The Underwater Research Robot Company

Technical Report

Marine Advance Technology Education

June 26, 2014

The UR² Team:

Elizabeth Thomson: (Eighth Grade)

- CEO and Safety Officer

Breanna Domrase (Eighth Grade)

- Payload Specialist

Nathan Cosbitt (Eighth Grade)

- Pilot

Sam Beatty (Eighth Grade)

- Pilot

Savannah Thomson (Seventh Grade)

- Lead Engineer

Josh Beatty (Seventh Grade)

- Data Specialist

Bob Thomson

- Mentor

Katie Thomson

- Mentor

Mission

OUR COMPANY IS DEDICATED TO FINDING, PROTECTING, AND PRESERVING OUR HISTORY

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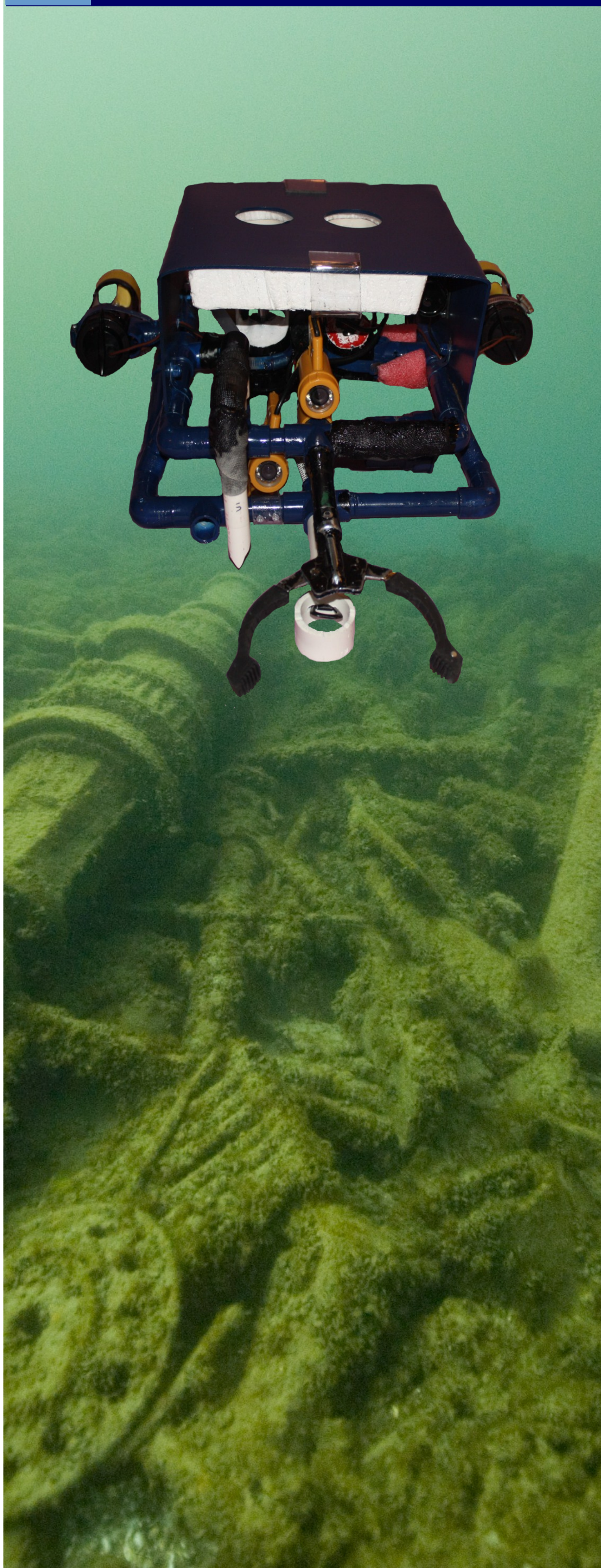

Abstract

We are a group of seventh and eighth grade students who are focused on preserving our freshwater resources and our local maritime history. We built our first ROV four years ago to collect samples from the wreck *Oscar T Flint*.

Our team designed a specially adapted remote control vehicle (ROV) for the purpose of completing this mission. We designed our ROV with payload tools to help document and identify shipwrecks located in the Thunder Bay National Marine Sanctuary. Our ROV is built small (35cmx20cmx22cm), in order to have a quick response in the water and navigate around shipwrecks. We developed a retractable measuring tool that allows us to accurately document shipwreck length, width, and height. Our thrusters have an engineered nozzle that provides three time the normal thrust to lift and remove debris from the shipwrecks. We have engineered multiple tools and sensors to collect conductive data and biological samples. We have tested our ROV to ensure that it is effective and capable of carrying out this mission successfully.

