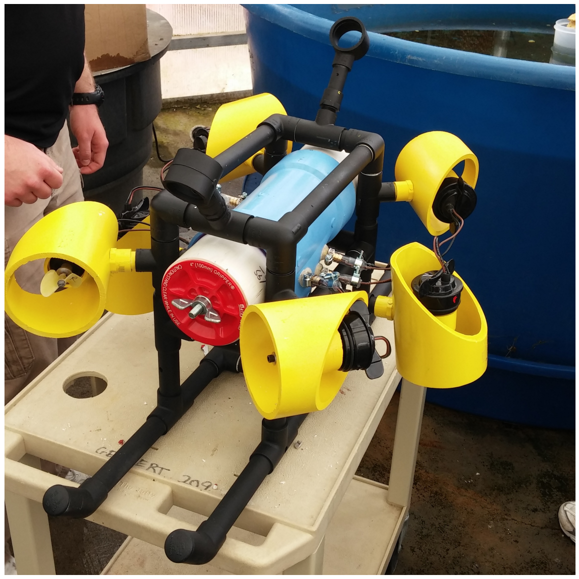
The Aquaholics
2014 Technical Report

Cape Henlopen High School
Lewes, DE



Team Roster

Mentors:

William Geppert   Les Proctor   Tyler Rommel

Name	**Position**
Angela Carroll	CEO, Team Captain
Graham Smith	Pilot, Electrical Engineer
Chris Ferri	Head Programmer
Derek LeGates	CFO
Sid Miller	Design Engineer
Nick Carroll	Safety Officer
Austin MacElrevey	Mechanical Engineer

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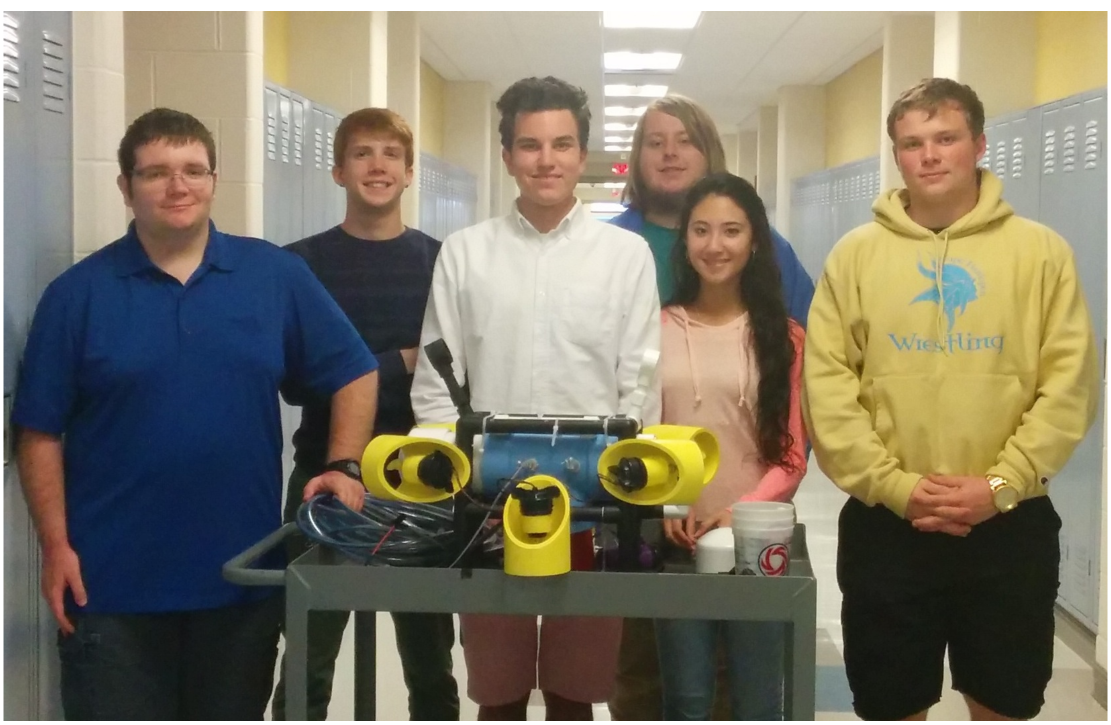
Abstract

The goal of the Aquaholics is to create a Remotely Operated Vehicle that can do its job just as well, if not better, than any other ROV but with far less expenses. We strive to keep our costs low by making our robot out of materials such as PVC, spray paint and zip ties, so that it can easily be modified, rather than more expensive things like machined plastic or metal. We found that it was more expensive to fix a mistake if we used materials like PVC rather than a metal, machined or 3D printed frame because those materials have to be completely redesigned and recreated, while PVC can just be taken apart, modified, and reassembled.

