The **Underwater Research Robot Company**

Technical Documentation

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Marine Advance Technology Education

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Abstract

Underwater Research Robot Company (UR²) is comprised of five students ranging from eighth to ninth grade who are focused on protecting, preventing, and preserving the Atlantic Ocean's ecosystem. Our UR² company has five years of experience as a team and a diverse skills in building remotely operated vehicles (ROV). The UR² robot has been upgraded and engineered to complete the three product demonstrations successfully by more advanced thrusters, a digital control systems, and specialized tools. UR² is designed to fit through the 75cm x 75cm hole in the ice. Our waterproof actuator is positioned to sample marine life such as a sea urchin and algae and also to repair and remove corroded pipelines.

We engineered a an underwater tape measure to determine iceberg volume and length of a pipeline. We also created an anode sensor to measure voltage of specified points on the leg of the oil platform for ground faults. We developed a pump to push water through a pipeline system to check flow paths to insure the flow path is correct. The UR² utilizes four cameras placed at exact locations for optimal visual aid. Underwater Research Robot Company is fully prepared to apply our inventive engineering and experience to perform these product demonstrations successfully.

Underwater Research Robot Company

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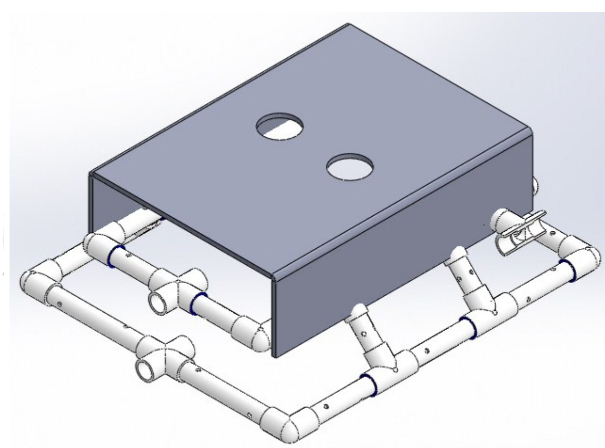
ROV Photo Profile

UR²

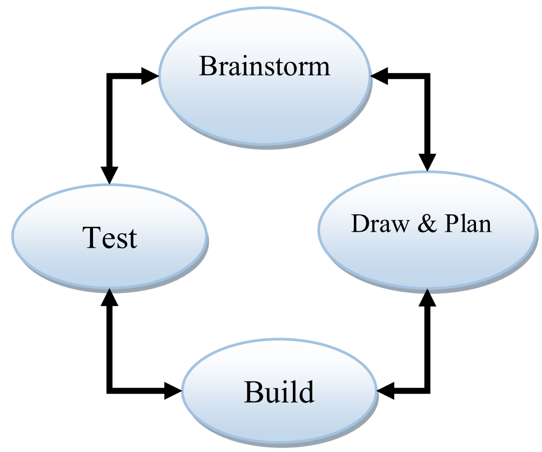
Top View

Side View

Original Concept Idea



Engineering Design Process



Each year we employed the engineering design process to improve and develop a more advanced and reliable ROV. We used this process to guide every step of the project:

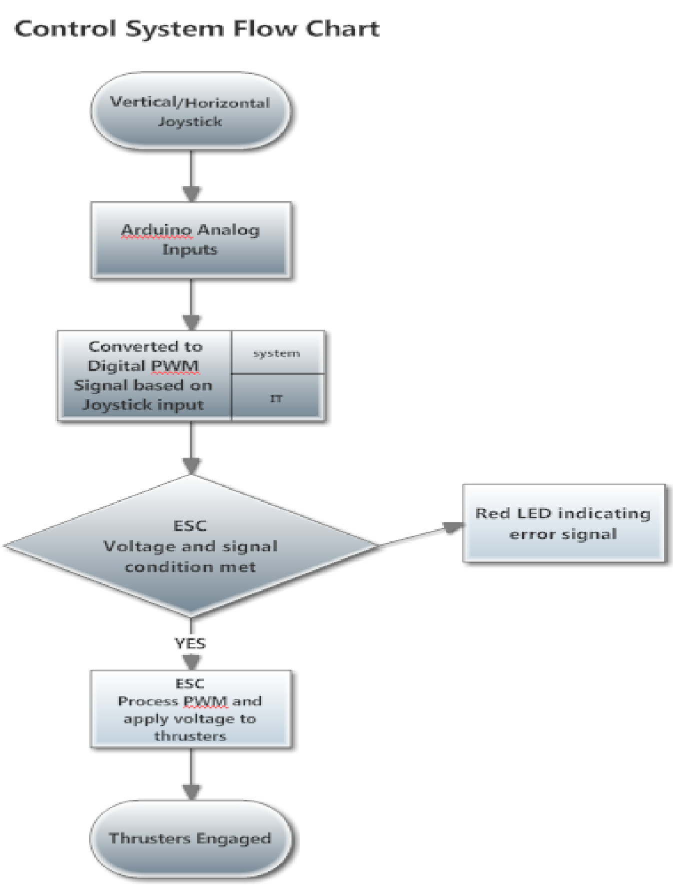
1. What is the problem or idea we want to solve or improve
2. Research the problem and past solutions
3. Brainstorm ideas for possible solutions
4. Evaluate potential solutions
5. Choose a solution: design & refine
6. Build a testable version for a proposed solution
7. Evaluate if the solution is what we want and will it work.

