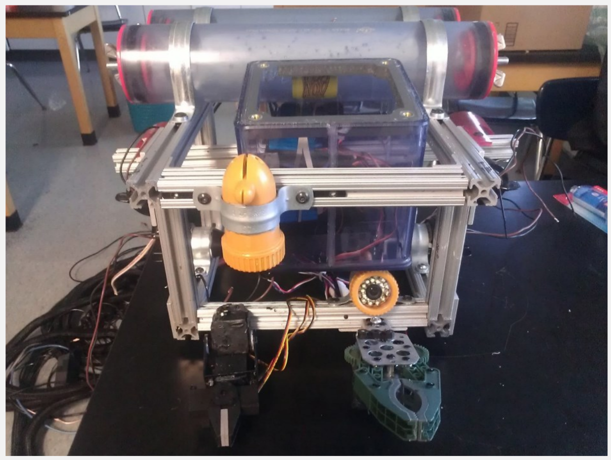
Midwest Precision Aquatics



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Abstract

MPA designs and builds ROVs to operate in extreme subsea environments. The MPA MK1 ROV features two remotely controlled claws to perform a variety of tasks in the servicing of a Regional Scale Node. A main claw handles heavy work such as placement of sensors and modules. For lighter but more precise tasks, the articulated claw can tilt and twist into any position necessary to perform tasks such as rotating levers, inserting plugs and connectors, and precisely placing delicate sensors. The two-claw system allows the ROV to transfer and control multiple objects, and use grab points when operating in difficult piloting conditions.

The MK1 is an extremely flexible and modular vehicle. The pilot control software can be easily modified to adapt to almost any mission task. The T-slotted framing system allows for quick prototyping and easy movement of motors, sensors, and claws depending on the mission specifics.

MPA also has skilled programmers who can integrate a variety of sensors such as the Arduino driven temperature sensor featured on the MK1, which boasts a clean graphical user interface to collect accurate and precise time and temperature data on your laptop or other devices.

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Safety

At Midwest Precision Aquatics, safety is our highest priority. We implemented many different safety protocols that were strictly monitored in order minimize the possible hazards while working on our ROV. First, we developed a set checklist to ensure that all members are have a safety plan before any work begins. The members of Midwest Precision Aquatics always wear safety goggles and proper personal protective equipment. We always get approval from our mentor or the CEO, and conduct safety checks prior to operating power tools.

Our vehicle is also build around the highest safety standards so that no one will be injured while working on or operating the ROV. All sharp edges and hand hazards are sanded down to make our vehicle safe for users and divers. We shroud and label our accessible propellers and moving parts. All of the propellers not enclosed inside of the ROV are covered with PVC enclosures. At Midwest Precision Aquatics, we never do any electrical work on live circuits. We are always sure to get verbal and visual confirmation that circuits and equipment are powered down prior to work. This way, we are able to avoid any possible complications that could arise from the live wires, such as electrocution. All of the wires are connected neatly and efficiently to reduce the possible power loss as well as the chance of electrocution. The ROV uses multiple fuses to prevent overloads and potential fire hazards. They are inserted at many points throughout our wiring and are constantly checked to make sure that they are functioning properly.

At Midwest Precision Aquatics, we take our time so that safety hazards can be avoided. We always follow the checklist before starting work on the ROV and take the utmost precaution to ensure the safety of our employees. We take pride in our workmanship, quality, and the safety of our product.

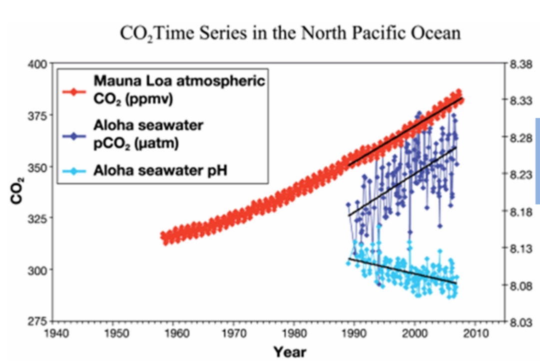
Theme

The future of our planet is closely linked to the health and maintenance of Earth's most vital resource, our oceans. They not only provide us with vast economic and natural resources, but they are key to the overall health of the planet. They produce more than half of the oxygen we breathe. They absorb a large portion of the carbon and pollutants that we produce. They drive our weather, and provide a tremendous heat sink to buffer the effects of global warming.