The challenge was to keep efficiency high as we cut costs. We found that we could cut holes in our Waterproof Electronics Housing to run wires back to the surface or to the motors and then reseal them without letting water get into the housing. We did this by using metal crimped fittings with rubber tubing filled with RTV on the end in order to keep the WEH waterproof.



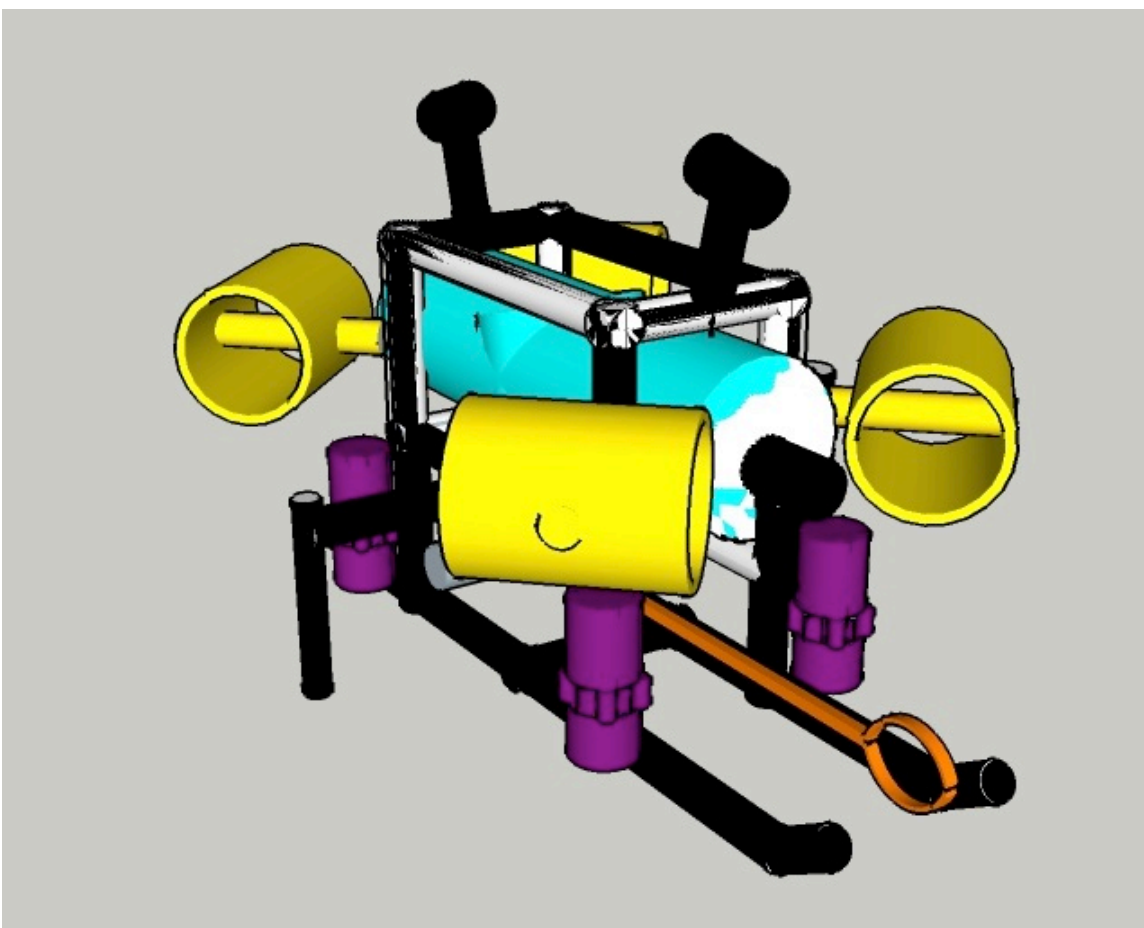
The Aquaholics: (Left to Right) Chris Ferri, Sid Miller, Derek LeGates, Graham Smith, Angela Carroll, and Nick Carroll

