"Aaaaargh" OV Engineering

Mate ROV International Competition 2015

Greater New Bedford Regional Vocational Technical High School
New Bedford, Massachusetts

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Table of Contents

Abstract

We members of "Aaaaargh" OV Engineering take personal pride in designing and producing the most efficient harsh climate Remotely Operated Vehicles specifically designed to survey icebergs, measure, determine the conductivity of anodes, and safely retrieve algae and sea urchin samples. With these technologies, we are able to determine the threat level an iceberg may pose to area oil company assets.

The concept and production of *The Black Pearl* was of our own engineers' design. We strive to exemplify our personal mantra: Keep it simple and complete the task. All team members participated in the creation of the custom frame, specialized tools and proprietary control system. Our engineers are fully knowledgeable on each aspect of the ROV's design and work as one team. We rigorously test the robot to account for any possible circumstances that may occur while we operate it to perform designated tasks. The process of testing is the longest phase of our process as this exercise leads to insight into improvement possibilities that returns us to the design stage time and time again. The engineers of "Aaaaargh" OV Engineering are committed to being the top rated designers and manufacturers of underwater vehicles.

Figure 1: Pictured above, team member working on *The Black Pearl*.

Completed ROV

The final product of this process is a Remotely Operated Vehicle designed specifically for this set of tasks, *The Black Pearl*. It is light and stable with enough power to retrieve pipeline from the sea floor. The intuitive controls combined with the multiple camera views allow the pilot to work through tasks quickly and afford the possibility of changing task orders when opportunities arise. The safety features include buoyancy set to slightly positive, fused power and labeled points of potential hazard. This reliable vehicle has performed well in many simulated product demonstrations.

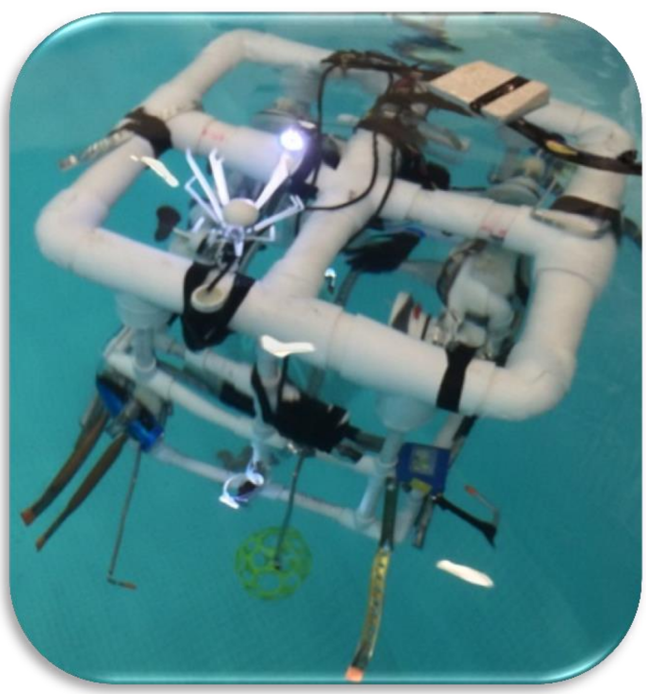


Figure 2: *The Black Pearl* during testing.

Design Rationale

At Aaaaargh OV Engineering our philosophy is to design the simplest tool that reliably completes the task. We find that tools with fewer moving parts are more reliable with easier trouble shooting procedures'. We execute this philosophy with teamwork every step of the way. The team approach allows us to sort through many options in group brainstorming sections and to divide complex tasks into smaller pieces for subgroups to complete. The typical workday starts with a team meeting to discuss today's tasks, discuss possible solutions and break up into smaller groups to complete their assignments. The day usually ends with a final team meeting to share what we've accomplished for the day, get instant feedback and provide some insight into tomorrow's objectives. Spending time together and talking about design solutions helped us to build strong bonds as teammates. Participating in activities together such as team trivia and group sing-alongs helped every team member be comfortable in being able to speak about his or her ideas freely. It was brainstorming sessions together that produced ideas for *The Black Pearl* that gave positive results.

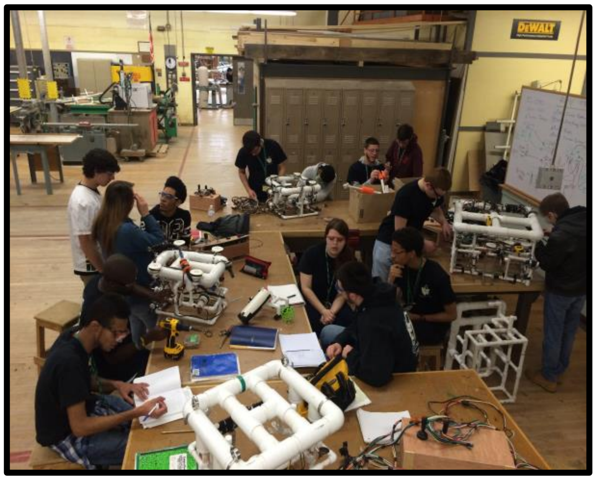


Figure 3: Pictured above, team work is the hallmark of Aaaaargh OV Engineering.

We employed the design process to create our robot because this approach has proven reliable throughout many facets of engineering. The generic steps in the design process are customized for our project and our approach to problem solving. Starting with studying the MATE ROV Competition Manual we realized we needed the competition props to fully understand the tasks and to properly test our solutions. The process of building the props was a good exercise in skills that would later be critical in building the ROV itself; skills such as measuring, cutting, cementing PVC, building to precise specifications and learning safe working procedures. The competition props were built following the manual published by MATE and these propos were used in multiple steps of the process culminating in simulated demonstrations runs at the local YMCA pool.

