# Sound School ROV Team

## The JUGGERNAUT


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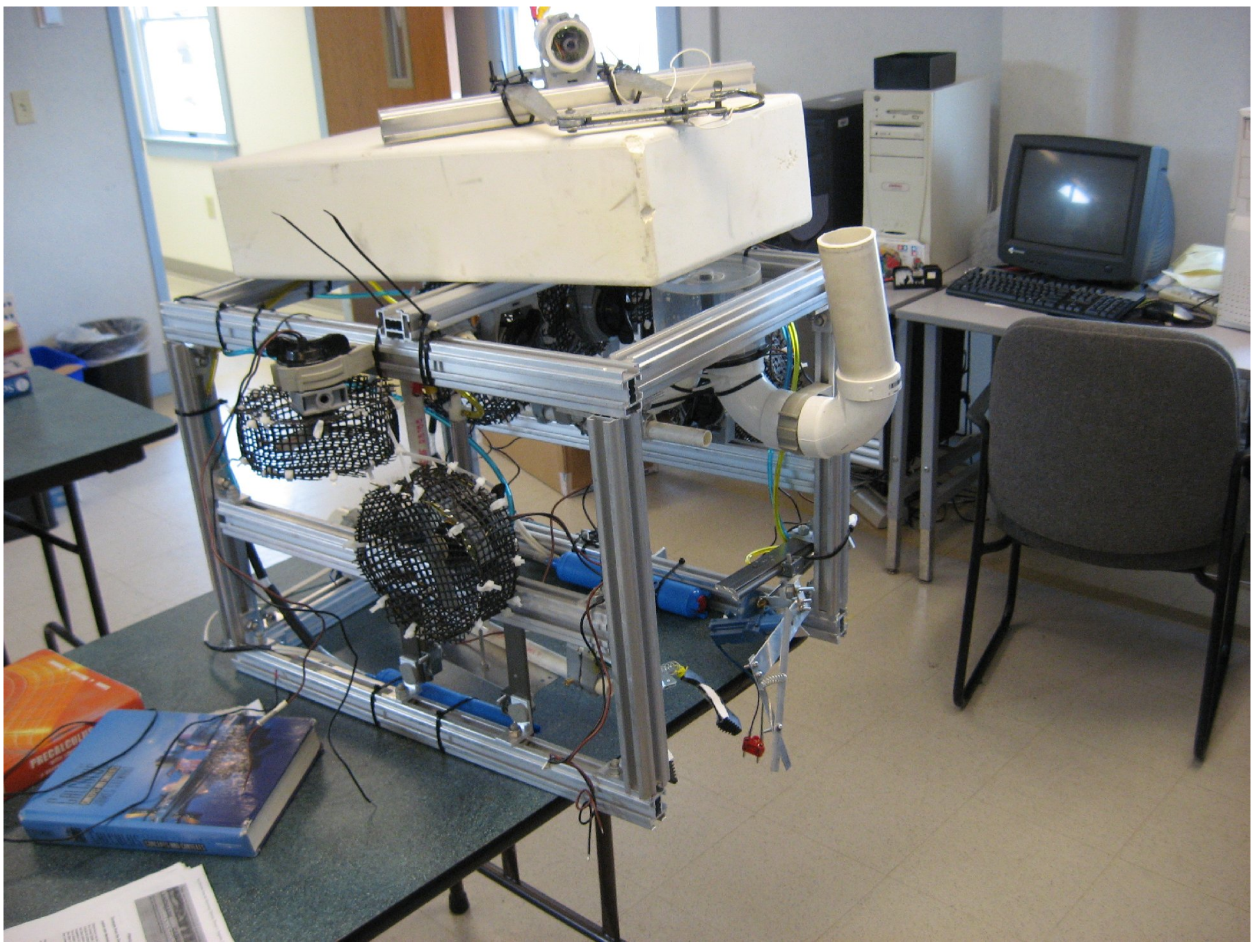


# Abstract

The object of this project was to create an underwater remotely operated vehicle in order to fulfill the mission tasks put forth by the MATE ROV competition. Because of past problems with the complexity of ROVs built by members of this team in previous competitions and class projects, and the complications inherent in working within the constraints of high school students' time schedules, we decided to build our ROV out of rather standard parts using simple mechanisms. This also resulted in a ROV with fairly easily interchangeable parts and tools that can be removed and replaced quickly.