The ocean environment has been significantly altered as we stress the ecosystem. Evidence of the absorption of carbon dioxide in the ocean can be seen through a corresponding decrease in the pH. The average temperature of the oceans has increased through the process of global warming, and pollutants, overfishing, spills, and commercial use have added to the problem.

While many of the atmospheric effects and outcomes of climate change are known, scientists have had difficulty quantifying the effects on our oceans. Until recently, ocean data was only collected for short periods of time over very small areas, and was mostly done from ships or surface sensors. Subsurface data such as temperature, salinity, microbiology, pH, currents, and other data sets at depth have been largely inaccessible until the past few decades. To get an accurate picture of our oceans, scientists need more data. Sensor networks through the Ocean Observatories Initiatives will help meet this demand.

By making this information widely available, scientists, citizens, and lawmakers can make more informed decisions about how we use and manage our precious ocean re-



CO_2 levels in the North Pacific (left)

Design Rationale

Structure

The framing system for the MK1 is unique and robust. The MK1 is made up of 80/20 T-slotted extruded aluminum. The frame is held together using L-shaped pieces as well as nuts and bolts which could easily be attached. This aluminum frame allows for great maneuverability as well as ease of access. The frame is highly versatile and modular. All components on the ROV can be easily and quickly moved to adjust the stability, balance, and function. In order to change a part or move it to a different location on the ROV, the only thing that would need to be done is to unscrew the bolt a bit. This would loosen the screw and pull it away from the nut, and therefore allow the piece to slide anywhere it was needed.

At Midwest Precision Aquatics, we chose this specific frame because it has a high strength to weight ratio. This allows for MK1 to be nimble as it travels underwater quickly, as well as very easy to modify. There were many points during the construction where we found it necessary to move parts around the ROV or even change the frame entirely, and were able to do this because of the shape and modularity of the T-slotted aluminum. The frame consists of a simple box made out of these aluminum bars. The front bar on the top side sticks out a bit in order to ensure an unobstructed camera view of the claw below it. If anything happens on the frame that needs to be changed, it is an easy fix and the ROV can quickly be returned to its original shape. Its strong yet lightweight frame also makes this material favorable as it allows for easy maneuverability and modification

Design Rationale

Control System and Electronics

The propulsion of MK1 is controlled by a PlayStation 2 (PS2) controller. The PlayStation controller sends a signal to one of four Electronic Speed Control (ESC) which each power a pair of propellers, in order to ensure every degree of motion. Each pair of thrusters is controllable to 15 different speeds, giving the pilot analog control of the ROV. The PlayStation controller communicate with the Arduino microcontroller which then sends Pulse Position Modulation (PPM) servo commands to the ESCs at 50 Hz. The ESC use those servo commands to drive the thruster motors at one of thirty different, preprogrammed speeds.

The two claws are also controlled by another PlayStation 2 (PS2) controller. The controller also sends a set of digital signals to an Arduino microcontroller onboard the ROV. Each button press on the controller is translated into pin outputs through team created software on the Arduino. This controller is used to drive a set of three servos in the main claw. The Arduino itself was not powerful enough to run the main claw so we used a mega moto shield to act as an H-bridge. The PS2 controller signal is transferred through an Cat-5e cable, and the controller has a positive an negative through the USB which goes all the way down to the ROV and then back up, all using digital signals.

We custom ordered a dry-box which is a six inch cube made out of quarter inch PVC. This box is completely watertight and each wire is individually sealed using a silicon potting compound, as well as a marine epoxy. This ensures that the ESCs, the Arduinos, and the rest of the electronics housed inside of the enclosure are kept safe and dry.

Design Rationale

Propulsion

Our ROV has eight 30W max waterproof bilge pump motors which drive plastic hobby propellers to propel our ROV. The bilge pump motors were stripped of the actual pump part so that a propeller could be fitted on it. The propellers were then screwed on and fastened tight. Each ESC channel controls one pair of motors and corresponds to one of the two control sticks on the PlayStation 2 controller for an intuitive pilot experience. The four pairs of motors control depth, forward/reverse, yaw/rotation, and left right slide for the ROV. The slide propulsion was added to ensure our pilot could make small and controlled maneuvers without having to back up when using a traditional tank drive setup. At Midwest Precision Aquatics, we wanted to make it as easy as possible to maneuver around all of the obstacles in the shortest amount of time possible. We were able to achieve this by using the eight different motors and propellers which could make the vehicle go in any direction possible. Most of the propellers are located in the middle of the ROV, so that they can keep the center of gravity near the center on the ROV. These motors allow for MK1 to travel up and down, forward and back, and slide left and right. Two of the motors are located on the far edge of the frame and even have a special crossbar that sticks outside of the actual frame itself. Because of this, special covers were built to ensure the safety of those around the ROV. These motors are used to control the ROV's left and right turning. Because these actual motors are so far out, a minimal amount of change is needed to make the robot turn either left or right. We wanted to make the pilots have to do the least amount of adjusting possible while down underwater. The unique propulsion system of MK1 allows the maximum amount of driving freedom with the least amount of adjusting needed.