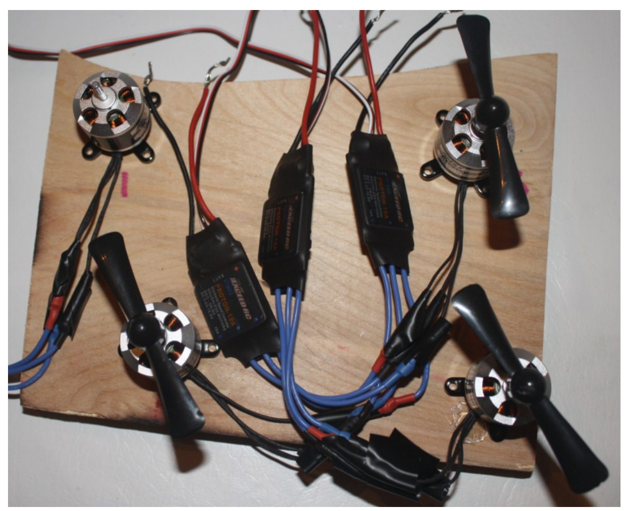
The Underwater Research Robot Company has produce several ROV designs that have experienced many successful research projects and competitive achievements. As a company we want to continually push the boundaries of our knowledge and expertise in order to continue developing high quality and reliable ROVs. This year's request for proposals left us to consider many design changes that would present challenges are design team has not attempted before. Before we started any design discussions, we broke the requested tasks down into individual sections and identified all the needs for this design (Appendix D). The goal was to brake this project down into parts and then sub-dived the jobs to different team members. Pilots look at each individual part of the tasks and decided what tools or equipment would be needed on the ROV to successfully complete the task. Then we grouped design needs and tasks that were similar to reduce redundancy in design.

We found this process extremely useful in keeping the design on task. We were able to keep the project on budget allowing us to be under budget. Being under budget provided funds to correct or refine a design solution that was not working as expected. Our goal was to develop an ROV system that was not only successful at meeting the requirements of the RFP, but went beyond those expectations to produce an ROV that was small, compact, and portable.

One way we discussed to improve portability was tether size and weight. To reduce the weight of the tether, we needed to change the way we control the ROV. This required a lot of background reading and work to change from a primarily analog system with many conductors to more digital input system with less conductors in the tether. This change lead to several problems including: funding challenges, needing more thrust to handle the currents in the flume tank at Internationals, rebuilding the entire robot from the ground up, and fulfilling our commitment to the Shipwreck Discovery Project hosted by the NOAA and the Thunder Bay National Marine Sanctuary.

At this point the design team started working on separate parts of the ROV design in order to reach our spring commitments and to be ready for the Great Lakes Regionals and Internationals in order to demonstrate our product design. The first steps we took to developing a new robot design was to look at control systems and new framing materials. We created a data systems flow chart to work as a guide to develop and understand our control system.





We built a thruster mock-up to understand how the Ardiuno would interact with brushless motors and understanding the power distribution before we actually used the final thruster configuration. These motors were inexpensive and gave us the freedom to experiment without damaging an expensive thruster.

Structure

PVC Framed Bottom / Polycarbonate Top

Our team took a long time deciding how we would construct our frame. If we changed the tether design and the type of thrusters, we would need to have room on the frame for additional electronics and bigger thrusters. We wanted to use different frame materials this year instead of PVC pipe. Using our experiences from three International Competitions and the conversations we 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.

We designed a compact frame so it could fit though the dimensions of the entrance of the ice hole. Our company 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 beyond what we felt comfortable with, so this was another reason we kept some of the stronger PVC tubing.

Ballast

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

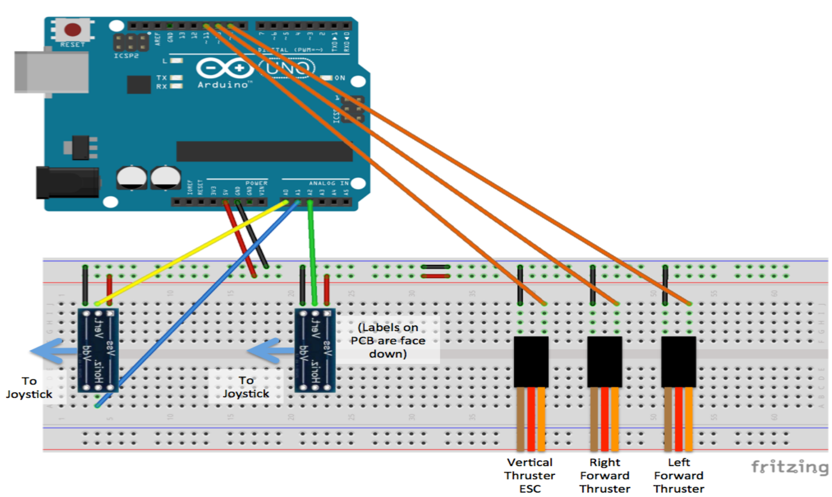
Using the polycarbonate gave us an opportunity to design our ROV to be ballasted in a way that allowed us to get away from the PVC ballast tubes. Our ROV ballast was designed to be positively buoyant. We designed it this way to help the ROV lift the mission sensors, debris, and hold position in the water column to work on equipment and pipe. We placed the vertical thruster so they would be in the center of the ROV just like a commercial ROV. The combination of using the polycarbonate and the closed cell foam has given us the ability to change vertical position with a slight adjustment of the joystick. On the surface, our robot weighs just a tenth over 5 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 tools.

Control

Parallax Inc. Analog Gimbal Joystick used to input pilot movement directions into the Arduino processor board.