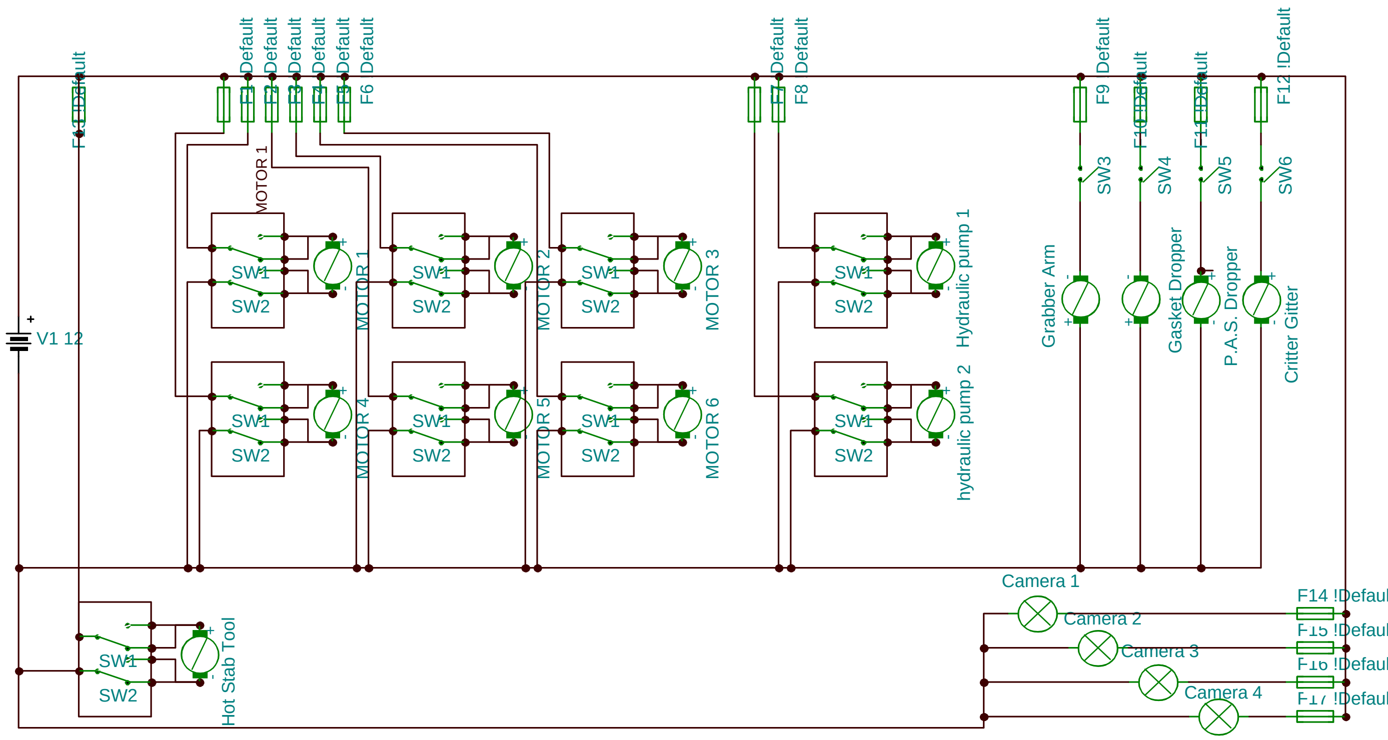
We also decided to build our ROV out of aluminum Trailex™ trailer material. This material is both lightweight and moveable, and easily manipulated. It allows us to have an interchangeable tool set, letting us take tools on and off at will. The size of our ROV was determined by the constraints of our motors (we should probably research thrust power).