Design Rationale

Ballasting

The MK1 also has a unique system to ensure that the vehicle is completely neutrally buoyant. The types of material that we used also helps to reduce the weight of the vehicle. The 80/20 aluminum is very light weight, and it also allowed for us to make the frame ROV as small as possible. Some of the buoyancy for the ROV is added by the PVC dry box on the ROV, which houses our onboard electronics. Additional buoyancy is added using two PVC pressure housings with end caps.. The users are able to unscrew one or both of the end caps on either of the pressure housings to flood the container and control buoyancy. The tether is also made neutrally buoyant with foam pipe insulation secured at regular intervals. This allows for MK 1 to be able to be neutrally buoyant in any environment.

Cameras

The Mk1 has 3 onboard cameras. Two Color Sharp underwater fishing cameras are used as the primary driving cameras. One is placed behind the main claw for a first person view of the claw target. The second looks down on the articulated claw to give a clear view for vertical placement of modules and gear. Each camera signal is transmitted through an RCA video cable to two headrest monitors mounted in custom display boxes. A third camera is mounted behind the articulated claw in case of a failure in the main claw, and is powered through USB and displayed on the poolside laptop. This also gives a first person view of the ROV. The use of three cameras on Mk1 allows for many different views to approach the mission from as well as to have a back up view if one fails.

Design Rationale

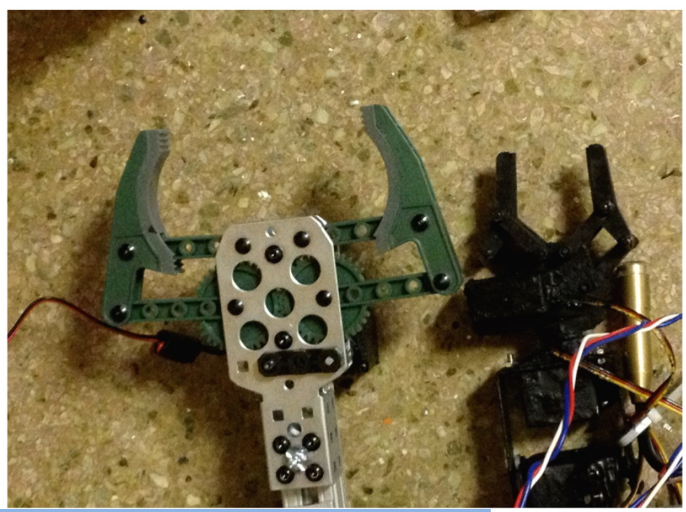
<u>Payload</u>

Temperature Sensor

A DS18B20 Waterproof Temperature Sensor was inserted into a rubber coupling which fits over the hydrothermal vent. The sensor sends serial data to an Arduino microcontroller through a 15m wire/tether. The Arduino transmits serial data to the laptop via USB. The serial data is displayed in a program/app written in Processing language which displays an updated time and temperature.

Main Claw

The large claw is designed for heavy work. The claw is powered by the 12V power supply through a Mega Moto motor shield laptop the Arduino which acts as an H-bridge to control current to the motor in two directions. The claw is opened and closed through the software interface with the PS2 controller.