Underwater Research Robot Company

UR^2

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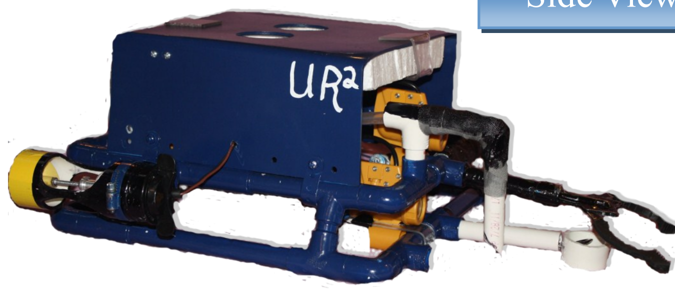
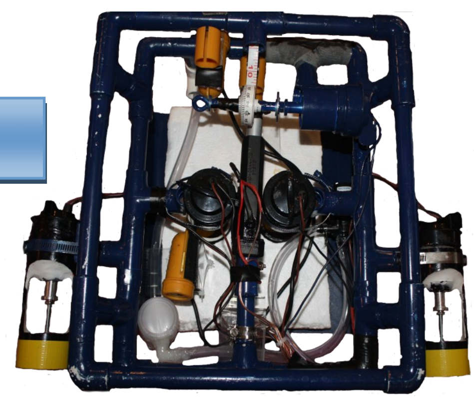
ROV Photo Profile

UR²

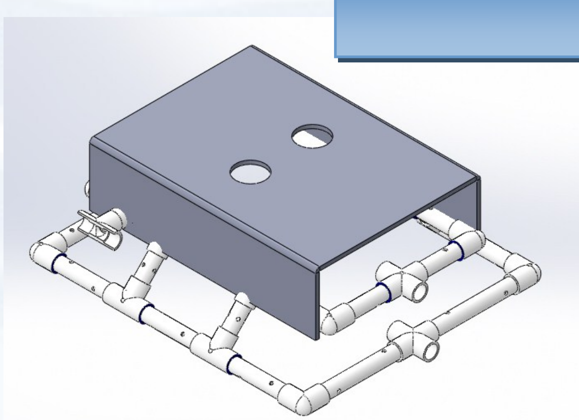
Side View



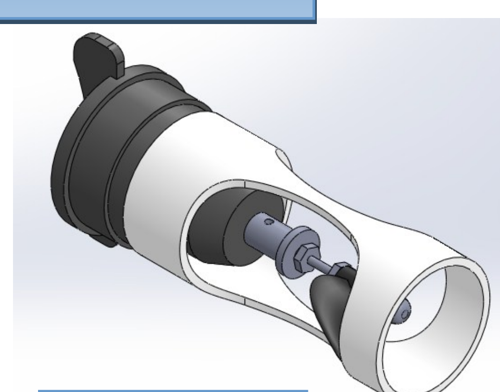
Bottom View



SolidWorks CAD composite of the original ROV frame and thruster design (see Appendix D for detailed drawing).



Frame Design



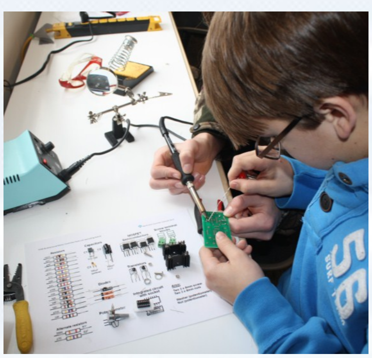
Thruster Design

Structure

PVC Framed Bottom / Polycarbonate Top

Our team took a long time deciding on how we would construct our frame. We began meeting just a few weeks after the Internationals 2013. We wanted to use a different frame material this year in stead of PVC pipe. Using our experiences from two International Competitions and the conversations we have had with other teams, we decided not to use all PVC tubing. We researched polycarbonate because it was light, affordable, and we could form it into any size or shape that we needed. Also, not many teams use this material so it would help us stand out in a good way. We designed everything with a purpose. We chose to make a compact frame so it could fit though the dimensions of the entrance into the shipwreck. The polycarbonate allowed us to develop a completely different ballast for our ROV. Our team decided to return to using PVC on the bottom structure of the ROV because it is more durable than the polycarbonate. Our actuator movement caused the polycarbonate to flex in and out, so this was another reason we went with the stronger PVC tubing. The polycarbonate top holds everything together and gave us an advantage that allows for better ROV control.

Control

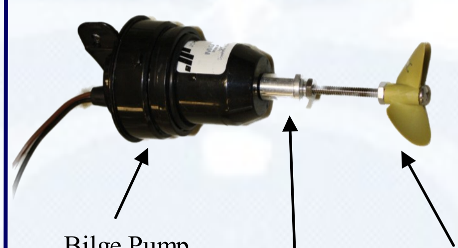


Sam and Elizabeth working on a control board.

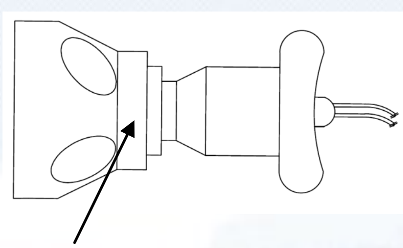
As we developed the frame, we stared developing a completely new control system for our ROV. We started by reviewing a lot of the basic circuit design in order to develop a more solid state controller. Our controllers are built with three by-directional, pulse-width modulators with H-bridges. This allows us to pilot our ROV with joysticks rather than DPDT toggle switches which are easier to maneuver. Our ROV has great control and makes moving around a shipwreck easier and avoid getting tangled into wreck debris. The controls are designed for two pilots, one controls ROV movements, and the other is for the manipulator, sampler, and measuring. We chose to have two pilots using the controllers because it is a lot harder to have one pilot doing all the work.