The challenges confronted in this project were not just those dealing with technical aspects and engineering skills, but rather with learning life skills. We had to put together our team, assign tasks, allocate timelines for completion, and raise money not only for parts and materials but also for travel. We gained budgeting, organization, cooperation and many other skills that will not only help us in our careers in engineering, but that will help us throughout our lives.

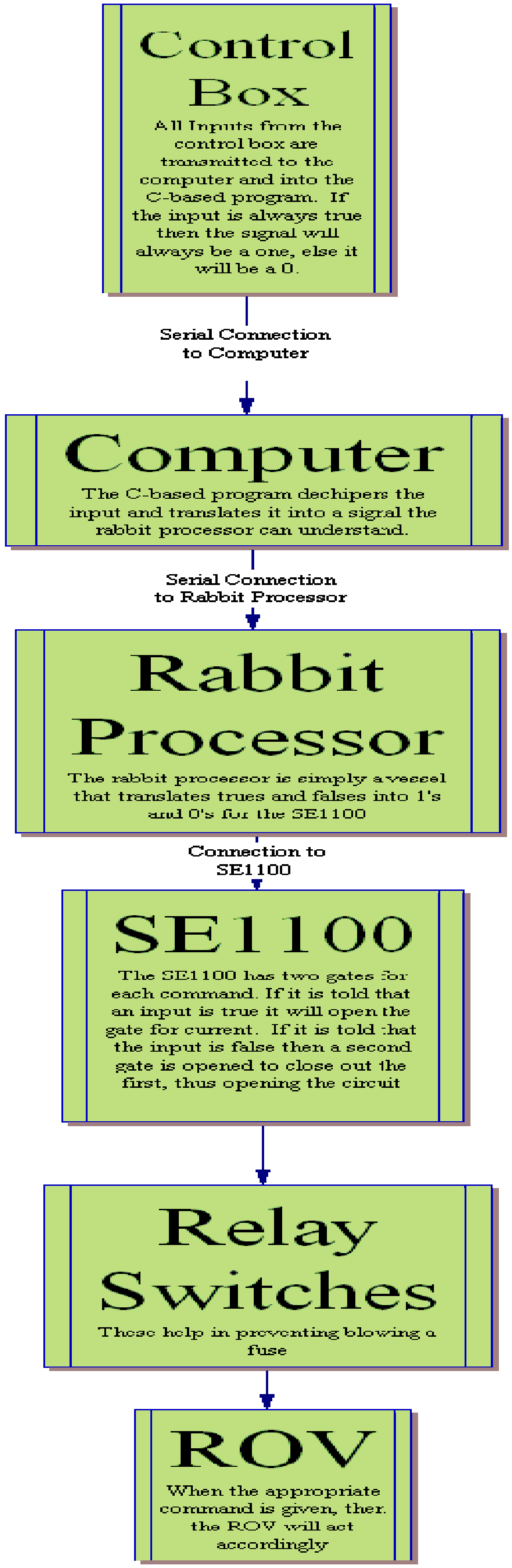
# Budget/Expenses

| *Expenses* | | *Assests* | |
|---|---|---|---|
| | | | |
| **Parts** | **Cost** | **Fundraising** | |
| Propellers | $ (41.80) | Meet the Teachers Night Donations | $ 400.00 |
| Syntactic Foam | $ (500.00) | Cell Phone and Ink Cartridges | $ 241.20 |
| Cameras | $ (500.00) | Cookie Dough | $ 700.00 |
| Motors | $ (119.94) | Ice Cream Social | $ 162.35 |
| Mockup Parts | $ (150.27) | **Total** | **$ 1,503.55** |
| Printer roll for poster display | $ (48.42) | **Donations** | |
| C++ Programming Software | $ (72.90) | SCCASM | $ 500.00 |
| Worm gear boxes | $ (48.00) | Dewberry | $ 250.00 |
| Envirotex Lite 2-part mix | $ (67.57) | Yale | $ 250.00 |
| Bolts & nuts | $ (21.91) | **Total** | **$ 1,000.00** |
| Channel connectors | $ (57.96) | **Donated Materials** | |
| Fuse & battery holders | $ (15.89) | Flotation Spheres | $ 500.00 |
| Propellers | $ (52.99) | **Total** | $ 500.00 |
| Barb fittings: mouse valves | $ (13.84) | | |
| Hose connectors | $ (26.16) | **Total Monetary Assets** | $ 2,503.55 |
| Worm gear boxes | $ (36.00) | | |
| Current shunt | $ (61.31) | | |
| Tech support - 1 year | $ (150.00) | | |
| 2 programming cables | $ (89.70) | | |
| 3x59 Clic Clamps | $ (9.60) | | |
| Trailex | $ (247.60) | | |
| **Total** | **$ (2,331.86)** | | |
| **Services** | | | |
| Shipping/Customs | $ (495.00) | **Total Expenses** | $ (12,126.86) |
| **Total** | **$ (495.00)** | **Expenses Paid for by Purchase Orders** | $ (8,467.54) |
| **Travel (Projected)** | | **Actual Expenses** | $ (3,659.32) |
| Airfare | $ (7,100.00) | **Total Monetary Assets** | $ 2,503.55 |
| Local Transportation | $ (600.00) | **Net Assets** | $ (1,155.77) |
| Lodging | $ (800.00) | | |
| Food | $ (800.00) | | |
| **Total** | **$ (9,300.00)** | | |

# Electrical Schematic



# Software Diagram


Control Box
All Inputs from the control box are transmitted to the computer and into the C-based program. If the input is always true then the signal will always be a one, else it will be a 0.
Serial Connection to Computer
Computer
The C-based program dechipers the input and translates it into a signal the rabbit processor can understand.
Serial Connection to Rabbit Processor
Rabbit Processor
The rabbit processor is simply a vessel that translates trues and falses into 1's and 0's for the SE1100
Connection to SE1100
SE1100