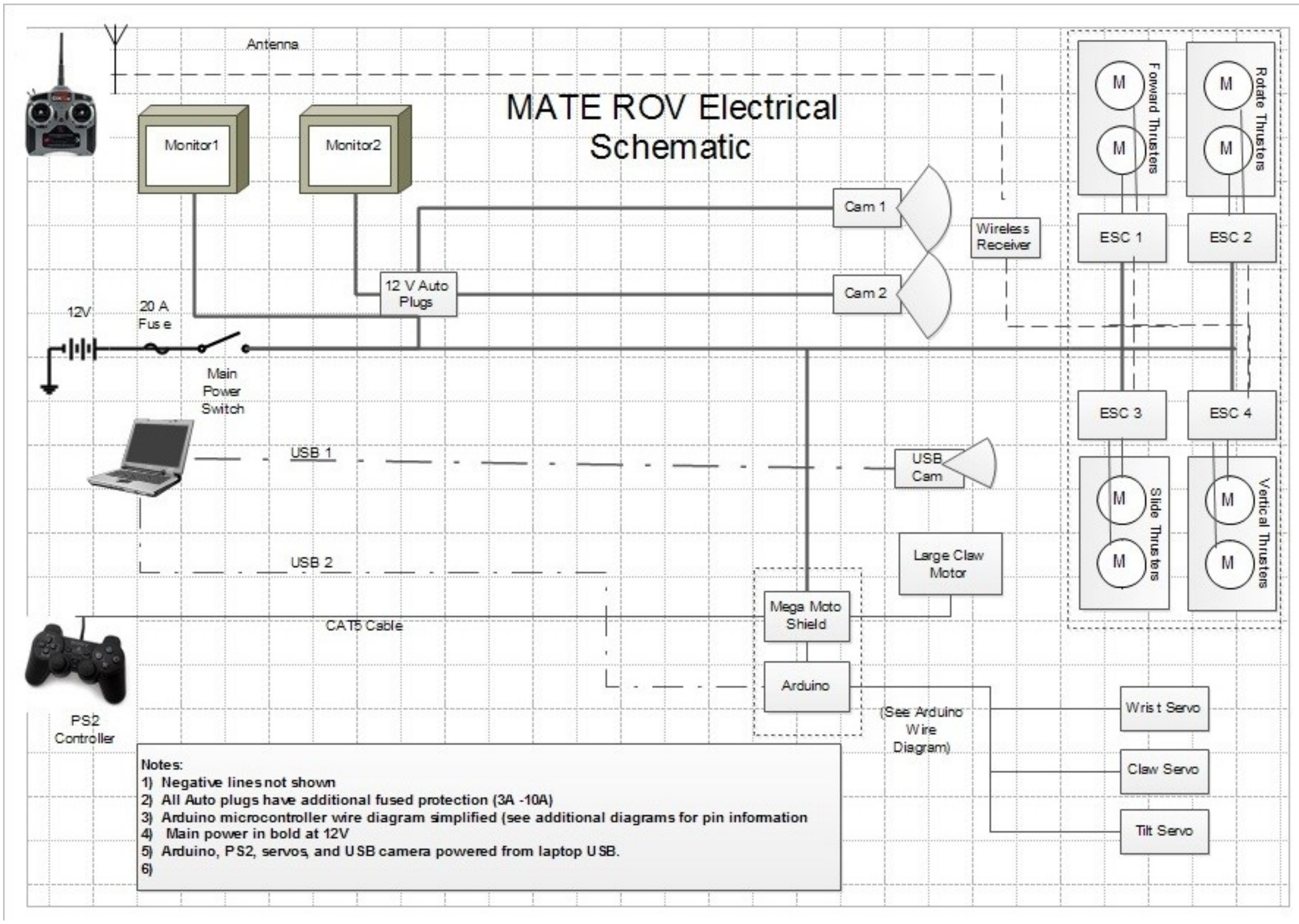
Main and articulated claw (above)

Articulated Claw

The smaller claw features three waterproofed 5V hobby servos powered by the Arduino microcontroller. Buttons on the PS2 controller send PPM servo signals to the three claw servos to control the tilt, rotating wrist, and claw position. This allows the ROV to manipulate objects at a variety of angles and ori-