Propulsion

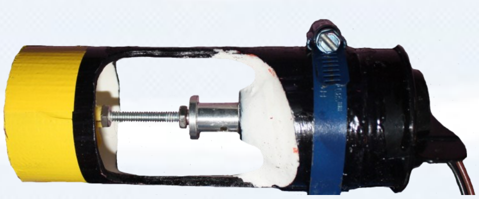
Basic Thruster Design



Old Thruster Design



Problem Area: water flow was slowed and not giving us same thrust forward as in reverse.



This design allow water flow over the motor and provides more thrust .

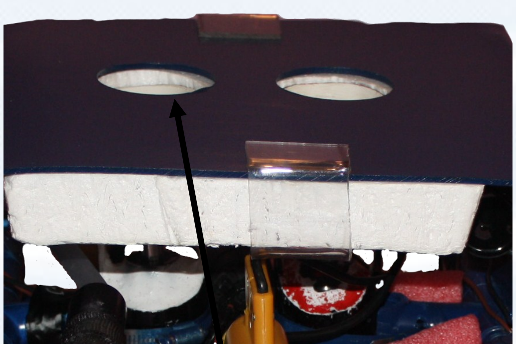
Propulsion is the one area that we spent the longest time developing a thruster that had more reliable thrust. Our design need came at the end of the 2013 International Competition because we had issues moving equipment. We had designed our ROV to move the equipment at our Regional, but when we got to Internationals, we could not lift some of the equipment. We were left to decide, either fundraise to buy commercial thrusters or engineer our current thrusters.

Last summer we got the chance to use a commercial ROV on a shipwrecks while on board the NOAA research vessel *Storm*. We took pictures of the commercial thrusters and started designing our own thruster based on what we saw. In the past, we have built and used thrusters with nozzles to control the water flow coming out of the thruster, but making the thrust increase in the other direction has been difficult. The power washes out in the other direction because of the shaft adaptor and the nozzle connection to the motor body. We took what we learned from the commercial ROV and developed a better thruster. This made a stronger propulsion system that allowed us to lift debris for this year's mission.

In engineering our new thruster design, we tested various propellers, motors, and nozzle lengths (see appendix B). We wanted to find the best combination that produced the highest possible forward thrust. Once we had that, we worked on different solutions to increase flow in the opposite direction. Our solution was a nozzle that was as small as possible, let the most water through, and caused the water to flow pass the thruster motor. We reached a combination of 9 Newtons forward and 7.5 Newtons in reverse.

Ballast

Closed cell foam in the center of the ROV frame.



Closed cell foam in the center of the ROV frame and vertical thrusters.

Using the polycarbonate gave us an opportunity to design our ROV to be ballasted in a way that allowed us to get away from the PVC ballast tubes. We were at the lake swimming and thinking about how we were going to put the tubes on the ROV if we use the polycarbonate and make a square top. I had my feet on a swim kick-board and I was standing on in about 1.5 meters of water. I thought that if the kick-board could keep me up then it should be way more than what we would need for the ROV. We started designing with the foam and it is closed cell which means that water can not get into it like normal plastic foam used for packaging.

Our ROV ballast was designed to be just positively buoyant. We designed it this way to help the ROV lift the mission sensors, debris, and hold position in the water column to deploy scientific equipment. Using this in combination with our pulse-width modulator controls, we can control buoyance with the thruster. The pulse-width modulator allows us to slow the thruster just enough so that the ROV becomes neutrally buoyant.

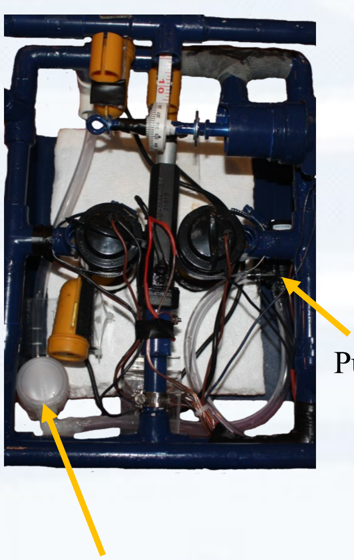
We placed the vertical thruster so that they would be in the center of the ROV just like a commercial ROV. The combination of using the polycarbonate, the closed cell foam, and the pulse-width modulators have given our ROV the ability to change vertical position with a slight turn of the variable resister controlling the power to the pulse-width modulator.

Out of the water our robot weighs 5.8 kgs. When the robot is in the water, it only takes 1.5 Newtons of force to lift it. This means that the majority of the thruster power is used for payload.

Retractor tool

Our ROV’s measuring tool was designed around experience we had two years ago that we had to manually pull it out and to retract it. Knowing this tool was not successful, we had to come up with a different idea. We eventually we modified one of our thrusters to have a tape measure attached to a retractor reel. We took that and hooked it up to a pulse-width modulator so we can limit the speed of the motor. When we connected it to a DPDT toggle switch it was way to fast and tangled the tape. There was no way to control the speed of the motor and the amount that comes out. We placed a loop on the end of the tape to snag screws on the ship. Our pilot flies backwards as the measuring tool measures the length, height and width of the ship. If we leave the modulator on, it adds some pressure on the tape and that allows us to recover the tape measure faster and it tangles less frequently.