The SE1100 has two gates for each command. If it is told that an input is true it will open the gate for current. If it is told that the input is false then a second gate is opened to close out the first, thus opening the circuit
Relay Switches
These help in preventing blowing a fuse
ROV
When the appropriate command is given, then the ROV will act accordingly

# Design Rationale

## Frame Design

Our frame design was influenced by several factors, mainly the desire to achieve both simplicity and mobility. Our frame is made out of Trailex™, aluminum trailer frame, which is good for two reasons. First it is easily attachable and detachable, making it simple for us to take our tools on and off to work on, and to switch them out during the missions. It is also a light material that allows many mounting points and the ability to move mounted objects, such as motors and cameras. It also allows for a strong material that is light but not breakable.

Our frame is a box frame, easily modifiable with an open front to provide space for tooling. We added bars on the sides for more mounting points. The frame is open which assists in finding camera viewpoints, and ways to view the whole system, not just individual parts. The whole system is also entirely moveable, with motors and cameras moving so that we can radically change the way our system works at a moment's notice. This has served us well several times, because as our tooling evolved, so did our need for space. The flexibility inherent in this system allowed us to constantly improve on design and function.

## Propulsion

After careful thought, we have decided to use a 6-motor configuration for our ROV. The vehicle is set up with two forward thrusters, two lateral thrusters, and two vertical thrusters. This is a simple layout allowing us great maneuverability with a fair amount of speed also. The motors we are using are 1000 gallon/hour bilge pump motors, which we adapted to accommodate propellers to use as thrust motors. We chose these motors because we decided to build our ROV out of aluminum, a fairly heavy material, and we had to choose motors that were powerful, but also fit within our power limitations. These motors seem to do just that. We also are using counter-rotating propellers so that our ROV does not "torque" and twist during the missions. The power and maneuverability is especially important this year due to the fact that we must maneuver against current. Although the exterior placement of the motors does increase the risk of getting caught on obstacles, this year's missions do not present as many subsea space limitations as past years' missions have, and exterior motor placement did not present significant problems during testing. The motors are on the outside of the ROV to allow us the most unrestricted flow and the largest turning radius. We believe that our motor setup will allow us to have an ROV that is both powerful and maneuverable, both important aspects of the mission tasks involved in this competition.