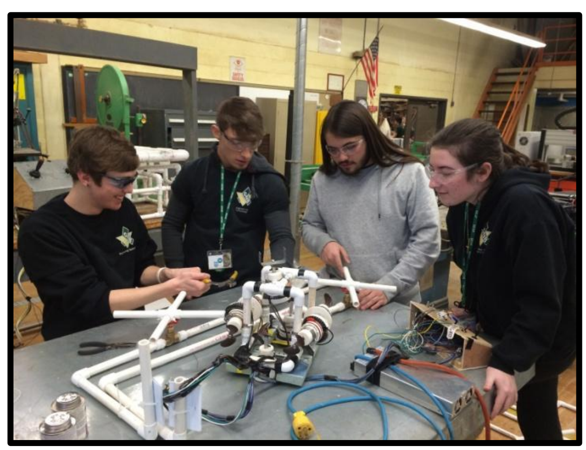


Figure 4: Pictured above, team works on building one of the valve props.

Vehicle Design

Our design process led to a vehicle that is light, agile and flexible in its ability to carry tools to the work zone. Multiple mounting points is an important part of our design as we anticipate tool evolution that will require more points of attachments. Our philosophy of simple, reliable instruments leads to more tools on our vehicle and in some cases, our specialized devices are used just for one task. *The Black Pearl* also uses multiple cameras to provide all necessary views for each task. The propulsion will include a tight turning radius, strafe capabilities and powerful ascend thrust. The tools will be focused on the front of the vehicle where the pilot has the most control and the most camera views.

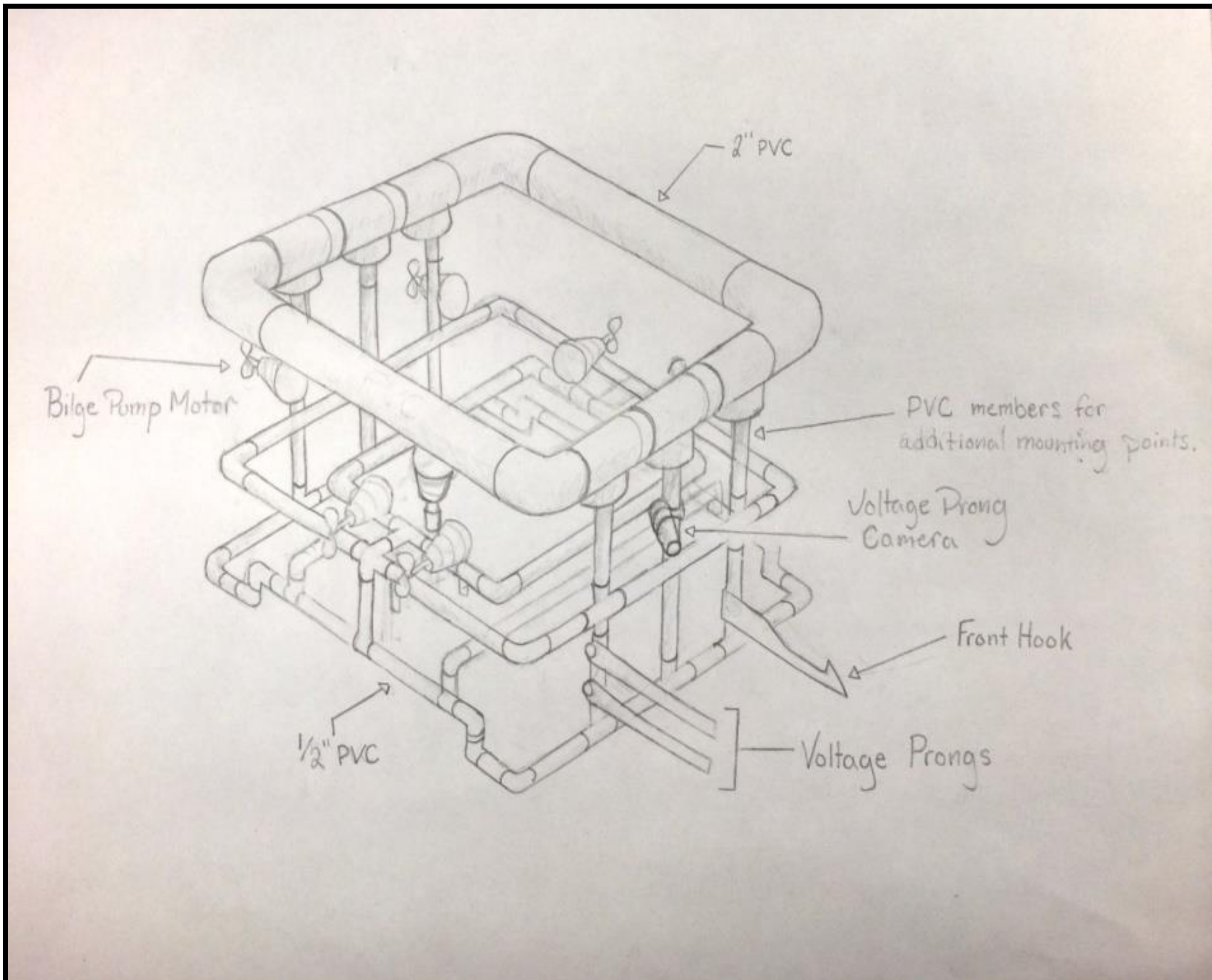


Figure 5: A sketch of *The Black Pearl* with tools, cameras, and motors.

Frame

From our brainstorming, we decided on a PVC frame made out of 1/2" and 2" PVC. We chose PVC because it is inexpensive, lightweight, and durable. The design included numerous mounting points. We initially dry fit the pieces together to see how the frame would sit when it was assembled, once we were satisfied with the alignment of the sections, we began priming and gluing the PVC pieces together to make the frame watertight. Making the frame watertight was one of the most intense parts of assembling *The Black Pearl* because teamwork was heavily involved in making sure the process flowed smoothly. When the PVC is airtight, it allows for naturally positive buoyancy and therefore when adding the cameras, motors, and tools to *The Black Pearl* still achieved positive buoyancy. We added weight after all the tools, motors, and cameras were mounted to achieve neutral buoyancy.