Sample Pump



Pump

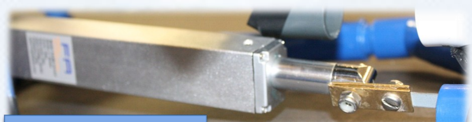
Sample Bottler

One of the tasks this year is to withdraw a bacteria sample. We took into consideration the sample amount of bacteria in the sample container is required for full points and the time need to retrieve the sample in. We wanted something that would take a good constant sample so we didn't have to keep retaking samples. We wanted something that would immediately take the sample with out delay.

We thought about several different ways we could take a sample. After a lot of brainstorming and debating, we finally decided on a 12 volt pump and eventually found a light weight and fully submersible pump. It fit our needs perfectly and it works great.

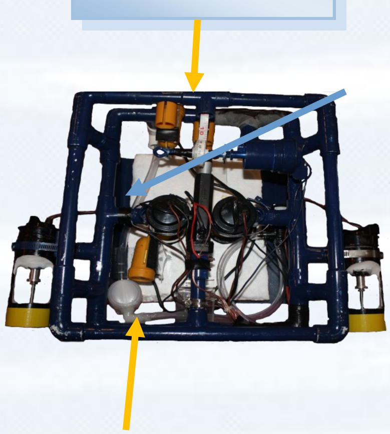
Payload Tools


Mechanical Grabber


Linear Actuator

In designing the grabber, we took a grabber stick and cut the pole off of it which left just the jaws and action rod. We took a linear actuator that we used last year and designed the frame around it so that it was in the centered and balanced. The actuator opens and closes the jaws of the gripper. The actuator only moves about six centimeter. This is just a little more than what we need to open and close the grabber. The pilot has to make sure he doesn't over drive the actuator because the actuator is strong enough to break the ROV frame. We know this because it has happened twice, but I think we've redesigned so it won't happen again. We positioned the actuator to be open all the way and then attached the arm. This way it won't split the ROV frame. We choose to purchase these part rather than building them because it was more reliable and our past attempts were not successful.

Cameras


Rear View Camera

The last thing we did was to place the cameras. In the past, we put the cameras on first and then find we would have to move them because we could not see to use the payload tools. So we designed the layout for them last this year. We built cameras, but they were not as successful as we hoped so we went back to commercial ones. The ROV is designed to support three cameras that are placed in positions to complete the mission. The cameras have a depth rating of 20 meters. We needed cameras that would support our budget, have the correct amount of cord length, proper connections with our monitors and be good quality. We placed one camera in order to see the operation of the mechanical grabber as we are using it. The second camera is placed to scan the below, locate equipment and have a clear view of the forward motion of the ROV. The third is used to see if our sample container is full. The cameras are color and they work great in poor lighting.

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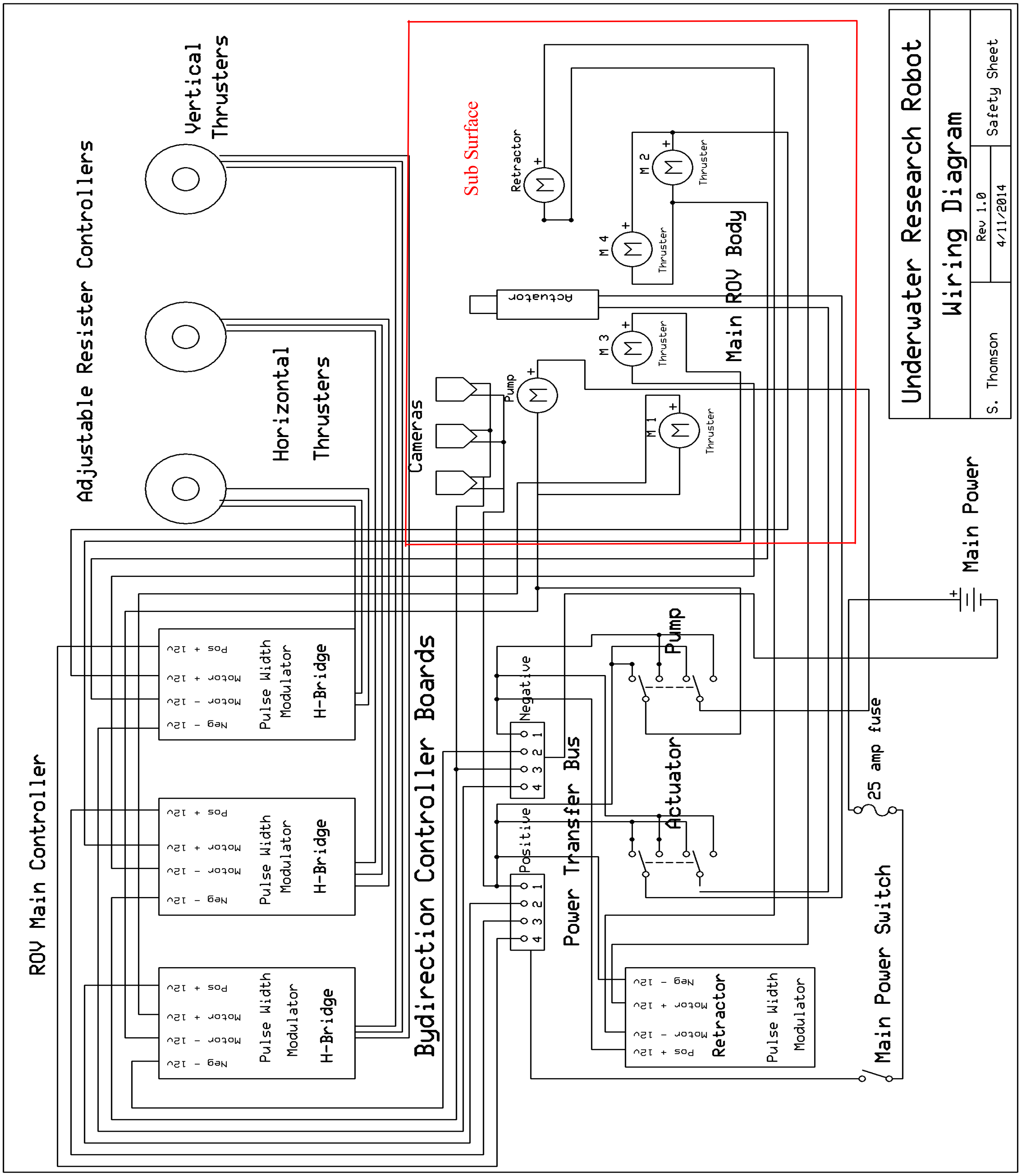
Electrical Schematic