Tether

With a main control system (digital) and a backup (analog), we have a main tether and one for the backup control system.

Our tether consists of one 75-foot Ethernet cable, two 55-foot AWG Standard Power Cables (8 Gauge), five 100-foot camera wires, and 55 feet of TechFlex™ in which to contain it all. This is a huge advantage for our ROV because the tether is lightweight and smaller in diameter (about 3 cm in diameter) than a standard analog control system tether (such as that used for our backup) would be. This gives the benefit of maneuverability as well as speed for our ROV, because the Ethernet cable and the two 8-Gauge power cables replace the twelve 55-foot speaker wire cables required in the backup tether. Having a limited number of lines running down the tether will make the ROV more maneuverable than if we had many various wires. The tether is encased in TechFlex™, which holds all the wires together while allowing for any necessary movement. Small buoys are threaded upon the tether for neutral buoyancy so there is less drag on the motors.

The backup tether is the same except that instead of the one cable running down to a single-board computer/processor, there are two wires for each electrical component. This tether will be used if our analog control system is needed. We are trying to avoid having to drop to this backup because this tether would be weighty, and would severely limit our maneuverability and speed. It involves running six 16-gauge pairs down for electrical/power signals, and the tether would be much more difficult to make neutrally buoyant.

Hydraulic system

We decided to use a hydraulic system because Task 3 involves precision to accomplish it. The Hydraulic system was also easy to use because it pulls water from the surrounding environment, allowing us to avoid carrying a payload of hydraulic fluid onboard. The hydraulic system uses two pumps, originally intended to draw water up from wells. Each of these pumps has hydraulic lines connected to it that are, in turn, connected to two cylinders that move the grabber arm and gasket dropper up and down.

Each of the pumps is on a separate switch. When we activate a pump it pushes one of the cylinders out and pulls one in, vice versa with the other pump. This way the pump works the cylinders in tandem, and since the pumps both have built-in exhaust valves we have no need for an exhaust system, as the water gets vented back into the pool. This design also seems to work better than mechanical or gear-driven designs which are harder to waterproof. We also made the devices the cylinders are required to lift neutrally buoyant in order to take some strain off of the cylinders.

## Control System

For our control system we chose the Rabbit™ 2000 Processor as the main component. The controls themselves are based on the HanaHo/PVG/Semco Hotrod Joystick. Our first and main reason for choosing this setup is the tether. Using a digital control system is preferable to that of an analog system for the reasons outlined in the Tether Rationale above, namely: maneuverability.

Our second reason for choosing this setup is the ease of use. With the Hotrod control box we can easily add or remove tools or motors without any need to rewire the control box or resend wire down the tether. All that is needed to change is a few lines of code and we will be able to add any tool we need for the ROV. In addition to the control's versatility it is also simple and easy to use, with two joysticks and a variety of pushbuttons for all or our tools.

### How it works

The Hotrod control box is a very simple design in itself. Every time a button is pushed or a joystick is moved forward, back, left, or right the Hotrod control box sends a signal to the processor, equivalent to pressing a specific key on a computer keyboard. Then the Dynamic C program sends a signal down the tether to the processor, telling it what to do. The processor then sends a message to a relay directing electrical current to a tool or motor so it can perform the task instructed. Using a series of these commands we can propel the ROV in any direction as well as turn on tools and hydraulic pumps when we need them.