In order to solve the tether problem, we needed to reduce the number of conductors in the tether. This required redesigning our ROV's control system. We brainstormed various ideas. The company developed background information through three different support resources. Our design team collaborated with Mathew Cook, President of SeaView Systems. In discussions with Mr. Cook, he assisted the company in creating different thruster and control systems. We were limited on the amount of funding. So, he suggested using Blue Robotic's thruster and developing our control system to be more like a RC control system. This solution solved our tether situation and increased the thrust of the ROV, but no one from the company really understood programming the RC receiver. We worked with Mike Precord, a student from Alpena Community College's Marine Technology Program, to instruct us on the RC controls. Issues concerning power and signal lost made us rethink the design and consider a microprocessor system, that uses an Arduino board with analogue joystick control. Blue Robotics and David Cummins, ACC's Marine Technology Professor, provided background and technical support.

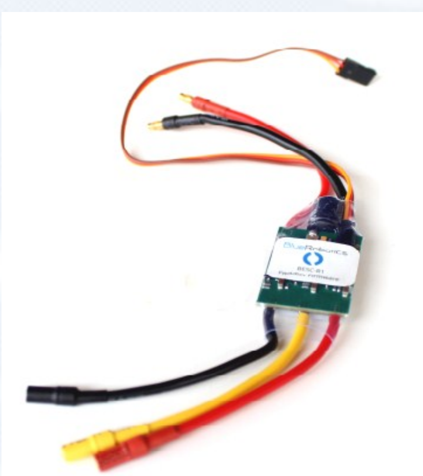
The Arduino system accommodates us with a reliable processor control that was within our budget. With support from Blue Robotics, we were able provide the Arduino the code to compute and convert the analog input from the joysticks to the electronic speed controllers needed to input power to the T100 thrusters.



Using the Arduino board and a general circuit breadboard, we were able to use the technical support from Blue Robotics to develop our analog to digital conversation processor. The Arduino takes the voltage signal from the joysticks and creates a digit modulated pulse signal that is read by the ESC which in turn controls the output of the thrusters.

Propulsion

Blue Robotics T100. This thruster produces five times the thrust of our previously designed thrusters. The T100s provide us more than enough power to work the ROV in heavy current situations.



25 amp electronic speed controller take the digital PWM signal and use that to control the power to the T100 thrusters

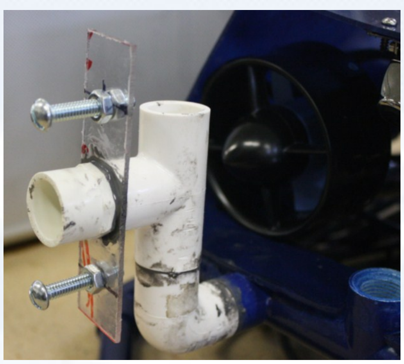
In the past, propulsion has been the one area that we spent the longest time developing a thruster that had more thrust. The conversion to the Blue Robotics T100s has solved our thrust issues, but created a variety of other time consuming design problems. The T100s require electronic speed controllers, but the design for the waterproof speed controllers was not ready for the market in the time period we needed the thrusters to build our ROV. That left us with waterproofing our own ESCs. We had two basic design decisions to make. One, to place the ESCs in a watertight enclosure on board the ROV or seal the ESCs individually. We decided to go with sealing them individually because we have watched many teams have issues with leaks and lose their watertight integrity ruining the whole electronics enclosure. Plus, we had never done it before and felt our design needs were already challenged. We had no fund available to purchase a commercial enclosure and felt building our own at this point was no a good option. We have waterproofed many things over the years and felt sealing each ESC would be easier and we could afford to replace one or two ESCs if something failed versus all of the ESCs at one time. Sealing the ESCs would be not effect our budget and would save us time. We sealed the ESCs using the two part acrylic that we used to make our first camera housing on our first robot.

To mount the T100s, we needed to design our own mounts. Our custom thruster mounts were created by forming polycarbonate sheeting that we heated and formed into mounting brackets. By creating our own brackets, we were able to place the thrusters to specific locations on the ROV to maximize the use of the T100s to meet our design needs.

Retractor Tool

Our ROV's measuring tool was designed around the experiences we had last year measuring the shipwreck. Knowing this tool was not successful, we had to come up with a different idea. We eventually 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 too fast and tangled the tape. There was no way to control the speed of the motor and the amount that comes out. This was the reason we change to the pulse width modulator. Our pilot flies backwards as the measuring tool measures the diameter and height of the iceberg. 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.

Anode GRD Tester

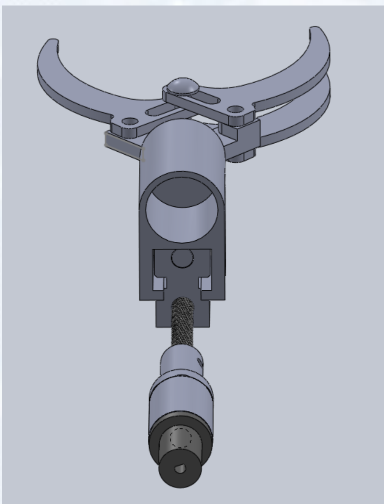


We designed a special sensor to be use for testing the grounding of anodes by measuring the voltage of four specified points along the leg of an oil platform to determine which are the subject to galvanic corrosion. We use a combination of PVC piping, polycarbonate, and bolts (electrode sensor contacts) to test the four contact points on the wellhead to see which one of them are grounded.

Flow Verification Pump

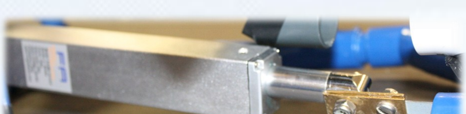
We thought about several different ways we could push water through the valve system to check flow direction in the third mission. After a lot of brainstorming and debating, we finally decided on a 12 volt pump and eventually found a lightweight and fully submersible pump. It fit our needs perfectly and it works great. Then we adapted the pump to mate with the two-inch pipeline system's coupler, ensuring a solid connection to the pipe so that we may force all of the water we have through it. This way, we do not lose any of the pressure within the water that we are pumping through the pipes.