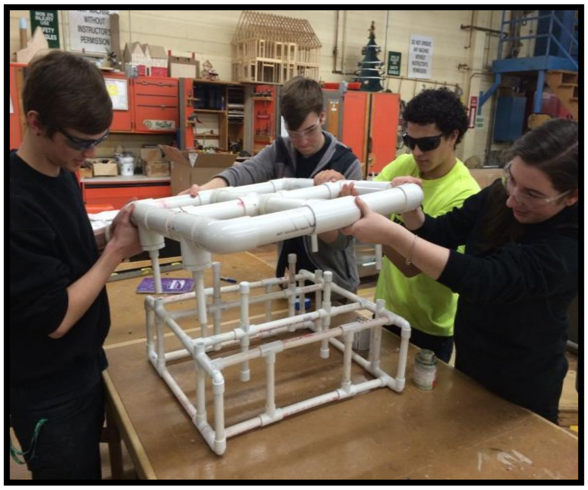


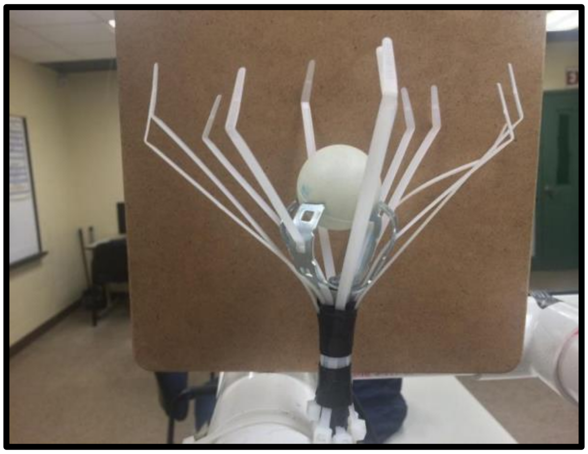
Figure 6: Pictured above, team members assemble the frame of *The Black Pearl*.

Creating the desired buoyancy actually turned out to be one of the most challenging aspects of the project. Although the frame was inherently positively buoyant we found this condition to be more than our descend motors could overcome. The ballast added, had to be distributed to create a level and stable robot. We ultimately produced buoyancy that was just slightly positively. A condition that allows the ROV to surface without ascend thrust in the unlikely event of power failure to our rig. The rigidity and strength of the frame was proven to be adequate as many trips to the testing tanks and a few rough landings in the shop produced no noticeable damage.

Figure 7: Two team members adjusting the buoyancy of the robot and tether in our tank.

Specialized Tools

Every tool on *The Black* Pearl is designed to be effective and reliable for its specific tasks, with a few tool pulling double duty on some assignments. To retrieve algae from beneath the ice, we created a tool that will operate by pushing on an algae sample to collect it. We bent pieces of aluminum using a vice and a mallet to form a ping-pong ball shape and attached zip-ties through the aluminum pieces to create a preventative



curtain to zone in on the algae sample and effectively retrieve and return the sample to the surface. This instrument has no moving parts and does not require electricity nor special controls. Just a deft propulsion and sure handed pilot to collect the sample time and again in just seconds. Adjustments to this tool can be made on site for samples that are discovered to be larger or smaller than anticipated by simply bending the aluminum fingers further apart or closer together.

Figure 8: The algae retrieval system.

We decided we needed something simple to efficiently collect the sea urchin as well. To collect the urchin, we created a zip-tie spear. The spear was made using an aluminum rod with cut zip-ties facing backwards. As the spear is thrust into the openings of the sample the cable ties entrap the flexible frame of the sample for retrieval to the surface. After retrieving the sample, a rubber band narrows the zip ties down to the metal to quickly remove the sample.

Figure 9: Pictured above, the zip-tie spear securing the sea urchin.

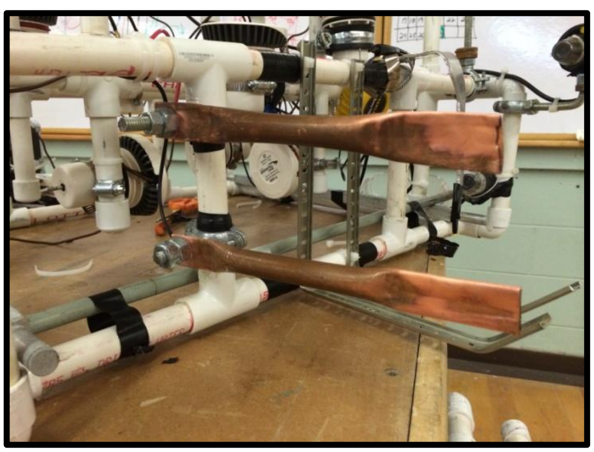


Figure 10: The copper anode testing mechanism.

To test the voltage flowing through the anodes, we used two sixty-foot lengths of wire, each respectively for a multimeter lead, which ran from the multimeter to the control box through the tether to the front of the robot. They each connected to a copper pipe. Each end of the pipe was flattened using a vice grip so that the surface area would provide ample opportunity to touch the anodes and test for voltage. On the end that needed to be connected to *The Black Pearl*, the flatness provided a surface to drill a hole through so that the screw connected to a bracket clamp could fit and be secured on the other side. Piloting *The Black Pearl* and manipulating the height to test the anodes proved difficult, to better attach to and measure the anodes for voltage, we must operate precisely.

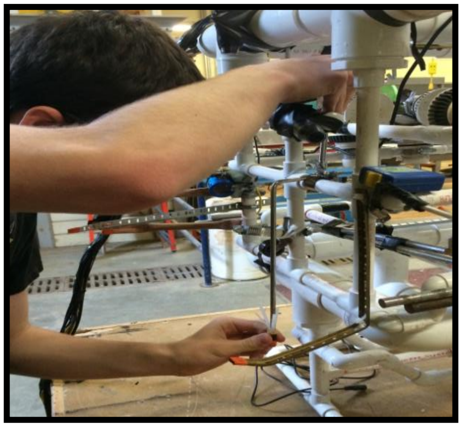


Figure 11: A team member attaching a tool and camera to *The Black Pearl*.