### Problems/Solutions

Unfortunately, the problem with a control system that relies on so many essential components is that if one of the components does not function then the whole system comes to a grinding halt. That was one of the most devastating problems for us while building and designing the control system. The core of our control system, the Rabbit™ processor, did not function or receive a signal from the computer, and no one on our team could figure out why. We eventually came to the conclusion that the only way to solve this on the time budget we had before the competition was to pay $150 for phone tech support on the processor. Until we are able to get this problem solved we will not be able to use our digital control system, and are forced to turn to alternative methods to control out ROV. Fortunately, we were able determine this problem soon enough to be able to start on a backup analog control system before the competition. Although this will not possess the benefits of a digital control system, it will assure us that we have a working control system for the competition, even if it is not what we intended. The digital control system still remains our primary concern and we are currently working overtime to see that it is resolved and in working order for the competition.

## Manipulator Arm

For the manipulator we modified an extended grabber, a simple grabber arm to help with physical limitations. This arm operates by retracting a wire that brings the two pincer arms together. We cut the grabber short to make the size more manageable, and then attached two electric solenoids to the wire to actuate the wire back and forth and open and close our pincers.

Our design rationale for the claw reflected our design rationale for the entire vehicle: keep it simple, and moveable. The claw is fully detachable due to the moveable nature of Trailex™, and we have a hydraulic system to move the arm up and down, as well as side to side. The fully detachable aspect is very important to us. This contest involves many tasks that require very different mechanisms. The arm is removable and thus allows us to switch different tools for different tasks, and to create space on the frame of our ROV.

Another motive for creating a manipulator is that it is a multiple use tool. The arm is being used for multiple tasks and cuts down on the weight of the ROV. By using the arm for several tasks we have fewer tools, less weight, and more room. The moveable aspect of the arm allows for flexibility in the uses available for the arm. The claw can work both on the ground and in the middle of the ROV, and we specifically designed the claw system, and the camera system, to allow us to do this.

## Happy Hooker

The first task requires threading a messenger line through a buoy anchor ring and returning it to the surface. To complete this task we decided to use a pre-made tool known in the industry as a happy hooker. A happy hooker is a horseshoe-shaped tool that works like a carabiner. It works by being able to open out on one side, and in on the other side. The reason we chose to use the happy hooker was that is a simple tool that efficiently completes the task needed, and is removable. We found this instrument through interaction with our team mentor, Craig Bussel of NURC-UConn/Avery Point. He recommended it after hearing the task described, saying that that the tool is used by many in the ROV industry. We mounted a camera on the happy hooker, allowing us to get a close up view of our tool and the task area.

## Critter Gitter

To collect the samples of algae, represented by ping pong balls, we are using a mechanism called a critter gitter. In plain terms, it is an underwater vacuum, the concept of which was also suggested to us by Craig Bussel.

This tool was made from scratch using everyday materials and a motor. The containment area of the critter gitter was made out of a plastic case that blank CDs are normally packaged in. The CD case was perfect because its flat bottom allowed pipes to be connected to it and it also has an easily removable cover for retrieving the sample. The rest of the tool was made of PVC. Affordable and easily available 2” PVC allows the ping pong ball to be collected without getting stuck or losing suction. The motor used is a 1000 gallon per hour bilge pump motor equipped with a small 2 inch diameter model engine prop. We chose to use the bilge pump motor because it is made to siphon and therefore has a large amount of suction force. The prop was used because it would fit inside the 2” PVC pipe and allow enough suction to complete the task.

Gasket Dropper

For the gasket dropper we decided to make a tool that was accurate and attached to the actual gasket, not just the pipe cleaner handle. To hold the gasket we fabricated a scissor mechanism with a spring to close it. We hold the gasket by placing the tool through the middle of it and then actuating a solenoid to spread out the tool and hold the gasket in place. This way, the only movement required to pick up or put down the gasket is the actuation of the solenoid. We also hooked the tool up to a hydraulic system to move it in sync with the claw that takes off the cap off the christmas tree. This allows us to move the gasket dropper out of the way of the manipulator.