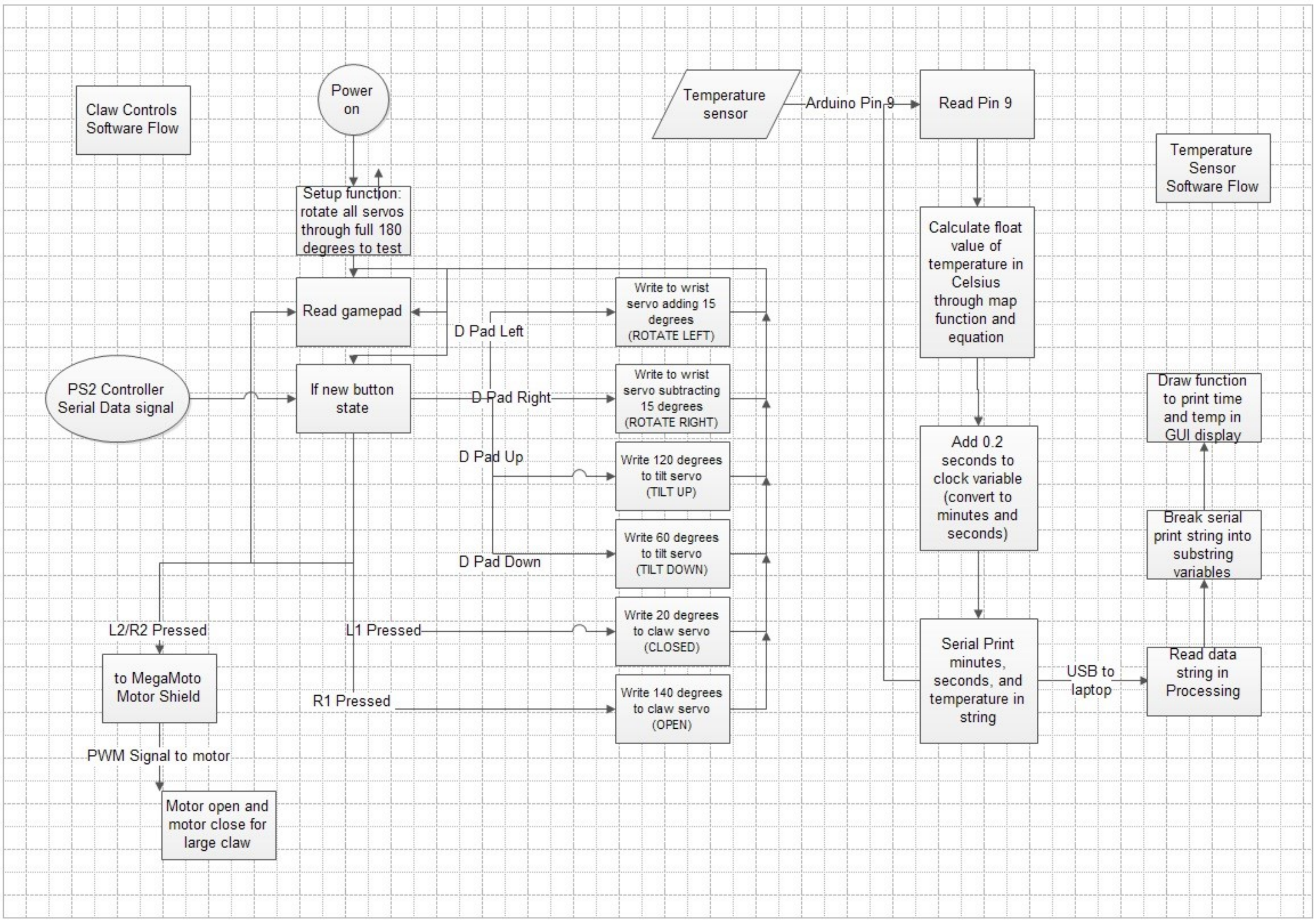
Schematics

Electrical Schematic



Schematics

Software Flow Diagram



Budget Sheet

Object	Quantity	Price per item	Total Cost	Note
Structure				
80/20 T-slotted extruded aluminum		$ 220.00	$ 220.00	
.25 hex bolts (box)	1	$ 30.00	$ 30.00	
Sillicon potting compound	1	$ 8.00	$ 8.00	
Marine epoxy	4	$ 6.00	$ 24.00	
Control System				
PS2 controller	2	$ -	$ -	Repurposed
Arduino micro controller	3	$ -	$ -	Repurposed
Electronic Speed Controls (ESC)	4	$ 23.00	$ 92.00	
Arduino mega	2	$ 30.00	$ 60.00	
Mega Moto motor controller shield	1	$ 30.00	$ 30.00	
Power wires (speaker wire)	1	$ 25.00	$ 25.00	
Arduino Uno	1	$ 22.00	$ 22.00	
Cat-5e cable (100ft)	1	$ 30.00	$ 30.00	
PVC Electrical Box	1	$ 120.00	$ 120.00	
Power Control box	1	$ 45.00	$ 45.00	
Assorted electrical parts	1	$ 60.00	$ 60.00	
Propulsion				
300W waterproof bilge pump motor	8	$ 20.00	$ 160.00	
Propeller parts on motor	8	$ 9.00	$ 72.00	
Ballasting				
Assorted PVC		$ 45.00	$ 45.00	
Rubber sealant	1	$ 12.00	$ 12.00	
Camera				
Camera (Underwater fishing)	2	$ -	$ -	Repurposed
Headrest Monitors	2	$ 75.00	$ 150.00	
Plexiglas (1/4" clear)	1	$ 30.00	$ 30.00	
Payload				
main claw	1	$ 23.00	$ 23.00	
Main claw 12V motor	1	$ 20.00	$ 20.00	
Articulated claw	1	$ 15.00	$ 15.00	
Claw servos	3	$ 15.00	$ 45.00	
Temperature sensor	1	$ 10.00	$ 10.00	
Temperature sensor tether/ mounting	1	$ 15.00	$ 15.00	
Travel				
Travel Expenses (Flight, Hotel, Transport etc.)	1	$ 5,000.00	$ 5,000.00	Donated by School
TOTAL			$ 6,363.00	