To measure the diameter of the iceberg, we attached a tape measure to the PVC frame with two zip-ties facing backward. Some of the tape measure protrudes from of the roll and is held out by electrical tape. The tape measure hooks around the PVC with the zip-ties securing it and when the robot is reversing, it is able to measure effectively the length of the diameter of the iceberg. We've also added a hook to *The Black Pearl* that will function as the seat for the passive acoustic sensor as we bring it down to the sea floor to a designated area.

Control System

Our control system is comprised of ¼" luan plywood box and basic analogue components. We utilize two eight-way joysticks with red push buttons. We have a switch that controls power to the entire system. The joysticks operate all the motors on *The Black Pearl*: forward/reverse, ascend/descend, and strafe right/left. We decided on two joysticks because the pilot, while operating the entire robot, does not need to remove his or her hands from the two joysticks after the power is turned on or until the power needs to be turned off, which means efficient operating technique. We chose an analog control system over a digital system because an analog solution is a more durable, economical and troubleshooting is simpler, especially if failures occur during a product demonstration.

Figure 12: The control box for *The Black Pearl*, above.

Vehicle Systems

Every member of our company is a first time participant in the MATE ROV competition. We made an original ROV design for this year's competition; the first step for the ROV was to brainstorm for the shape of the frame, motor locations and camera placements. Within our technical building, we have manufacturing capabilities that allow us to build any components that our design required. We purchased only stock materials (PVC pipes, metals, wires, switches, cameras, motors, etc.) and did not use any commercial systems for our project. We decided to re-use some materials in shop to help lower the cost of the ROV, and to prevent a time delay while waiting for delivery. All major systems of our ROV were designed and built by the members of our company in house using basic components.

The propulsion system is made up of motors pulled from simple bilge pumps. The motors we purchased are highly effective and durable, which makes them a smart purchase for the ROV project. The impellors are removed from the bilge pump and we designed an aluminum shaft that fits over the motor stem and receives a plastic propeller, turning the bilge pump into a thruster. We mount these thrusters using two hose clamps to any part of our pvc frame. The motors ($45.65 each) are controlled by joysticks ($19.40 each) that are a crucial part for the operation of the ROV. An H-Bridge relay is inserted at the controlled end of the motors allowing the thrusters to operate in both directions creating greater control of our vehicle with a simple, reliable system.

Figure 13: A typical motor found on *The Black Pearl*

The cameras are an expensive purchase but immensely important to the operation of the underwater vehicle so we decide to re-use last year’s cameras in order to save valuable time and lower the overall cost of the ROV. Some cameras had slight technical issues, the wires connecting to the cameras were frayed which required repair. To fix the cameras, we had to cut the wire and re-attach the end fitting, solder it and then apply electrical tape. Although we were able to re-use some basic parts in our shop, all of our team members were new to this competition so we started from scratch in search of task solutions.

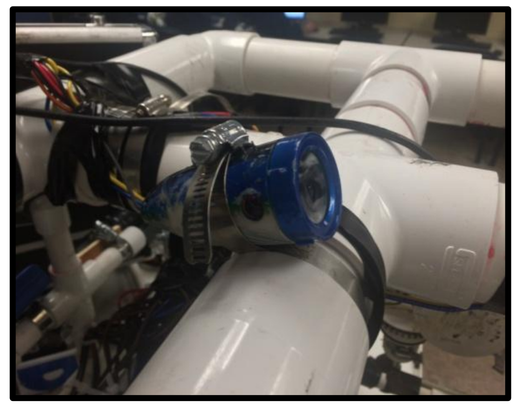


Figure 14: A typical camera found on *The Black Pearl*.

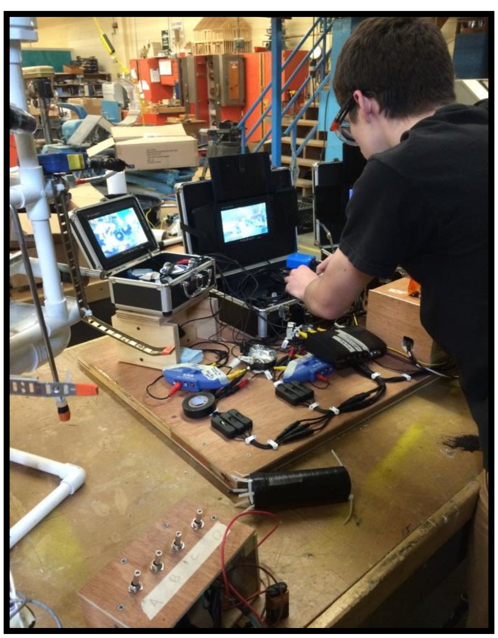


Figure 15: Above, a team member sets up camera views.

For the cameras, we have three monitors that allow us to switch through eight different camera views to most effectively view tools and operate *The Black Pearl*. Each camera has its own power switch allowing us to only power cameras that are currently in use, this minimizes power draw and keeps the flow adequate to the rest of systems being operated. The camera video signal is fed into three a/v boxes which allow us to choose between camera views with the flick of a switch. Determining camera positions and grouping views together for simultaneous viewing was an extremely important part of our project and it took a real team effort to get this system to work.