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Expense Sheet

ROV Finical Development Report

Item	Cost	Source
Scheduled 40 PVC Pipe	$45.00	Besser Foundation
Polycarbonate	$12.00	The Robot Factory
Tether	$75.00	Besser Foundation
Controllers	$120.00	MATE Grant
Thrusters	$120.00	MATE Grant
3 Cameras	$240.00	Besser Foundation
4 –Way Monitor	$150.00	Besser Foundation
Retractor Device	$34.00	The Robot Factory
Conductivity Meter	$200.00	Donation
Mechanical Grabber	$18.00	The Robot Factory
Linear Actuator	$340.00	The Robot Factory
Electrical tape/wire ties	$17.50	The Robot Factory
Swim Board	$8.00	The Robot Factory
Pool Time	$300.00	The Robot Factory
Total Team Cost for ROV	$0	Donated = $1,579.50

Projected Funding Source	Funding Support
Personal Donations	$2,200.00
MATE Grants	$400.00
Ossineke Building Supplies	$300.00
Robot Factory and TBNMS Estimated In-kind Support	$2,500.00
Estimated Travel Expenses (local team)	-$120.00
Total	$5,280.00

At our company work space, we work to maintain a safe and friendly work environment. Research teams have their own assigned area to store equipment and projects.

Our goal is to make every member of our company aware of situation that may lead to an injury or damage to equipment.

The Underwater Research Robot Company's goal is to provide a safe and positive work and learning experience. To do this our company has adopted our parent company's, The Robot Factory 4-H Club, safety procedures. Each company member must practice our three safety rules. First proper clothes must be worn while working on and with the ROV. This includes safety goggles, closed toed shoes, and long pants when working with cutting tools, soldering equipment, and industrial glues. The second rule is to work with a positive attitude. When you show-up to work, intend to get something accomplished. If you show-up to work and don't have something to do, you will most likely start messing around and that usually leads to someone getting hurt. Our last rule is to clean-up after yourself. Most injuries around the company come from someone slipping or tripping on something that was left on the floor and not put away. It can be as simple as some pieces of PVC tubing that got left on the floor.

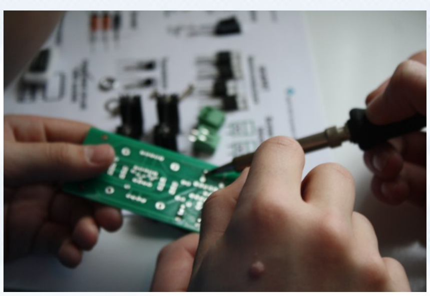
Our motto is a safe company is a happy company that leads to positive productivity. We have a great team, but if we don't have everyone on the team working together, that puts us at a disadvantage. This is why it is important for us to have consistent safety practices. Our Safety Check Sheet (Appendix A) is an example of our dedication to maintain a safe working environment. Also, we have appointed our CEO as our safety officer. She has the our teams permission to stop work at anytime if an unsafe condition occurs.

Safety features that we added to our ROV focused on improving stain reliefs, covering sharp edges/parts, warning signs, and keeping the majority of equipment inside of the frame of the ROV.

Underwater Research Robot Company

The Big Challenge

Our team was recently was honored for our hard work and determination at our state capital in Lansing, Michigan.



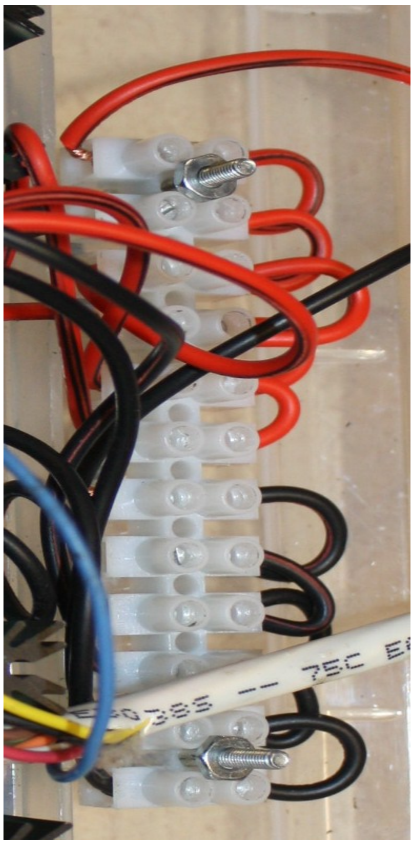
Building the motor driver cards took a great deal of time and work soldering and re-soldering. This made our ROV more controllable and allowed us to be more competitive.