	Re-Used	Donated	Purchased
245 cm of ¾” PVC			$2.25
Waterproof Electronics Housing (WEH)			$6.78
84 cm of 4” PVC			$20.88
2x 4” PVC end Caps			$15.42
2x 4” test plugs			$11.58
2x 1 ½” test plugs			6.38
6x ¾” PVC T’s			$27.18
4x ¾” PVC Corners			$6.80
8x ¾” to ½” PVC T’s slip			$6.40
48 cm of ½” PVC			$2.03
9x 1 ¼” to ½” PVC T’s slip			$14.31
2x ¾” to ½” PVC T’s threaded			$3.12
1x 1 ¼” to ½” PVC T’s threaded			$1.95
4x 4 way ¾” PVC connectors			$14.43
8x ½” PVC couplings			$19.2
4 Marine Batteries			$367.86
Conductivity Sensor			$165.00
500 GPH Marine Pump Catriges			$130.68
2 Iron Rods			$10.68

Drive Dogs and Propellers			$71.04
DC/DC converters			$277.50
Butane Torch			$19.95
Heatshrink			$36.98
Spray Paint			$9.61
Wing Nuts			$1.18
4 Way surveillance video splitter			$91.49
3/8 inch vinyl tubing			$23.40
Adhesive Sealant			$20.07
BNC Video Cable and Adapters			$51.63
BNC Phono Adapter			$7.49
CCTV Color Underwater Camera			$95.98
PS3 controller			$19.99
36 AA batteries			$12.97
Zipties			$28.44
2 Cameras	$200.90		
16 Gauge Speaker Wire	$96.58		
Cat-5 Cable	$17.25		
1 Macbook Laptop		Yes	
2 Dell Laptops		Free	
TV monitor	$229.00		
Arduino Mega			$45.00
Xbox controller			$39.99
Measuring Tape			$6.99
2 Rental Vans for drive to Michigan			$900
Bus to regionals			$807.55

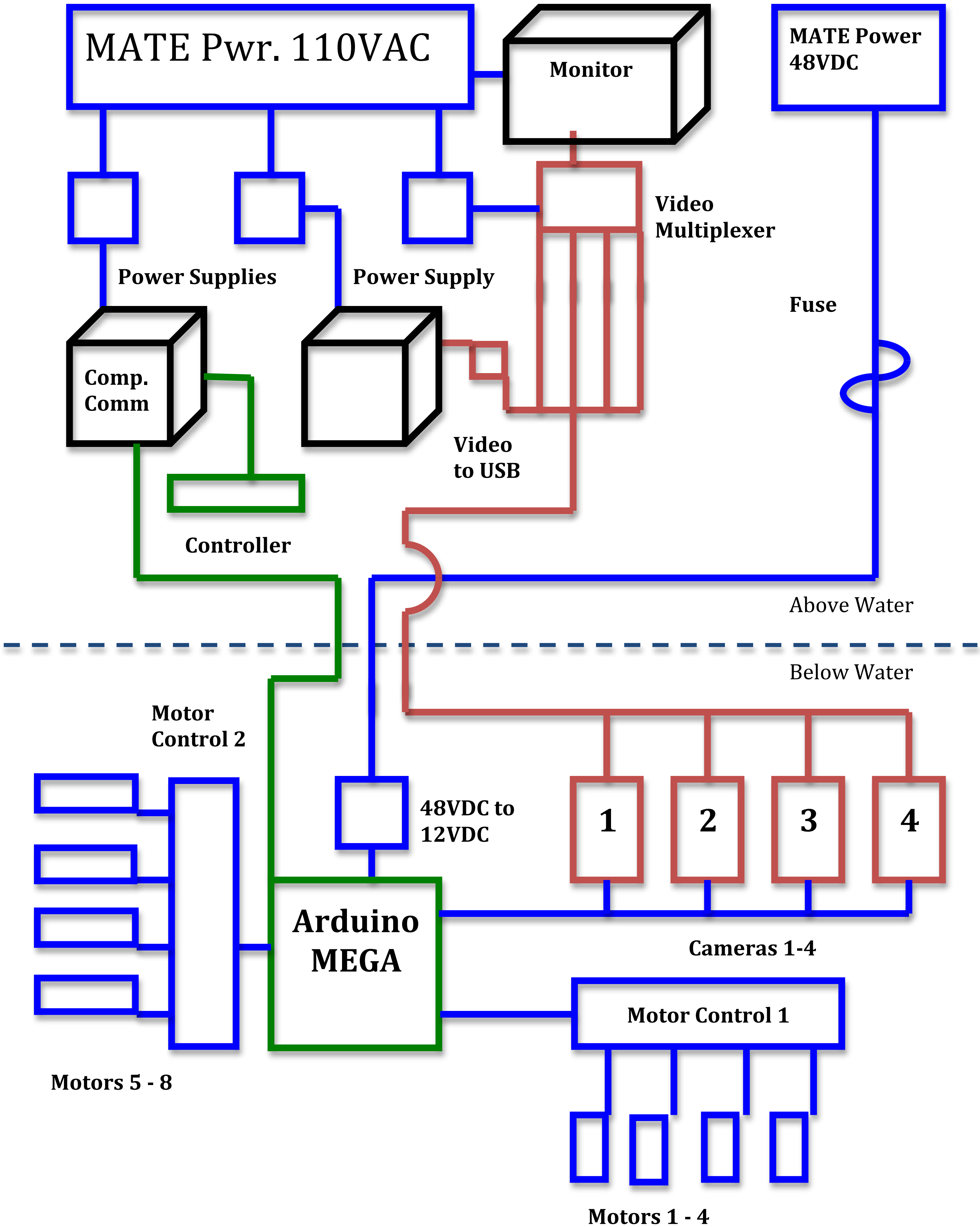
8 People for 5 nights at CCR			$870
Competition Fees			$100
Cost of Gas for 851 miles x2 vans			$269.48
Total ROV Cost			$1,692.63
Total Cost			$4,639.66