Problems Faced and Troubleshooting

At Midwest Precision Aquatics, we faced several problems, although we were able to overcome each and everyone of them. The first problem that we ran into was the time that our employees were spending on the ROV. Many of us had other responsibilities after school and could not always make time to work on the ROV because of sports or other extra-curricular activities. Two of our members had to return home to China late in the season, which left us a bit short handed. The time constraints were also difficult because we learned that we would be attending the International Competition only after a team dropped out just two weeks prior to the competition. Another major challenge that we faced was that during our regional competition, one of the pressure housings containing the electronics flooded. Much of our preparation time prior to competition has been recovering from the damage. In addition, the mega moto shield pin setup was very confusing and took many hours of trial and error to finally work out the correct pin sequence. Our programmer had difficulty with the PlayStation controller wiring and library for the Arduino microcontroller. The interface frequently failed, and it was challenging to get it to read data from the controller and write data to the servos. The PlayStation controller communicating with ESC was unreliable, and would often drop the 50Hz signal or fail to properly arm on startup.

Troubleshooting was a very important part of our process and insured that our ROV would be able to operate at the competition. For the students and time available to us, we developed a schedule where people could come in and work and created a time log where everyone had to put in at least 100 hours to participate. After our ROV flooded, we were forced to go back to the drawing board for our pressure houses. We eventually decided that a custom built PVC electrical housing would work the best. The incorporation of the cube led us to completely redesign the frame or our ROV.

Lessons Learned

One of the most important lessons that we learned at Midwest Precision Aquatics was how to manage our time. We were often running out of time for when parts of the ROV were due to be finished. Eventually we were able to work out a set schedule so things would be completed on time and people would show up enough. In addition, it allowed for us to gat a better start on planning next year's competition. We now know what needs to be done and how much time needs to be put in for a functional ROV that can accomplish the tasks. We also learned what parts worked and what parts did not work so that we can use for other future projects. Finally, we were able to learn how important it is to be able to monitor the ocean to regulate the health of the water.

Future Improvements

One of the main improvements that we hope to accomplish for next year's competition is to recruit more people to work for our company. This will allow us to divide up the work over a greater number of people. We will become more efficient in or work and be able to accomplish more as well. We would also like to use a PlayStation controller as the sole means of driving our ROV. Currently we are using a hobby controller receiver to deliver the necessary ESC signal, however the PlayStation controller would eliminate the need for additional hardware that is redundant to the Arduino. We would reduce the amount of wires in our tether by housing all of our microcontrollers onboard the ROV. We would also like to build our own custom claw from scratch by designing all of the individual parts.

Reflections

At Midwest Precision Aquatics, the MK1 is a very unique, robust, and efficient ROV that is able to accomplish the tasks that it is asked for. The MATE competition has sparked our interests in building and designing ROVs and has been highly influential to our company.

This experience has allowed for us to become closer as team members as well as friends. It has allowed for us to develop a bond that helps us to accomplish the work that is asked of us all while working together as a team to produce the final product of our ROV.

Throughout our time working on the ROV and operating it, we experienced many difficulties that we were able to overcome together. We learned what to do, what not to do, what materials to use and more. Our hard work and dedication has truly paid off as we proudly present our result of hundreds of hours of work, the MK1.

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Acknowledgements

Midwest Precision Aquatics would like to acknowledge and thank the following individuals and organizations for their help on the ROV, and making our company possible.

- MATE—Thank you for allowing to participate in this competition. Your organization made it possible for us to compete and sparked a desire for ROVs in many of us.
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- Dr. Raaflaub and MPA Administration—Thank you for your support or our ROV and company
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