Two of our greatest challenges was working to make our robot better then last year's and working around everyone's schedules in order to meet the demands of creating a better engineered ROV.

What also makes our team great is what also makes our team hard to beat. All of us are honor roll students and we play in multiple sports. We try not to miss a sport meet or extra curriculum activity, but some days this occurs in order to meet the responsibilities and needs of engineering our ROV, preparing for regionals, and to win our regional event. This makes us a strong competitor at the international competition. The international competition is in our home town and our goal is to win it and show Alpena what it is all about.

The second change we had to overcome was the bi-direction pulse width modulators. Soldering these boards together was tough. We got help from Bob Richardson. Mr. Richardson mentors the Scottsdale, MI ROV team that looks for downed fighter pilots lost during WWII. He helped train us on how to build and wire them. David Cummins from Alpena Community College helped us learn how they work. Mr. Cummins allowed us to come to his classroom and we learned how the H-bridge works to allow the modulator to change the direct of the thruster. We wanted to up-grade from DPDT toggle switch and make our ROV easier to control and more competitive.

Troubleshooting (A team effort)



Our power bus transfers the power to all the units of our ROV. This allows us to use one single point of power connected to a 25 amp fuse. All the connections are made in the main control box. It is safer and more reliable.

Last year we worked on trouble shooting and it helped us a lot. Mr. Thomson would break our ROV and have us find what happened. This helped us this year because we didn't have Mr. Thomson around much because he was working with younger teams and would only offered advice when we were really stumped. The best way to troubleshoot is to start at the source. So, lets say the actuator is not working, this happens every so often, so you start with the power. Does anything else work? If nothing else is working like the thrusters, than it has to be a main power problem. Maybe the plugs are not in the battery all the way or the fuse is blown.

Once you know you have good power, than it is either a loose wire (this is usually what happens to us) or the part is broken. We took care of the loose wires by soldering them together and sealing them. So, we hope we spend less time troubleshooting and more time getting the mission completed.

To help prevent problems and to create a more reliable power source, our team redesigned our single point power source. This design provides a source of power into the main controller. Inside the main controller the power is transferred to the rest of the ROV's needs. The last few years, we had spilt the power outside the control box and had lots of wires running everywhere. Our new design has eliminated tangling and that separation of wire connections. We accumulated over twenty hours of pool time testing all systems on the ROV, but pressed on until we solved all the problems.

Underwater Research Robot Company

Lesson Learned

Consistent Determination

Our first year qualifying for Internationals, second place.

Our second year qualifying for Internationals, first place.

Our third year qualifying for Internationals, first place.

Our team learned many things, but one important thing was that no matter what we all did, if everybody didn't agree on it, things never worked right. For example, when we built the frame design, it was originally going to be all polycarbonate, but we came to an agreement, we were not ready to completely leave the reliability of PVC tubing. This was something we compromised on, so that each member of the team felt they had a say in the design of the frame. Last year we would disagree over the smallest things and we took more time getting things done. This year we understood there was no time to waste and work much better as a team. Most of our team has been together for four years and we won our regional two years in a row so we know each other well. We experienced typical ROV problems and we solved them like a true team would. As a team, we have learned that it takes solving problems and compromising on ideas, so that everyone feels good about the solution. This is a hard thing to do sometimes, but we believe this made us better competitors.

We learned to save time and money by reusing many of the parts. Items that we reused were the grabber, the thruster parts, actuator, control boxes, and tether wires. This allowed us to spend more time working on the problems for this year's competition.

As a team we learned the importance of safety. We have had team members injured in the past, because we did not have the right safety precautions in place. Our company decided to challenge ourselves by learning how to use SolidWorks (CAD program) in order to make our diagrams more technical. All-in-all these experiences taught us new life skills.

Future Improvements

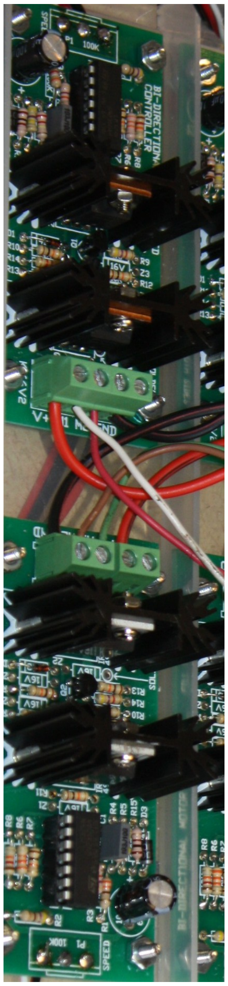
One thing we would like to do is get more involved with active research. We have worked with some shipwrecks and invasive species, but we would really like to complete a research project of our own and get it published.

This image is from the *Oscar T. Flint*. It was taken with our ROV in 15 meters of water. We would like to build an ROV that could reach some of the deeper wrecks at 30 and 40 meters.