Payload Tools



Prototype rendering of grabber that is designed to attach to a replacement bilge pump motor that can be controlled with a simple DPDT toggle switch, or a more advanced PWM control.

Mechanical Grabber



Linear Actuator

Each year the mission requires a lot of lifting and moving objects and sensors. Our team started designing a prototype of a new analog controlled manipulator. The goal was to create a simple, reliable design that could be controlled by a variety of ways. Using SolidWorks, our 3D printer, and the help of a mentoring engineer, Quade Kimball, we designed a lighter and more affordable grabber (see appendix for full design drawing). The grabber was not ready for this year's competition and we were not able to work out all the design flaws at the time we starting building our ROV frame. We have been able to print all the parts and assemble a usable prototype, but we do not want to risk the reliability of such an import component of the ROV for the sake of having a new design. The retractor pin breaks under a load when closed all the way.

As a result of our testing, we went with a simple, but very reliable design. Our design used 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 center and balanced. The actuator opens and closes the jaws of the gripper. The actuator only moves about six centimeters. 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 we think we've redesigned it 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.

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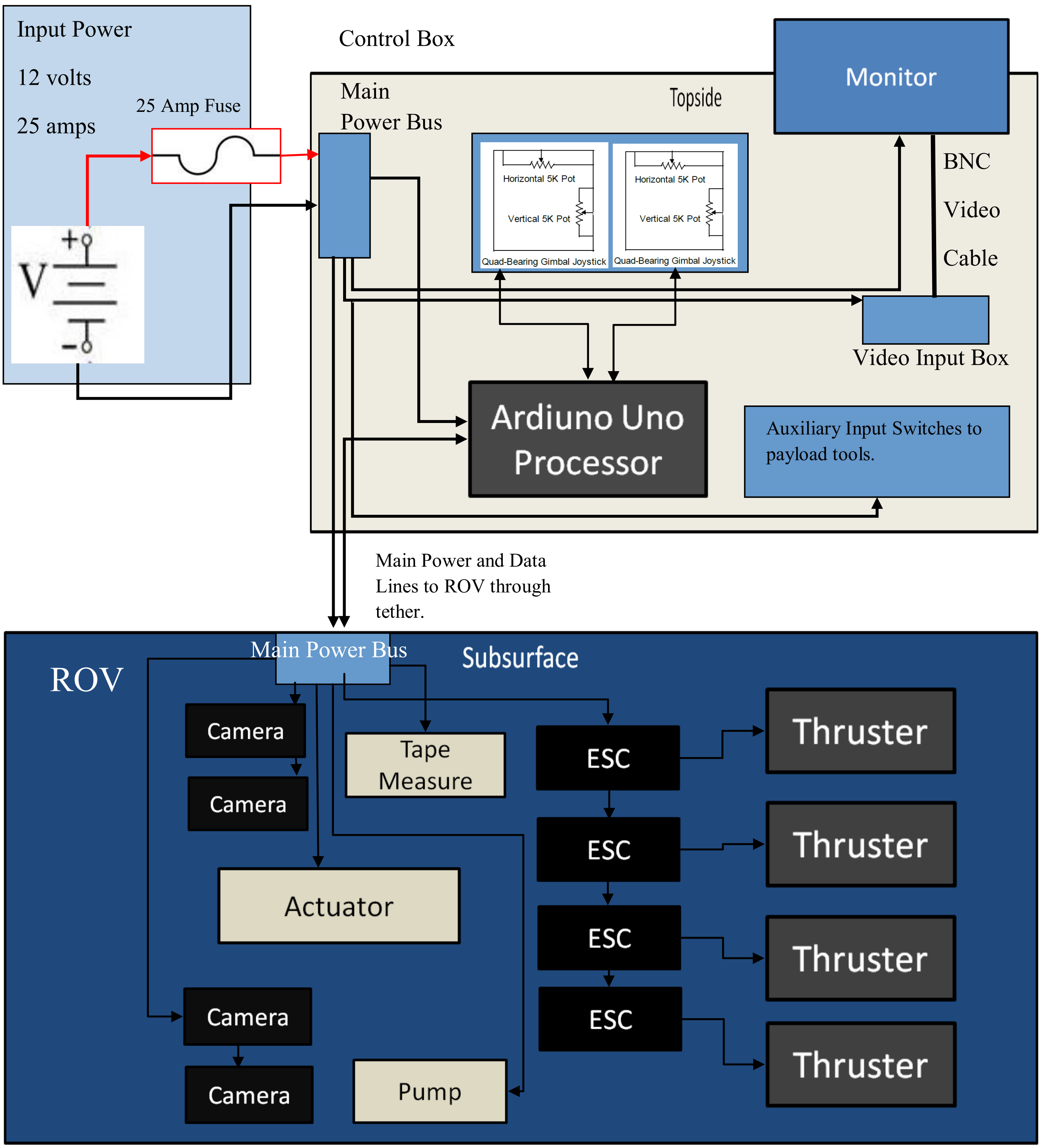
System Integrated Diagram (SID)