CHEF	$3,300
Cape Henlopen School District	$1,000+ Cost of vans and gas ($1,169.48)
Aleta M Thompson	$50

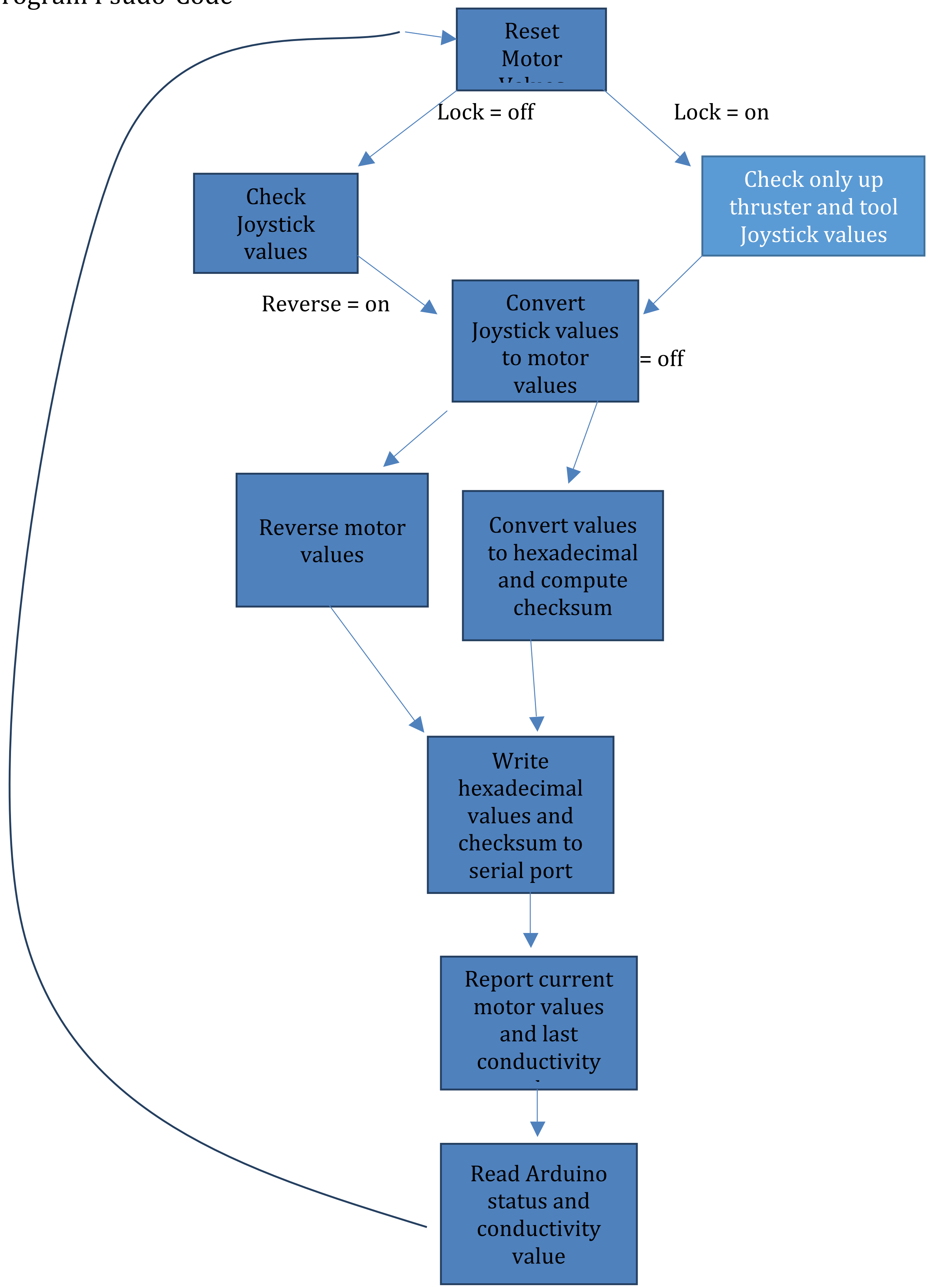


3D Model of Loki

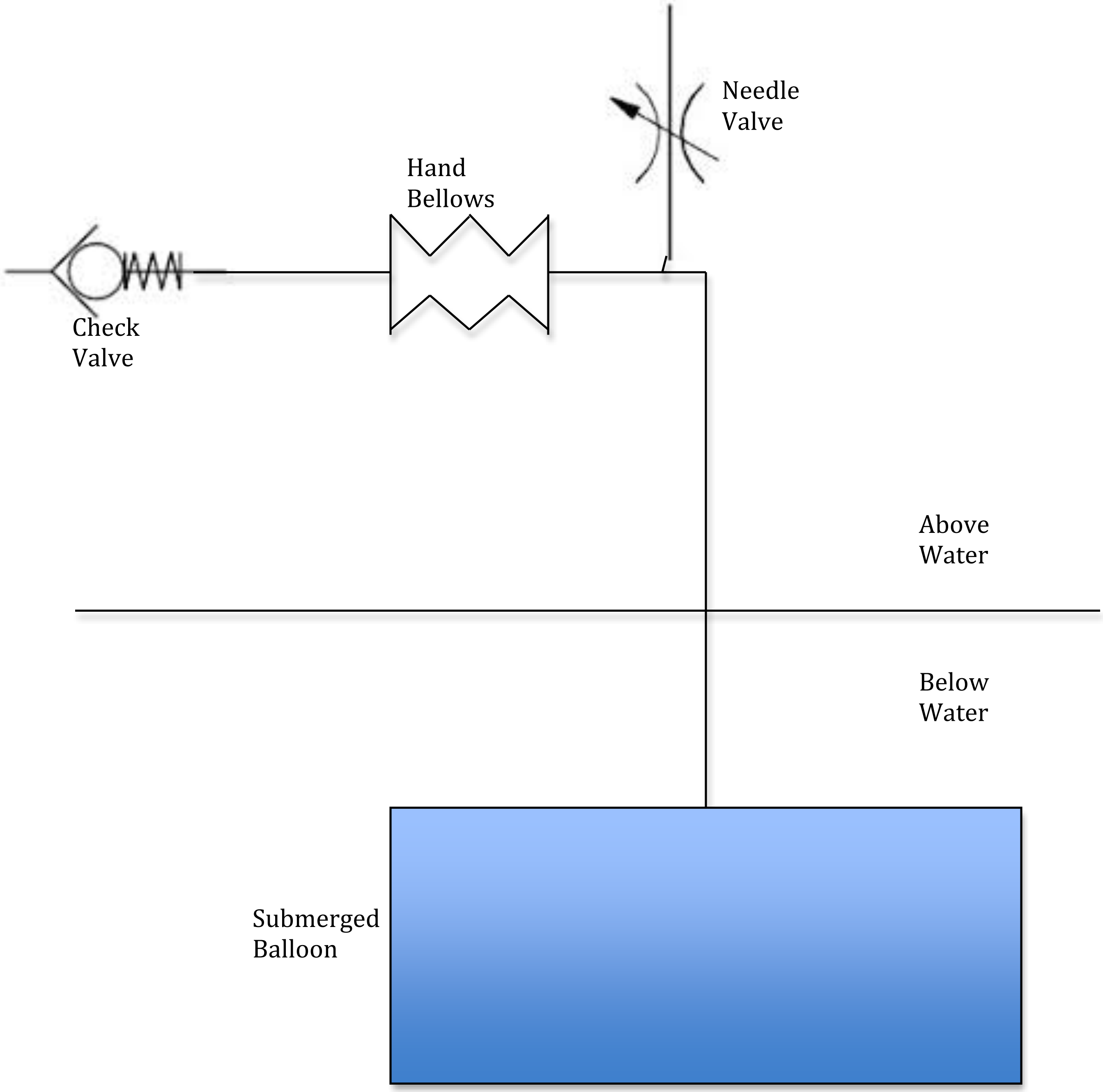
System Integration Diagram



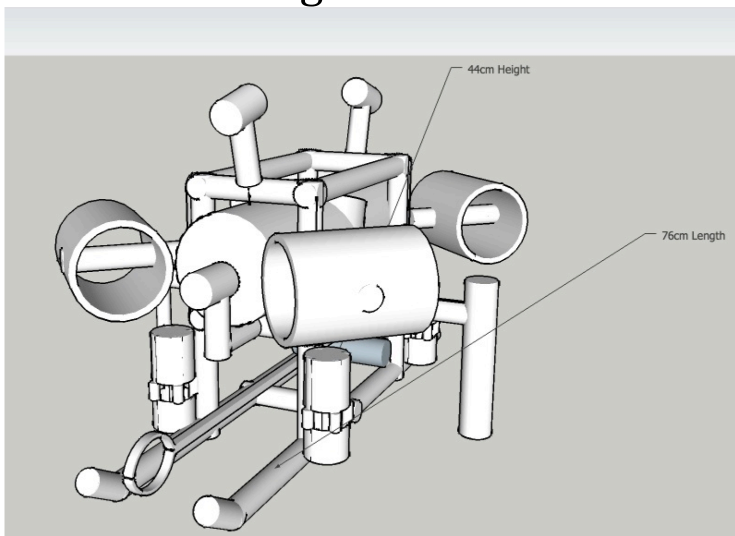
Program Psudo-Code



Fluid Integration Diagram



Design Rational



The majority of our components were designed and built for this specific mission. We reused some tools and parts from past competitions to keep costs down. For example we re-used the television which displays our camera feeds because we could not justify spending hundreds of dollars on a new television that had the same functionality.

General Component Orientation

Placing the components of the ROV was as much objective as it was subjective. The design needed to make sense functionally and to be convenient. While placing internal components, the Engineering Team chose to consider ease of connections and buoyancy. The Waterproof Electronics Housing was placed in the center because it allows for all of the