# Description of at Least One Challenge

The biggest challenge we have faced during the course of our project has been the construction of our control system. Because we put off construction of a control system for too long, we ran into several problems based on our time constraints and the many other tasks to which our team members were assigned.

Our first choice was to use a Rabbit™ processor and program it using C++. No one on the team had ever worked with C++ or a Rabbit™ processor, and learning these tools required a large commitment of time. One team member put a lot of work into learning C++ and writing a program that fits the needs of our system.

Unfortunately, there have been problems with the Rabbit™ processor. We have made numerous efforts to troubleshoot the processor, e-mailing and calling (once the one-year support fee was paid) tech support and making contacts with experts we thought might be able to help. Unfortunately, we have not been able to rectify the situation, and we are faced with a time crunch. This failure to start earlier places us in an uncomfortable situation, and we have begun looking into other options.

When it became apparent that our digital system might not work, we began to look into an analog system. While it is bulky, and not as technologically advanced, this system seems like the most dependable alternative.

This challenge has not been without its lessons however. We learned throughout this process that at any time components can go bad, and things can go wrong. We have learned how to improvise, overcome, and adapt to changing situations, skills which will be very important to us in later life. While the challenges we have faced throughout this process have been daunting, we have faced each one of them down through the power of teamwork and determination, and thus learned from each one.

# Troubleshooting Techniques

One of the most important techniques throughout building the ROV has been our approach to troubleshooting. We had several problems and we approached each one in generally the same way. The first thing that we would do is to gather all of our information on the component we were having problems with. We would gather all of our manuals, online information, and collective experience, and try to pinpoint the exact problem within the system, systematically eliminating components until we found the trouble area. After that, we looked at solutions that other people have used, if we found a fix for our problem then we continued on. If not then we looked at the exact process and try to find a fix for ourselves. For example: our hydraulic systems were not working, and our casings for our controllers were flooding. We searched the whole hydraulic system for leaks, and we checked to make sure our pumps were working. We then moved to our Mouse control valves, and realized our exhaust system was outputting water into the waterproof casings. By researching this we then realized that our control valves were made for pneumatics, not for hydraulics. We first looked at a way to waterproof the Mouse valvess so that they would work with our hydraulic system using our manual and online help. After that attempt failed, we looked at replacing the valves with hydraulic equivalents, but that was not cost effective. Finally, we came up with a way to create our hydraulics system without the controllers, solving our problem.

This method of using all the information available to us and breaking larger systems down into their smaller components saved time (and headache medication) for all the people involved in troubleshooting (which was basically the whole team).

# Description of at least one lesson learned or skill gained

We learned two main lessons while working on this project. The first lesson was how to work with a group of people in a professional environment. Working with one person you know very well is not complicated, but working in a group with people that you may not necessarily know well, or like, is difficult. Eight people translates to eight different opinions, styles, and attitudes that often clash with each other. Sorting and mapping out how each idea will fit into the project in a mature fashion is a hard skill to learn. In all honesty, arguing was an instinctive beginning to making decisions, but it quickly changed to constructive discussions where all ideas were respected. Setting order to brainstorming and building sessions allowed the entire process of planning and building to be more productive. Throughout the project we gained a level of comfort and companionship with our teammates that we are very proud of. We developed from eight individuals with all sorts of different interests and goals to a unit with one main goal and purpose. We have developed into a team, and become close. We are very proud of each other, and of this development.

In addition to learning how to function professionally and efficiently in a group, we also learned a great deal about time management. Planning for the project began almost a year before the competition was scheduled. It is essential to look ahead and make an educated guess about when something should be done, and how long it will take to complete any given task. Planning for something is much easier than making it happen. Following through with a schedule has been one of the hardest skills to master, yet is has been one of the most rewarding. Every career in the world is based on deadlines, not to mention so many aspects of life. We have gained (or improved) the ability to budget our time, and to plan ahead. Throughout the project we have constantly assessed ourselves on our abilities in terms of time management, and we appointed different managers to be in charge of each task. We have improved a great deal, but it is a constant struggle to continue managing our time in an efficient manner.