Financial Summary

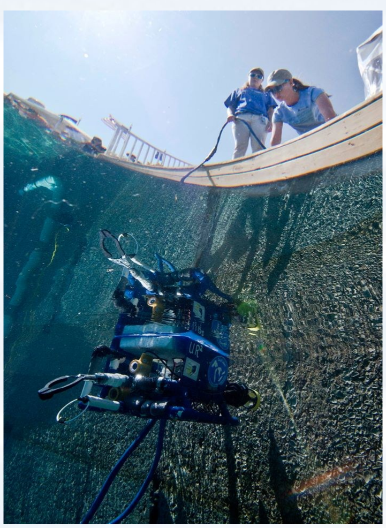
Appendix E lists travel budget for Internationals

Underwater Research Robot Company

Available Funds	Funding Support
Personal Donations	$2,200.00
Grants	$400.00
Ossineke Building Supplies	$300.00
Robot Factory 4-H Club In-kind Support (Not totaled as Available Funds)	($2,500.00)
Total	$2,900.00
Expenditures	**Cost**
Scheduled 40 PVC Pipe	$45.00
Polycarbonate	$80.00
Tether Conductors	$15.00
Adiuno Controller System (all parts including practice control model)	$350.00
Thrusters and ESCs	$1100.00
Consumables (Tape, solider, etc…)	$110.00
Pool Time	$600.00
Total	$2,300.00
Re-used Parts	**Value**
4 Cameras	$260.00
4 –Way Monitor	$150.00
Actuator and Grabber Mechanism	$400.00
Retractor Device	$34.00
Total	$840.00
Total Value of ROV	**Amount**
Purchased Items	$2,300.00
Re-used Items	$840.00
Total	$3,140.00
Final Accounting Summary	
Available Funds	$2,900.00
Expenditures	$2,300.00
Net Balance	**$600.00**

Company Safety

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



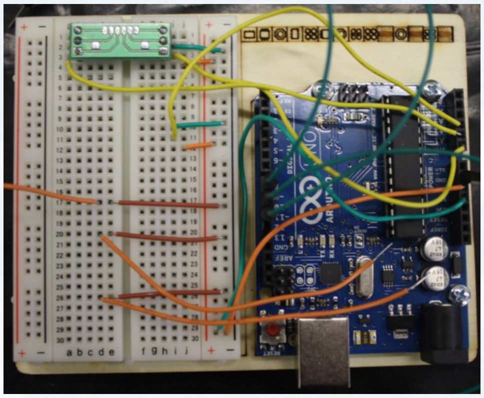
Our goal is to make every member of our company aware of situations that may lead to an injury or damage to equipment.

The Underwater Research Robot Company's goal is to provide a safe and positive working 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. Show-up to work with the intention 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 company, 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 our company's permission to stop work at anytime if an unsafe condition occurs.

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

The Big Challenge



This is the Arduino Uno we used to control our Blue Robotics T100s. This has taken us a long time to make the conversion and we hope it makes our ROV more competitive.

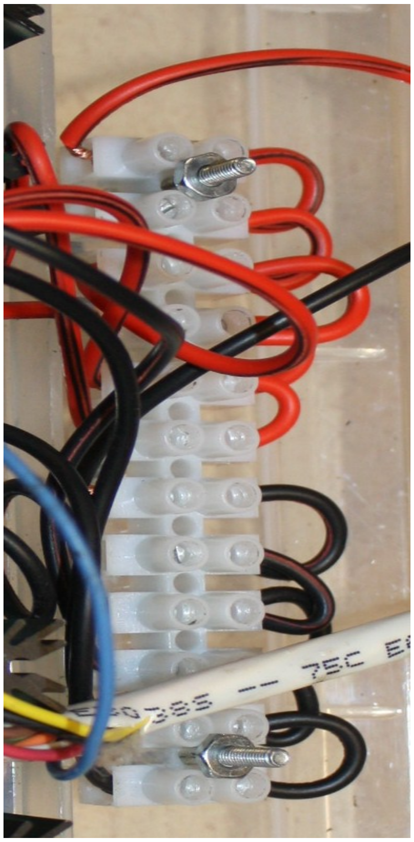
Two of our greatest challenges were working to make our robot better then last year's and working around everyone's schedules in order to meet the demands of creating a better engineered ROV. Everyone of our team members are very busy with academics and sports. We have to meet after school and not everyone can make it all the time. This makes it hard to develop and share ideas. We try not to miss sporting events, or extra curriculum activity, but some days this occurs in order to meet the responsibilities and needs of engineering our ROV.

Due to the challenges of having student athletes on the team, we had a long time teammate leave the team in order to take advantage of some sport's opportunities that came her way. We've had the same team for nearly five years. This left us short handed and we all had to take on more responsibilities. We hope this may be an opportunity to pull in some new people and make the team bigger and bring in people that may not be so sport orientated.

Internationals always brings us opportunities to share and learn. Making it to Internationals has been one of our best learning opportunities and it has pushed us to be a better team.

As a growth point, not knowing how the Arduino processor works and the difference between brushed and brushless thruster has been a long haul and we still have a ways to go with it. If it wasn't for the support of Mr. Cummins and Rusty from Blue Robotics, we would have never made it into the water. All of the team was needed to gain the knowledge to not only learn to build a new control system, but to have the ability to fix it. We have been a team for many years and we have grow together, but understanding the Ardiuno has to be one of our greatest achievements. We still have many things to learn and grow, but that fist step was a big one and trusting our ability to make that step was huge. It has given us confidence to keep learning.

Troubleshooting (A team effort)



Our power bus transfers the power to all the units on the ROV. This allows us to use one single point of power connection to a 25 amp fuse. We originally thought this caused our power loss and the wires were connected wrong. The company thought this was the problem because we were not always gentle with our controllers during practice and had loosen connections.