electronics to connect in the center. It is filled with air so it also provides the main source of buoyancy. By placing it in the middle of the ROV, the ROV remains well balanced.

The cameras are placed so as to provide a wide range of view while still providing up-close and detailed video. The main camera is directly in front of the robot to provide a general view. There is a camera that faces backwards for backing out of the shipwreck and to look backwards in case the tether gets tangled. There is also a claw camera so the pilot can easily see the claw and what it is attempting to grab or manipulate.

Cameras

As in years passed Aquaholics has opted to use waterproof Speco Systems brand surveillance cameras. These cameras have, however, been slightly adapted for use on Loki. The power plug has been snipped off and the power wires stripped and soldered to the ROV control board. The two video signal wires running to and from the surface are soldered within the electronics housing to the video signal wires that connect to the cameras. We also purchased a color Pro Video waterproof color CCTV camera to complete the photo mosaic task and determine the type of cargo the ship was carrying. For an explanation of camera placement, see "General Component Orientation".

Buoyancy

The ROV Loki's Buoyancy Control system is relatively simple. By trial and error, the Engineering Team placed a combination of sealed PVC cylinders and steel rods about the ROV so as to achieve both stability and neutral buoyancy.

Tether

The Engineering team's primary goal when designing the tether was to achieve a balance between keeping the tether lightweight and maneuverable while minimizing voltage drop. Through practice and experimentation the team determined that the optimal type of wire for providing power down to the ROV was 16-gauge speaker wire. The tether also includes a cat5e cable to relay programming commands down to the ROV. These two cables are enclosed in a clear vinyl tube to waterproof them when they enter the waterproof electronics housing. The tether also includes 4 camera wires to provide video back to the surface.