One of our team's future goals is to purchase commercial thrusters. We completed a lot of testing on our thrusters to come up with the best possible design that we could build. Commercial thrusters allow our ROV to move easier and raise heaver objects. This year we designed our ROV to be positively buoyant which helped in completing the mission tasks of raising and exchange testing equipment, however it takes all the power of the ROV to get back to the surface. We believe commercial thruster would give us the reliable power when needed for tasks.

The second improvement we would like to see happen is to learn more about micro processors so, that we can take the next step in control systems. We started learning about micro processers this year, but we know just the basic information about them and have a great deal more to learn before using them well.

Another possibility to improve upon would be to have more experience with the SolidWorks program. We started working with solid works at the beginning of the year, but we were already building our ROV so it was a little to late. We hope to have more time and experience working with SolidWorks in order to design a ROV first and then building it from there.



The bi-direction controllers that we received through a grant with the MATE Center, the Thunder Bay National Marine Sanctuary, and the Robot Factory have made piloting our ROV very easy.

As a whole, our team has matured and grown together. We have made a lot of improvements since last year. We have gained experience, improved ours skills, knowledge, confidence & team work. Critical thinking is another asset gained.

Our team has improved at presenting our ROV missions to the public. We have gained confidence presenting to small and large groups of people. When we do a presentation, we are very confident with our words and answering questions. All members are ready to answer questions as needed. The team has had an excellent experience with our ROV from interviews at schools to interviews around the state. We have also done many presentations throughout the years. We have been interviewed several times on our local television news station. In addition to being interviewed on the local news, we were interviewed on two different radio stations and NPR!.

We are always a dedicated team no matter is we are meeting to create, working on repairs or practicing the mission. Our team works well together and encourages one another. Each member is of equal value. Our team recognizes that we need each other to be the best that we can be.

Due to several design changes and adjustments, our ROV is much more efficient. It is more hydrodynamic which decrease drag, so we don't waste time in the water getting down to the mission. Last year's ROV required two of us to carry it and we still had a hard time. Because of the small more compact design of our current ROV, it is easier to handle it, even by one person. This year our control system is more complex which allows it to pilot better, complete mission tasks and shipwreck research. We could not have made the up-grade to our control system if all team members did not contribute. It was truly a team effort.

Thank you very much to:

Our SolidWorks Mentors

- Chris O'Bryan
- Eric Kalenauskas

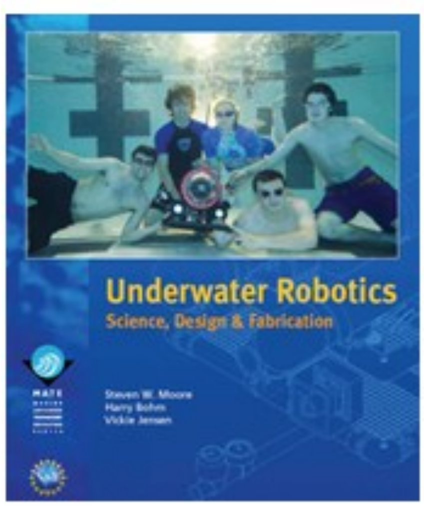
Technical Advisors

- David Cummins: Alpena Community College
- Bob Richards: Stockbridge High School

Team Support

- Thunder Bay National Marine Sanctuary
- The Robot Factory 4-H Club
- Marine Advanced Technology Education Center
- SolidWorks Corp.
- Oceaneering
- All the volunteer divers and NOAA staff members that make everything possible.

References:



Underwater Robotics: Science, Design & Fabrication : by Steven W. Moore, Harry Bohm, Vickie Jensen

Safety Check-Off Sheet

◊ All team members have no lose clothing, everyone is wearing closed-toe shoes, and long hair is tied back.

◊ Work area is free from hazards and safe for working with ROV.

◊ Tether, power cables, and extension cords are free and not tangled.

◊ 115v outlet has a visible GFI.

◊ Inspect ROV for any visible problems or lose equipment.

◊ Power up ROV and equipment.

◊ Complete operation check on thrusters, cameras, and payload tools.

◊ On deck personnel inspect ROV deployment area and water is clear to place ROV in the water.

◊ ROV is placed in water and on deck tether hander give the “Away” signal.

Thruster Development Data

Motor	Propeller	Directional	Brass Adapter	Length/Wholes	Output (Newton's)
500	4.5 cm	none	Brass Adapter	13.97 cm	4.8
750	4.5 cm	none	Brass Adapter	13.97 cm	6.2
1000	4.5 cm	none	Brass Adapter	13.97 cm	6.3
1250	4.5 cm	none	Brass Adapter	13.97 cm	6.2
500	4.5 cm	yes	Regular Adapter	13.97 cm	6
750	4.5 cm	none	Regular Adapter	13.97 cm	6.1
1000	4.5 cm	yes	Regular Adapter	13.97 cm	6 to 7
1250	4.5 cm	yes	Regular Adapter	13.97 cm	6
500	6.35cm	none	Regular Adapter	13.97 cm	6.2
750	6.35cm	none	Regular Adapter	13.97 cm	5
1000	6.35cm	none	Regular Adapter	13.97 cm	4.8
1250	6.35cm	none	Regular Adapter	13.97 cm	6.4

Appendix C

Team Readiness Timeline

2013 MATE International Competition

Finished 15th Place

July 2013: Start brainstorming new frame and thruster design

August 2013: Building and testing thrusters. (see Appendix B)

Sept. 2013: Building frame and reviewing basic ckt design workshop

October 2013: Build thruster proto types and final testing. Ideas for tether and order materials for tether.