Two weeks before last year's International Competition during our practice runs in the pool, our actuator and other subsystems stopped working. When we recovered the ROV and started checking for power, everything was good and the subsystems were working correctly. It continued all through practice. The next day we started taking things apart checking connections, making sure seals were good, and power was steady. We thought that it was something broken in the actuator, and we even took that apart. Everything was working well, so we went back to the pool and it happened again. Our technicians believed it was water in a connection causing problems. Back out of the water it started working fine. Just by chance, the pilots were still trouble shooting the actuator, when our payload specialist picked up the ROV by the tether and most of the ROV lost power. Upon further examination, we saw that it wasn't the problem. It was our strain relief on the ROV side of the tether. We had tightened it too much, so the wires in the tether had been stretched and broken. Every time we lifted the tether, the actuator would work because the wires touched, but when we dropped it down, the actuator wouldn't work because the wires had separated.

To fix it, we cut the entire tether off ten centimeters in front of the strain relief and then we reconnected the wires. We made sure the wires were soldiered together. Then, we put the strain relief on the tether. This time we made sure that we didn't tighten it as much as we had previously. We tested it to make sure it worked and it was successful. Lesson, tighter is not always better.

Lesson Learned

Consistent Determination

Our second year qualifying for Internationals, first place.

Our third year qualifying for Internationals, first place.

Our fourth year qualifying for Internationals, first place.

Our team learned many things, but one important thing was that no matter what we did, if everybody didn't agree, things wouldn't 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 each member of the team felt they had a voice 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 we work much better as a team. The majority of our company has been together for four years and we won our regional three 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 company, we have learned it takes problem solving and compromising, so everyone feels good about the solution. This is a hard thing to do sometimes, but we believe this makes us better competitors.

We learned to save time and money by reusing many of the parts. Items that we reused were the grabber, actuator, control boxes, and tether wires. This allowed us to spend money on other items and more time working on the design 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.

Future Improvements

Shipwreck Discovery is a project that our team is participating in as mentors for a one week ROV camp this summer and than later in the summer, we will be using our own ROV to investigate a shipwreck.

This anchor sit on the forward part of the *Oscar T. Flint*, which shouldn't be there because the wreck was dynamited. The picture was taken with our ROV in 15 meters of water last year. That is what got us interested in investigating these artifacts.

This year's improvements have all focused on designing and building a stronger and more technically advanced ROV than we have ever attempted before. Our company may have raised the bar a little to high, but we took on the task. This year we are using an Arduino processor to control our ROV. This year's goal was to just get the thruster working and learn as much as we can for future years. We have watched a lot of teams at Internationals design some amazing technology. Our company though it was time for us to start taking some bigger risks. In the past, we always agreed that simple was best because if simple breaks; it's easier to fix. We have seen many teams be successful and watched a lot of teams never make it to the water because loss of programming. With no risk, there is no reward and the Arduino opens a lot of learning opportunities including creating our own sensors and developing more advanced control systems.

After this year's competition, we teamed with the Thunder Bay National Marine Sanctuary, Alpena Community College, and The Robot Factory 4-H Club to put our ROV engineering skills to the test this summer. We will be investigating a shipwreck in the Sanctuary that has artifacts on it that don't belong there. After the *Oscar T. Flint* sunk, a demolition crew strapped dynamite to the upper half of the ship to clear the shipping lane and blew the top off of her. Sometime in her future, artifacts appeared on her. We have been tasked to document all the artifacts that we can find with our ROV and than research those artifacts in our local archives to see where these artifacts may have come from, or what shipwreck they were taken from and then placed on the *Oscar T. Flint*. This will be a true evaluation of our improvements to our ROV.

Since our previous competitions and experiences, our team has improved in almost all areas, such as teamwork, knowledge, confidence, skill sets, and problem solving. We have been attending these competitions and using the opportunities given to us by the wonderful people that presented them to us. We have developed so much since our first competition back in fifth grade, but that does not mean that we are using our potential to its fullest extent. Our team strives to continue rise in position in these competitions, drawing people and opportunities to us, letting us improve more and giving us experiences that we can reflect on and use to our advantage.

One of the opportunities presented to us because of our consistent improvement and developing skills was our team being invited to the Thunder Bay National Marine Sanctuary expansion celebration. The company had the opportunity to sit in with a small group of people to listen to a presentation by Dr. Robert Ballard, Dr. James P. Delgado, and Dr. Jane Lubchenco. At the time, we didn't think our company realized how special it was to be in the same room with these three pioneers. After the presentations were over, we waited for an opportunity for a picture with them. As we stood quietly waiting off to the side, Dr. Lubchenco noticed us standing there and came over to talk to us. We had our team shirts on and she inquired about the ROV competition. Then Dr. Ballard and Dr. Delgado join us as well. The three of them took the time to talk with us for over twenty minutes about robotics and underwater exploration. In the ROV world, it doesn't get much cooler than that moment.

Our team getting an opportunity to speak with Dr. Lubchenco, Dr. Delgado, and Dr. Ballard.

Thank you very much to:

Our SolidWorks Mentors

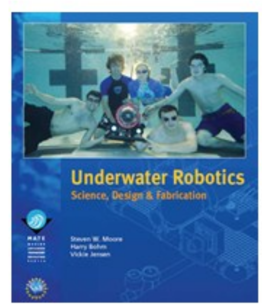
- Chris O'Bryan
- Quade Kimball

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.