Waterproof Electronics Housing

To comply with the rule that the electronics must be housed underwater, the Engineering Team proposed many ideas including making a housing out of PVC tubing, using a modified Otterbox, and dipping the board in plastic. Ultimately the Engineering Team chose to use the housing made out of PVC tubing. The main housing is a 4" hub sanitary tee. Coming out of the two top openings are 4" PVC tubes glued and sealed to the sanitary tee. These 4" PVC tubes' openings are sealed with 4" plastic test plugs that can provide waterproofing but can also be removed to provide easy access to the Arduino board and electronics inside. The bottom opening is sealed with a piece of aluminum used as a heat sink for the DC-DC converters. The biggest problem we faced with the waterproof electronics housing was how to get wires in and out of the PVC. Motor wires, camera wires and the tether enter the Waterproof Electronics Housing through brass pipe nipples screwed into the sanitary tee and sealed with silicon. A short piece of clear vinyl tubing is connected to the nipple and where the wires enter the tubing it is sealed with silicon and the tubing is clamped with 7/16"-1/2" fuel injection hose clamps at the wire entry points and where the tubing is connected to the nipple to ensure nothing comes loose.

Motors

In the initial stages of motor design, our engineers struggled to answer the question of how to satisfy the 48-volt Explorer Class power requirement. We had 48-volt bilge pump motors but they were large, bulky, and heavy and we would have to manufacture our own drive dogs in order to use propellers. We also had 12-bolt bilge pump motors but they are the wrong voltage. Our engineers considered using large resistors to drop the voltage but abandoned this idea in favor of a more elegant solution. We decided to use a DC-DC converter to step down the voltage to a level appropriate for 12-volt bilge pump motors, which still have enough force to easily maneuver the ROV. The motor placement allows for many different maneuvers including up, down, forward, backward, left turn, right turn, crab left, and, crab right.

Frame

The engineering team decided to make a frame that consists of a rectangle, sized 33x 17x33 cm, connected to two skids 73cm in length. This design allows for the ROV to easily fit inside the shipwreck and also allows for many points for instruments to be connected.

The question of material was answered with great consideration to cost as well as effectiveness of materials. Based on these two factors, the possible materials were quickly narrowed down to a choice between PVC piping and aluminum angle stock. PVC is an easily accessible material that is equally cost effective. Its buoyancy is also easily controlled. However, PVC is less structurally sound than the aluminum angle stock. Aluminum also has a low corrosion rate due to the protective layer of aluminum oxide that forms on its surface in the presence of oxygen and also serves as ballast for the machine. On the other hand, it is much less cost effective when compared to PVC.

The team decided to use PVC because of its cost effectiveness but also, and more importantly, because of its ease of use. PVC is very easy to cut, and lends itself to many unique designs, perfect for solving mission tasks. It is also very easy to add on such things as motor guards and camera holders.

Robotic Arm

The claw is the most important tool on our ROV. Many key items affect it's performance. We positioned the claw in a specific configuration so that we are able to accomplish all of the tasks set out for us. This required us to place the claw in view of the forward facing camera. The claw's orientation is also a variable that we had to work on and test. We finally chose a vertical position because it allowed us to pick up not only the plate and bottles, but open the cargo container and remove debris. We made the claw from an inexpensive piece of hardware that is able to pick up and manipulate all the objects needed. The mouth of the claw is wide enough to pick up the bottles and it is lined with soft rubber to provide friction.

Conductivity Sensor

We placed the Conductivity sensor on the side of the robot so that we could easily dip it into the bucket by lowering the robot. We purchased a ready made conductivity sensor so that we knew it would read correctly when we measured conductivity. We wired it into our Arduino so that we could read the results that we find on the computer that we are using poolside.

Measuring Tape

The engineering team decided to use a measuring tape to determine the size of the shipwreck. Instead of a contractor's metal tape measure, that was used in past years, they decided to use a fabric tape measure similar to one a tailor would use. This would not rust, and would be more flexible and able to be manipulated underwater. They designed a wheel which could spool out or reel in the measuring tape. This wheel is on the back of the robot and the tape can be read by one of our front cameras.

Commercial Components

On our ROV we used commercially available cameras, motors, and conductivity sensors. These are components which, given our time constraints and manufacturing abilities, were more cost efficient to buy rather than build. We also used Adruino microprocessors and motor drives. We investigated custom made PCB's, but we could not improve upon the functionality of the inexpensive boards such as the Arduino Mega.