November 2013: Basic frame completed and camera workshop

December 2013: Frame, thrusters, and camera system in place. Brainstorming mission subsystems and how measure wreck.

January 2014: Building controller boards and designing new control panels.

February 2014: Putting all components together to start setting buoyance and mission testing sub systems

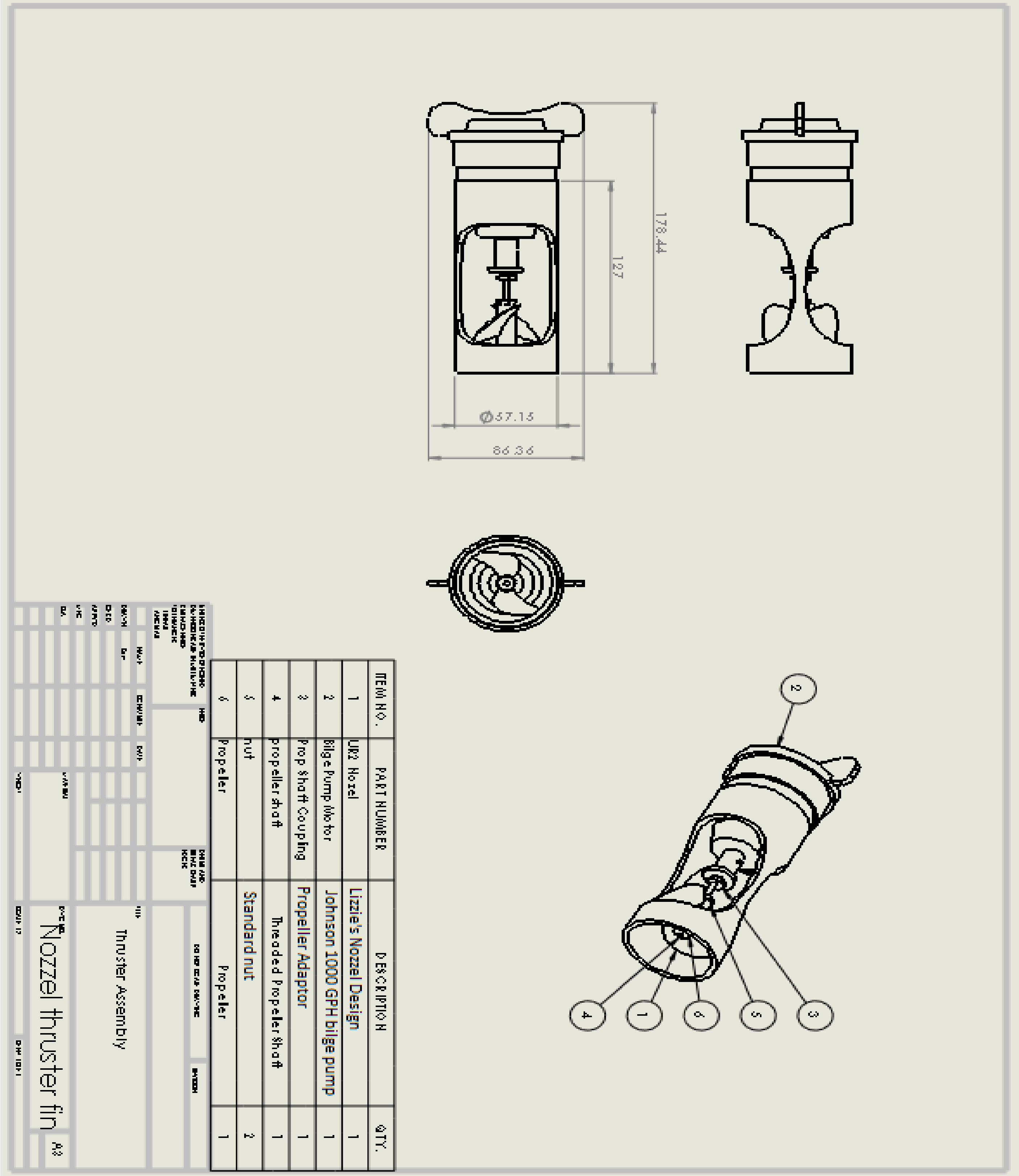
March 2014: ROV in the water to test and fix issues with buoyance and sub systems. Begin drafting tech report.

April 2014: In the pool for complete system operations. Continue drafting tech report and poster ideas. End of April practicing mission

May 2014: Practice mission, complete tech report, and poster.

May 17, 2014: Place in top three at Great Lakes Regional.
(We placed First)

June 26, 2014: Internationals—goal is to place in the top ten.


178.44
127
Ø57.15
86.36
2
4
1
6
5
3
ITEM NO.
PART NUMBER
DESCRIPTION
QTY.
1
UR2 Nozel
Lizzie's Nozzel Design
1
2
Bilge Pump Motor
Johnson 1000 GPH bilge pump
1
3
Prop Shaft Coupling
Propeller Adaptor
1
4
propeller shaft
Threaded Propeller Shaft
1
5
nut
Standard nut
2
6
Propeler
Propeler
1
Thruster Assembly
Nozzel thruster fin
A3