# Discussion of Future Improvements

Troubleshooting Manual

We would like to create a troubleshooting manual for the ROV for one simple reason: it is complicated, and the knowledge of how to make work is fragmented. For example, there is one only one person on the team who understands the programming that runs the control system on our ROV. We would like to create a manual (complete with a copy of the programs necessary on CD) that would allow future classes at Sound School to operate the Juggernaut effectively.

Different Tooling

The Juggernaut will be used in other environments by other people at Sound School in the future. We would like to add sensors or tools that would be helpful to the classes at Sound, such as temperature, salinity, depth, or other sensors that the science and tech classes could use. We could also extend the tether to allow deeper searches in the Long Island Sound, and adapt power needs to allow the Juggernaut to be operated offshore.

# Inuit Culture and Polar Exploration

When speaking of the Inuit culture, it is impossible to separate it from the environment in which the Inuit evolved. Observations of the Inuit culture in the late 1800's spoke of a family structure and culture that evolved around the specific needs of an environment that some thought of as uninhabitable, an environment that does not allow for mistakes. Examples of this type of culture include structure of villages, often groups of 10-12 families that band together to control hunting. Too much hunting could deplete the already small stock of game and thus cause starvation. It is important to note that the whole life of an Inuit revolved around survival in the harsh environment of the artic circle. We see more adaptation of this sort in the tools they used to survive. Igloos, for example, are a popular symbol of Inuit culture that highlights this need for survival quite well. The igloos construction is of materials naturally found in an environment with almost no natural material, an adaptation of the natives in months of the winter in which no building materials could be found. Other aspects of Inuit life that show this are there ways of transportation, the inventing of snow shoes, and taming of dogs to pull their sleds. All these adaptations point to how people can survive in the Polar Regions.

We can see the change that human exploration has brought to the poles by examining the Inuit way of life, before outside interference and after. When hunting became easier, when the Inuit gained rifles, and when other food supplies became available, hunting became less tied to the existence of the Inuit, and therefore animal husbandry became less important. The culture of the Inuit decayed, old traditions have been lost. Some of the basic skills needed to take on the artic environment have been eliminated from the Inuit culture. It is important to note that as a world we are responsible for our actions regarding some of the last free spaces on our earth, the Artic and Antarctic regions. There is work being done to preserve the Inuit culture, and that is important. The Artic regions are places of glory and wonder, and we would never want to change that.

Sources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# Reflections on the Experience

Participating in the MATE International ROV Competition has been one of the most rewarding experiences of all of our lives. We have learned so much that we never thought would have come out of the project.

The creation of the project has done more than anyone could have ever imagined. It has helped with all the practical skills we accumulated in our engineering class such as electronics, mechanics, pneumatics, and computer drafting with CADKey and SolidWorks.

Most importantly, each team member has been pushed into his or her own personal direction as we have found ourselves through the work accomplished. Working long hours after school, writing professional business letters asking for monetary donations, selling cookie dough, meeting with professionals, and learning to get along with seven other people have all been valuable lessons, and have greatly added to our cumulative high school experience.

One of the best things about this experience is that we have been pushed to the limits of our abilities in several ways. On a small team like ours, everyone must pitch in to accomplish the task at hand. Because none of us are good at everything, we must all work in areas in which we are weak, or feel uncomfortable. Some of us are very good at working with people, some are good with electronics, and so everyone got to work in areas which were not their obvious strengths, and improve all their skills. We also learned to allow ourselves to learn from others, people we might not necessarily ask questions of we must go to for help. This is both humbling and educational.

The experience we have gained through this competition has been one that none of us will ever forget. The skills we have gained will stay with us forever, no matter what field we enter. Communication, writing, design, and friendship are valuable to all.

# Acknowledgments


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