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

Arduino for Dummies: by A Wiley Brand, 2013

Web Sites:

http://www.suncor.com/

http://www.hibernia.com/

http://www.provincialaerospace.com/

UR^2 Safety Check-off Sheet

Checklist Items	YES	NO	Action Required
Electrical schematics & power distribution diagrams	☐	☐	☐
Technical report	☐	☐	☐
RANGER CLASS SAFETY CHECKLIST (safety inspection)	☐	☐	☐

Part 2: Physical

Checklist Items	YES	NO	Action Required
All items are secure to ROV and will not fall off	☐	☐	☐
Hazardous items are identified and protection provided	☐	☐	☐
Propellers are enclosed inside the frame or are shielded that they will not make contact with items outside of the ROV	☐	☐	☐
No sharp edges or elements on the ROV that could cause injury to personnel or damage to pool surface	☐	☐	☐

Part 3: Electrical

Checklist Items	YES	NO	Action Required
Single attachment point to power source	☐	☐	☐
25 amp single inline fuse, no frays in tether or conductors.	☐	☐	☐

Underwater Research Robot Company Meetings Schedule

Designer: Katie Nicholson

Date: 9/13/14

Daily Tasks

Research how ROVs are used in areas with ice.	**9/13/2014**
Research parts that are unique to ROV's that are used in ice areas	**9/20/2014**
Discuss building options	**10/11/2014**

Design Ideas

Create basic sketch	**12/6/2014**
Sketch out the original tools for competition success	**12/13/2014**
Decided on tool ideas	**12/20/2014**

Compile Parts

Order parts through vendors	**1/24/2015**
Receive parts	**1/31/2015**
Make a prototype of ROV	**2/7/2015**

Testing and Evaluation

Create safety checklist for poolside	**3/7/2015**
Generate a testing checksheet	**3/14/2015**

Documentation Drafting

Technical Report Outline	**4/6/2015**
Technical Report writing	**4/8/2015**
	4/10/2015
	4/12/2015
Company Spec. Sheet	**4/18/2015**
Finalize Technical Report	**4/20/2015**
Poster Board Drafting	**4/21/2015**
	4/23/2015
Finalize Poster Board	**4/24/2015**
All CAD drawing Finalized	**4/27/2015**
SID Completion	**4/29/2015**

Competition

Pick team members roles	**10/18/2014**
Set goals and due dates for whole ROV team	**11/8/2014**
Cycle each due date for individual members	**11/22/2014**

Design Details

Finalize ROV frame sketch	**12/27/2014**
Compile a list of needed materials	**1/3/2015**
Find possible vendors	**1/10/2015**
Sequence operation	**1/17/2015**

Safety Finalization

Secure loose components	**2/14/2015**
Finish wire installation	**2/21/2015**
Mark areas that are dangerous	**2/28/2015**

Presentation

Create a presentation outline	**3/21/2015**
Distinguish certain roles for the presentation	**3/28/2015**
Practice Presentation	**4/1/2015**

Documentation

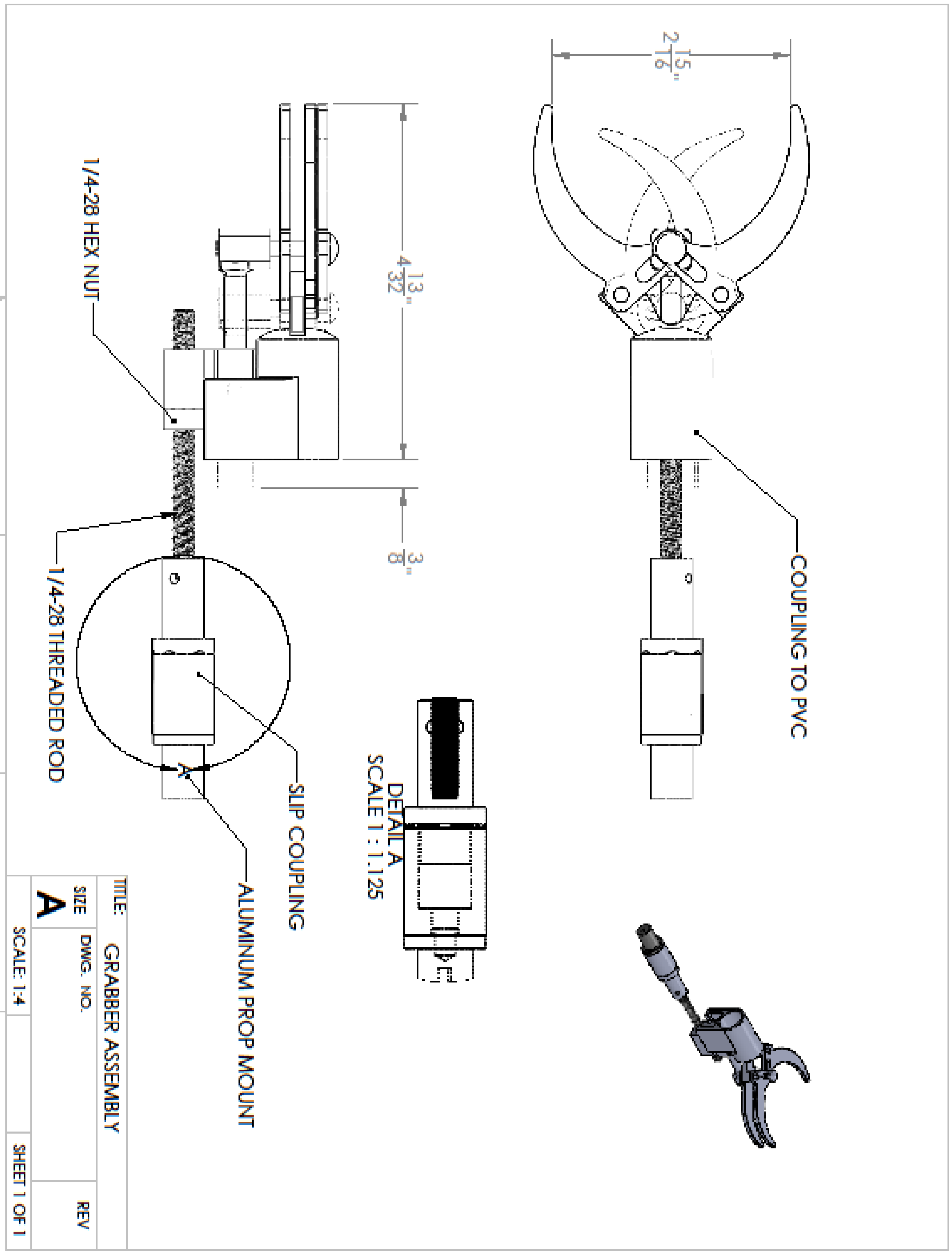
Technical Report	**4/24/2015**
Company Spec. Sheet	**4/18/2015**
Poster Display	**4/24/2015**