The Black Pearl Budget Summary

Funding

Type	Description	Amount
1	Funding Provided by School Department	$ 1,000.00
2	Funding Provided by GNBVT Engineering Shop	$ 1,000.00
3	Fundraisers	$ 250.00
	Total Funds	$ 2,250.00

Expenditures

Item	Description	Quantity	Units	Unit-Price	Cost
1	Snap-Action Wire Block	8	each	$ 0.95	$ 7.60
2	PVC - Pipe 2"	1.0	each	$ 6.85	$ 6.85
3	PVC - Pipe 1/2"	1.0	each	$ 21.14	$ 21.14
4	PVC - Fittings 1/2"	1	each	$ 12.87	$ 12.87
5	PVC - Fittings 2"	14	each	$ 1.89	$ 26.46
6	Wire - 18 AWG - 100' Rolls	10	each	$ 14.99	$ 149.90
7	Zip Ties 8" 100/box	1	each	$ 19.99	$ 19.99
8	Zip Ties 5.5" 1,000/box	1	each	$ 22.00	$ 22.00
9	Electrical Tape 3/4" X 30' 9 Pack	1	each	$ 15.49	$ 15.49
10	Relay	8	each	$ 2.25	$ 18.00
11	Solder 25'	1	each	$ 5.99	$ 5.99
12	Hose Clap 10 Pack	3	each	$ 7.40	$ 22.20
13	Joy Sticks-analog w/ push button	2	each	$ 19.40	$ 38.80
14	Switches - Toggle	1	each	$ 3.25	$ 3.25
15	Switches - Rocker	1	each	$ 6.97	$ 6.97
16	Swimming Noodle	3	each	$ 4.99	$ 14.97
17	Foam Board Insulation	1	each	$ 11.68	$ 11.68
18	Measuring Tape	2	each	$ 8.26	$ 16.52
19	2"x4x8' Wood Fir Stud	2	each	$ 2.67	$ 5.34
20	Propellers	12	each	$ 2.89	$ 34.68
21	Bilge Pump Motors	14	each	$ 45.65	$ 639.10
22	1/4" Luan Plywood 4'x8'	2	each	$ 28.28	$ 56.56
				Total	$ 1,156.36

Note: No items were donated for this project.
No services were donated for this project.

The Black Pearl Budget Summary - Continued

Value of Re-Used Items

Item	Description	Quantity	Units	Unit-Price	Cost
1	Monitors - Re-used- value listed	3	each	$ 189.00	$ 567.00
2	Cameras - Re-used - value listed	8	each	$ 89.99	$ 719.92
				Total	$ 1,286.92

Total Final Vehicle Value

1	Purchased Items	$ 1,156.36
2	Re-used Items - Value	$ 1,286.92
	Total Value	$ 2,443.28

Remaining in Budget

1	Product Budget	$ 2,250.00
2	Expenditures	$ 1,156.36
	Total Amount Left in Budget	$ 1,093.64

Traveling & Logistics Costs to International Competition

Item	Description	Quantity	Units	Unit-Price	Cost
1	Flights - St. John's, Newfoundland	8	seat	$ 689.00	$ 5,512.00
2	Lodging - Hampton Inn St. John's	6	room/5 days	$ 752.00	$ 4,512.00
3	Meals - Per Diem(Gov. Services Rate)	32	pp/day	$ 83.00	$ 2,656.00
4	Rental Car - 2 Minivan	2	per van	$ 723.00	$ 1,446.00
5	Room Cleaning tip, parking, gas, etc	5	per day	$ 50.00	$ 250.00
6	Team T-Shirts	16	each	$ 30.00	$ 480.00
7	Shipping	2	each way	$ 528.00	$ 1,056.00
8	Transportation between school and airport	2	bus	$ 150.00	$ 300.00
				Projected Cost for Traveling & Logistics	$ 16,212.00

Troubleshooting

Troubleshooting is a major aspect in the design process. When problems occurred during testing we had to work under pressure to identify and solve the problem at hand. There was always room for improvement after testing. We made a scoring sheet and took notes while testing to record our results. This helped us stay organized and focused when we came back from testing. We were able to set up a game plan to follow so that we used our time wisely.

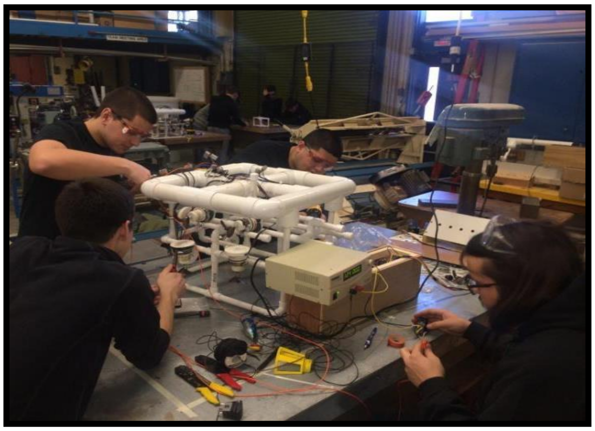


Figure 16: Team members are running a dry test on the motors, cameras, and tools

There were many different testing procedures we used on the ROV. Before heading to the YMCA for the pool test we went through a checklist at shop. A dry test and buoyancy test had to be completed and approved by our instructor. A dry test consisted of plugging in the power to the ROV and making sure all controls and motors were functioning properly. We tested the buoyancy in a small tank that we have in our shop. We then added weight or foam so that the ROV would be as close to neutrally buoyant as possible (with a slightly positive buoyancy). At the pool we would set up a simulated version of the competition and try to score as many points as possible. We realized the best way to score the most points was to complete the tasks in a specific order. To be more efficient we grouped together the most similar tasks so that we were not wasting time traveling from task to task. We found the most important thing while in the pool is to use the time to your advantage. After each testing day we would compile all our notes and brainstorm as a team the best way to improve our design and the execution of tasks. Some of our most energetic discussion cenetered on our tactical choices for tast order and testing assignments. The competition for lead pilot culminated in several rounds of complete demonstration runs with Kolby and Taylor virtually tied for average points scored during the runs. This sort of healthy competition helps our team prepare by pushing each other to be their best and growing our confidence for the final demonstration runs and the hours practicing are priceless.