Safety

Throughout the development of the ROV, Loki, safety was always our top priority. We took many safety precautions to ensure of the safety of our teammates. One example of an accident avoided is that we made sure to label all battery terminals and connections so that they could be attached correctly every time and no electric shorts could occur. While keeping functionality and cost-effectiveness as a guiding principle in the design process, we still observed the following procedures to ensure the safety of all our personnel:

- Closed toed shoes are worn at all times
- Protective eye wear are worn when power tools are in use
- Gloves or masks are always worn when handling any noxious chemicals, such as PVC cement
- Before adding the electronics we went through a waterproof testing process, sealing the frame and electronics housing as we would with electronics (using dummy plugs) and submerging the frame for house to look for leaks of any kind even with the extended time under water
- The safety officer, and mentors are present to supervise the practice of all safety procedures to ensure the general safety of the team
- Safety check list see appendix

As a result of our safety comes-first philosophy, our ROV has the following safety features:

- All propellers have a safety shroud, and are identified with a safety color

- A dive bag is attached for emergencies to bring the ROV to the surface manually
- The wires are kept short and neat to stay out of the way of the propellers
- A heat sink is at the bottom of our electronic housing to keep it from over heating

(For safety check list see appendix)

Initial Testing in a Small Environment

Teamwork

To complete our robot, and our tech report, we broke down the task into smaller parts and assigned each team member tasks. We then brought together these individual tasks and compiled them into a complete, concise final product.

We worked on the robot 7:55-9:30 and 10:30-12:00 every other day in school. We also met often after school to continue working.

Description of challenges and troubleshooting methods:

During the production of our ROV, we encountered many problems. Our first major obstacle was in designing the frame for our robot. As we started building, we failed to take into consideration the electrical housing components and the placement of the motors. As we redesigned the robot to better accommodate these key parts we again overlooked another function that was crucial to our success: the arm. During our final construction we finally figured out how to include everything we needed while still keeping the size small and allowing our ROV to be maneuverable.

Another problem for us occurred in our programming. The program seemed to be written very well and seemed to work correctly but when we used our first computer, a Mac, the programming would randomly shut off the ROV while it was underwater and we couldn't find a problem. Eventually we switched over to a PC and the same program would work on the new laptop so that took care of this problem.

Our final major problem was the buoyancy of our robot. We managed to get our ROV neutrally buoyant but the end caps we had covering our electrical housing would fill up with water slowly and after 15 minutes they would be filled with water, causing major problems with our mobility. To fix these buoyancy issues we had to add and remove weight through trail and error until we came across a solution that worked.

We faced interpersonal difficulties when our schedules conflicted or our communications broke down. We worked hard to find times where the team could meet together. Some times we would meet in smaller groups to focus on individual issues that did not require the whole team.

Description of at least one lesson learned or skill gained:

One important lesson we learned through the construction process and a major difference from last year is the waterproofing of our ROV. Our robot last year failed because it wasn't waterproof like we expected so this year we made it a huge focus for our group and we spent a lot of time working to prevent this problem from happening this year. We learned to be flexible with our schedules. All of our team members are seniors and are very busy with the last year of school, but we worked out these issues and were able to complete our robot and practice our given tasks.

Discussion of future improvements

A future improvement our team next year will have to focus on is better communication and more time as a group working together. This year our team almost never had every member working at the same time and if next years team wants to be better than our team this is what communication and time together will be very important.

Reflection:

As a team, we have grown together in many ways through the trials and tribulations of building a robot. Being one of the only high school teams competing at the explorer level, we have had many struggles due to a low budget and not as many mentors as other teams. We had a very small budget compared to the multi-thousand dollar budgets of college teams and many of the things we needed are paid for out of pocket by our teachers and ourselves. We also found that many other schools bring in mentors from the community that have professional experience with robotics, while we get help from three different school employees who are great mentors in their own right, but just don't have as many real world experiences that other mentors working in the field would have.

Acknowledgements:

The Aquaholics Robotics team would like to thank the following people and organizations for their help throughout the building and designing process and the opportunity they have given us to compete in this year's competition in Alpena, Michigan.

- The Mate Center,
- Mate's Mid-Atlantic Regional Coordinators,
- All of the contributors and donors mentioned in our "Project Expenses" chart, most notably (hopefully) the Cape Henlopen School Board,
- Our Mentors and teachers throughout the process Mr. William Geppert and Mr. John Proctor for the countless hours they've devoted to helping us succeed.
- The Hampton Inn in Rehoboth, DE for letting us use their pool facilities as a practice space.

References:

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Appendix

Safety Check List

The following safety checklist is consulted before any practice session or work on the ROV is done, to ensure the safety of all team members:

Safety Officer is present	
Closed toed shoes are worn	
Proper eye wear	
Masks or gloves are worn if necessary	
Stress relief on wires	
Check all connections	
If practicing outside, do weather conditions create an unsafe environment	
Are all electronics above the surface, clear of the splash zone	
Are there any other people in the pool	