Pool Practice Days **4/15/2015-5/15/2015**

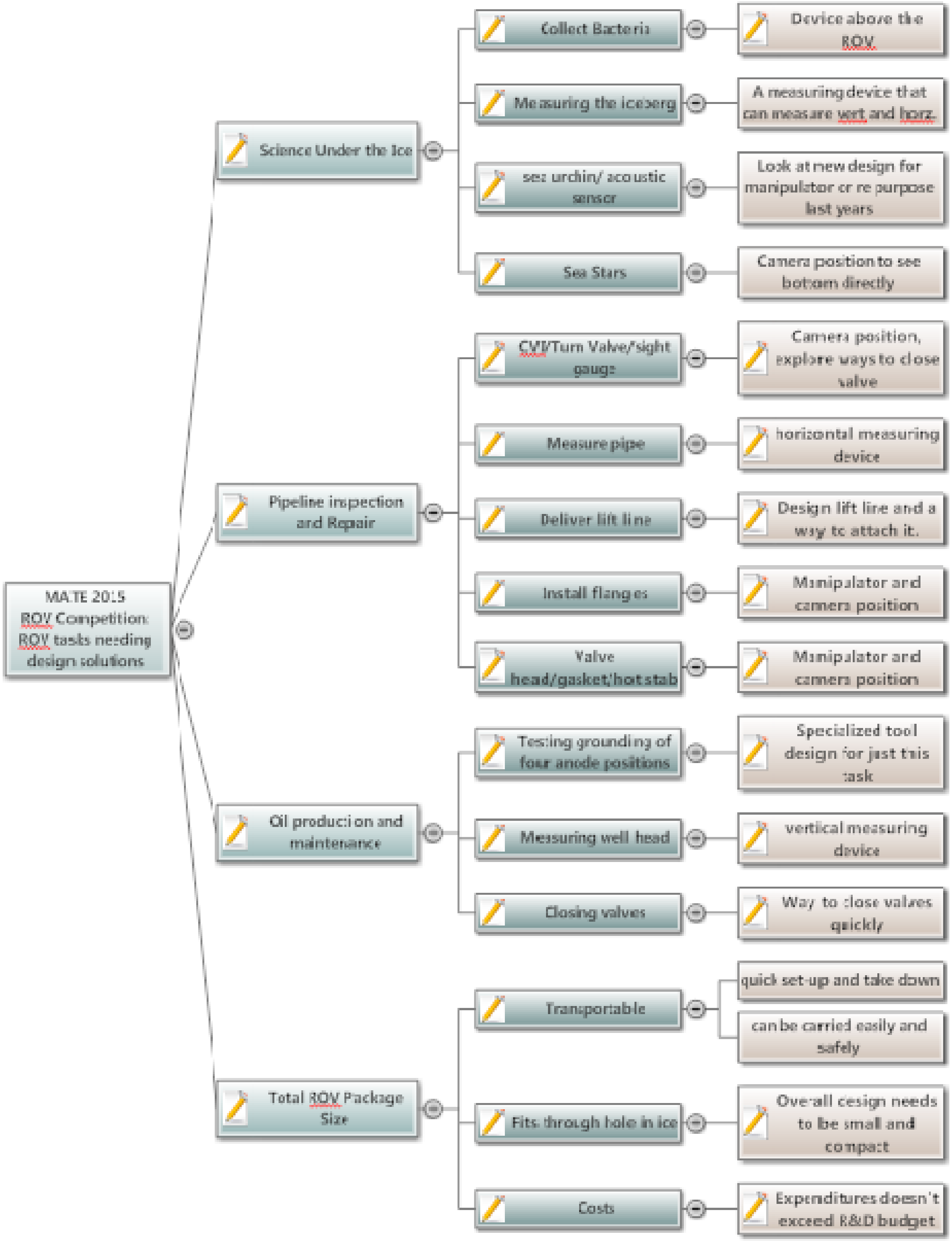
Continued Preparations for Internationals

Underwater Research Robot Company

Appendix C
Grabber Print



Appendix D
Design Mind Map



Underwater Research Robot Company

Appendix E

Travel Budget for Internationals

Estimated Cost	Funding Support
Plane Tickets (Seven Tickets)	$5,300.00
Room Costs (Three Rooms for four nights	$2,400.00
ROV Shipping and supplies	$400.00
Food and misc expenditures	$1,0000
Total	$9,100.00
Estimated Fund Raising Activities	**Cost**
Spaghetti Dinner and Auction	$1,750.00
Bottle Drive	$800.00
www.gofundit.com	$6,000.00
Personal Donations	$2,000.00
Total Estimated Funds Raised by June 20, 2015	$10,550.00