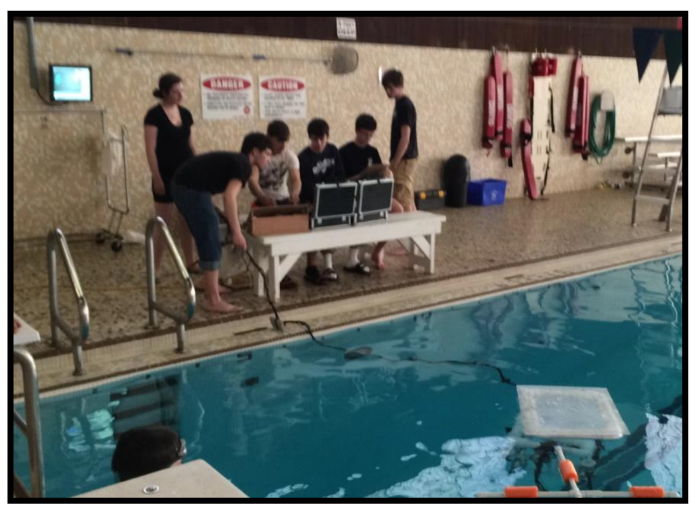


Figure 17: Testing at the YMCA pool.

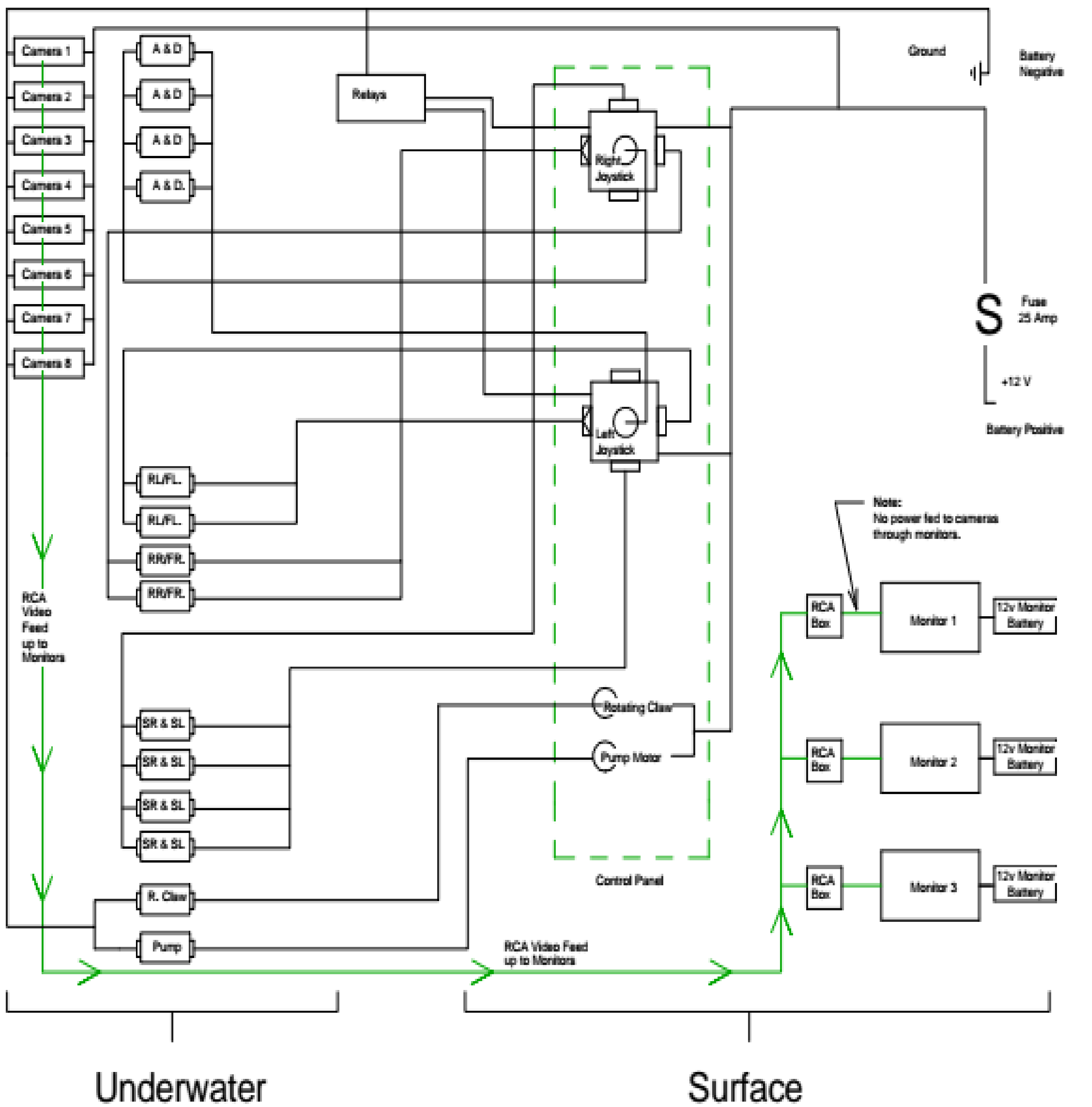
Safety

Safety was the number one priority and was always taken into consideration while designing and building *The Black Pearl*. We ensured safety at all times during the assembly of the robot, not just for ourselves but everyone involved by implementing several safety steps. One of which was using personal protective equipment (PPE) this was important while constructing, transporting and operating the ROV. The PPE we used were safety glasses, rubber coated gloves, ear plugs and steel toe boots which were used at different times when the robot was being worked on or transported. Safety glasses were worn whenever we worked on the ROV to ensure that our eyes were properly protected. Earplugs were worn when operating heavy machinery to protect the operator's hearing. Rubber coated gloves were worn when transporting the ROV to provide a better grip reducing the chances of dropping the robot preventing damage to it and us. Steel toe boots were used at all times throughout the construction of the robot this was to make sure our feet were protected if something heavy was to fall on them.

Figure 18: The system we employ for safety.

Along with using PPE there were several other processes which took place for maximum safety. Most importantly everyone who worked on the ROV received a 10 hour OSHA Safety Card ensuring we were all taught the proper methods to work safely. Also when soldering connections of wire, position holders were used to hold the wires in place so that no one would be at risk of getting burned. Every motor was shrouded to protect the tether and anyone's hands from getting hit with a rotating propeller. The robot is also slightly positively buoyant. This is in case of a malfunction; it will float up to the surface to be retrieved. The control box has a fuse so that if too much electricity is being put into the ROV no one gets hurt, instead the fuse will interrupt the circuit and everyone is safe. If there was ever an unsafe moment in progress, we would stop production immediately until a safe way to proceed was created.

Figure 19: Above are examples of the safety equipment we use while working on *The Black Pearl*.



System Integration Diagram

Figure 20: Pictured above is the System Integration Diagram of *The Black Pearl*, which shows how the motors on the robot are connected to the joysticks in the control box as well as the cameras connected to the monitors.

Challenges

While working on this project we encountered several problems that we had to overcome using teamwork and the design process. A technical problem we faced was that our original ROV frame was not completely sealed and it took on water during testing. To solve this problem the following day we designed and created an entirely new frame and emphasized the need to fully seal and fully seat all of the PVC joints to ensure that it would be watertight. The following week when we tested the ROV did not take in water and our methods of fixing it proved reliable and the ROV worked very well. Another problem we faced was the lack of transportation for testing. We only had one school van available at a time. This made it difficult for everyone to attend our testing sessions. To resolve this problem we broke up the group into two different teams, which we would rotate for testing. This allowed for a fair way to pick the students who went for testing each week.

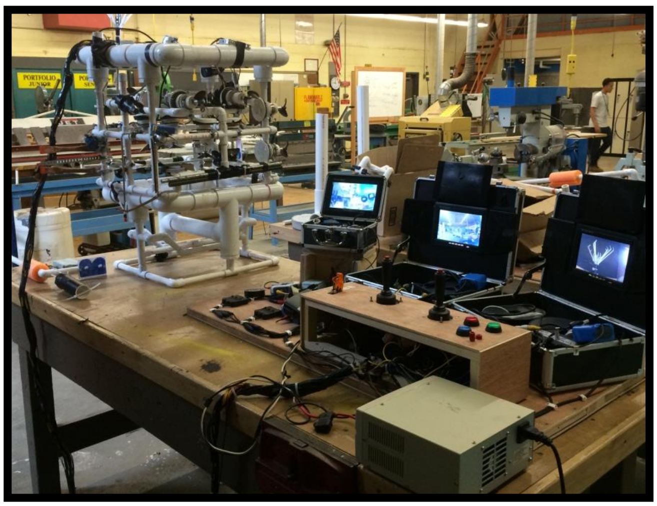


Figure 21: The completed ROV on its stand with the three monitors displaying camera views is shown above.

Lessons Learned

Throughout our time working on the ROV we have learned numerous skills, both technical and personal, helping us gain insight on bettering our abilities to perform many complicated tasks. Wiring two relays into an H bridge circuit for instance, was a very useful skill learned, one, which we applied many times during the building process of the ROV. Wiring an H bridge involved us gaining an understanding in how each wire functions in accordance to the inputs on the control box and allowed us to run motors in both directions with analog wiring. Other technical skills included soldering, measuring with calipers and using a multi-meter. We also used many computer software programs including Autodesk Inventor 2015 and National Instruments MultiSIM. In addition to these technical skills we learned many interpersonal skills like operating as a team, more efficiently managing time by setting daily objectives and learning how to better communicate our individual thoughts on the project. Lastly, learning how to plan our daily tasks and objectives by keeping track of time and dates on a shop calendar helped us immensely by teaching us to set realistic time constraints for our project.

Future Improvements

In the future we would like to redesign our control system to integrate wireless cameras and use a digital control system to reduce the weight of our tether. To do so we will need greater control of the propulsion system with lower voltage communications. A way we could do this would be by using Arduino systems which we have used in several other projects and would like to incorporate into our next ROV. To include the wireless optics we will have to research and purchase the proper cameras needed that will best suit our ROV. To overcome these technical challenges we will educate ourselves in these systems.

Reflections

The whole project was a success, but more than that the class came together as a whole. We've always been close as a group but this project was the first that needed full participation of the class. We worked hard together, we overcame the problems together, and we felt the joy of success together. Taking on the challenges of the MATE ROV competition has brought our group of engineers into more than a group, we became a family. We all, as a group, have worked together to bring out the best in each other. Thanks to the MATE ROV project, we have turned into a group of engineers that are so closely knit that there is no problem we could not overcome.

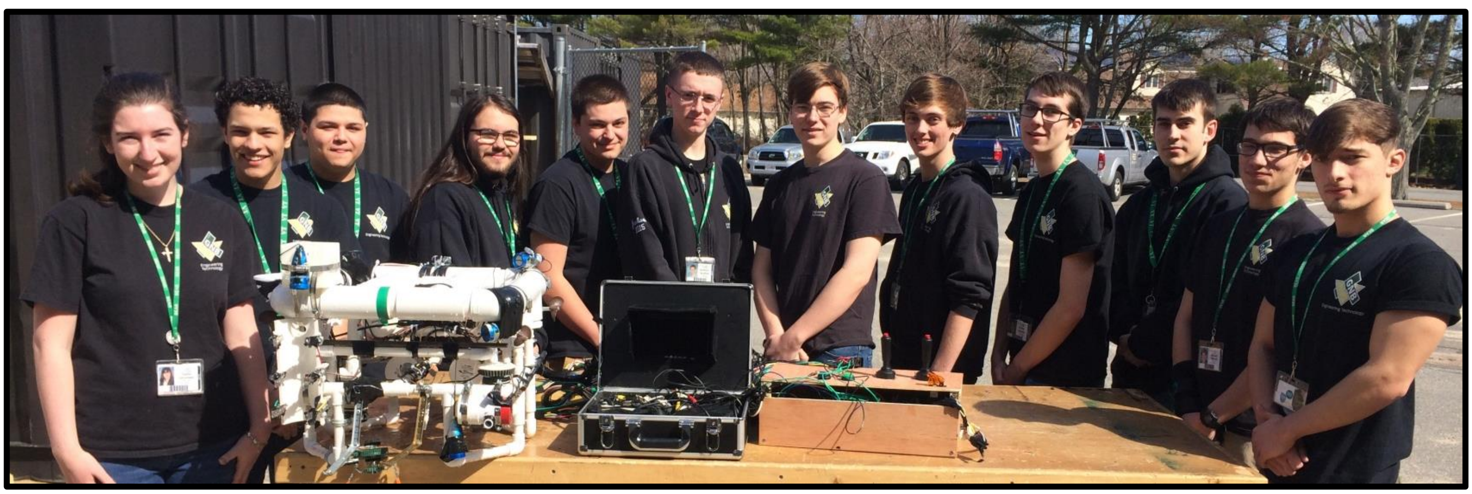


Figure 22: All the students in our shop are pictured here. Although not all are members of the final team, we would like to thank them all for being part of our great class and supporting us along the way. You all help make this a great senior year of high school. Thank You!

Teamwork

T.E.A.M. - Together Everyone Accomplishes More.

To get this project done, we realized that we needed to work as a team. We were able to complete our design and manufacturing of our ROV only because we worked as a team. We learned that if we divided the project into small tasks to accomplish throughout the day and we worked together, we got it done faster and with positive outcomes. To stay motivated throughout the day, we would have team meetings to discuss the goals we wanted to achieve before the day's end. In doing this we would go back to our task at hand excited and ready to work.

Figure 23: Testing the ROV and teamwork skills.

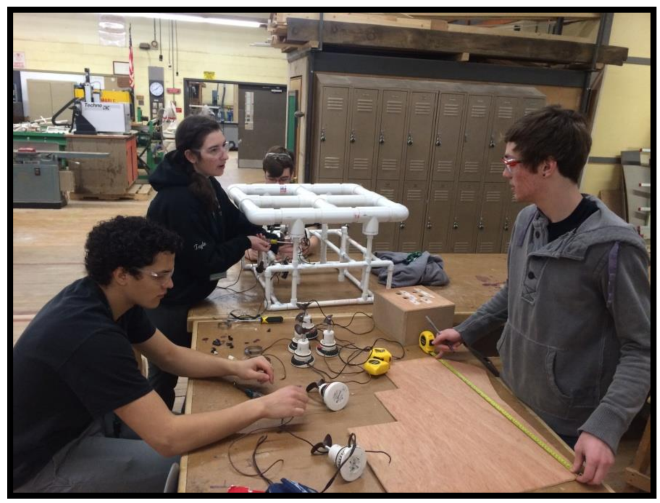


Figure 24: Team members discussing how to build the control box.

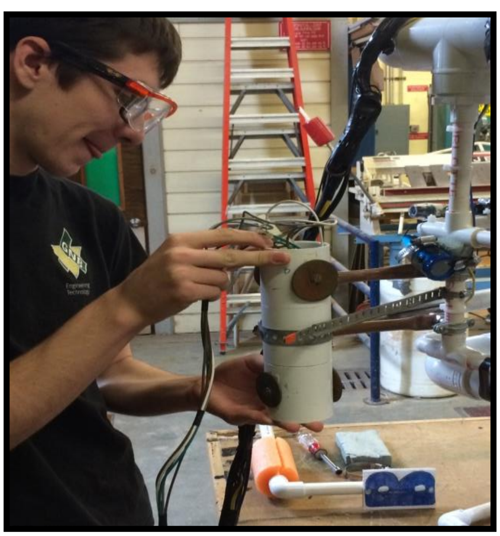


Figure 25: Testing the anode tester.

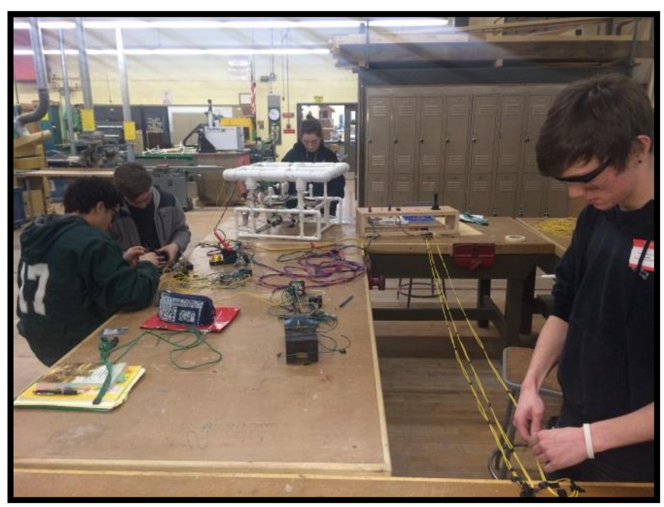


Figure 26: Working on the tether and control box.

Safety Checklist

Shop Manufacturing Checklist:

- Safety glasses for all team members.
- Every team member works with a partner.
- ROV off at all times while working.
- Team members must have certification to operate tools/machinery safely.
- All team members have shop-approved gear.
- ROV is disconnected from the power source.

Operating ROV Safety Checklist:

- ROV switch is off.
- No exposed wire.
- Fuse in place.
- Motor guards are tightly secured.
- Assigned team members place ROV in the water.
- Make sure all team members are clear of the ROV before connecting power.
- Turn the power on.

Tether Safety Checklist:

- Tether in a safe location while transporting.
- Tether wrapped correctly to prevent damage.
- Tether not tangled.
- Make sure no damage has been done with connection to the ROV.
- Make sure tether is straight before starting the competition.
- Avoid stepping on the tether.
- Give the correct amount of slack during your team's run.
- Make sure the tether doesn't tangle during the mission.
- Avoid pulling the tether.

Acknowledgements

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Figure 27: We would like to thank the entire faculty at the school and all people involved in running the MATE competitions, it's been a great experience and a fun way to learn.

Figure 28: Team members work on the props on the start of project seems a long time ago.

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