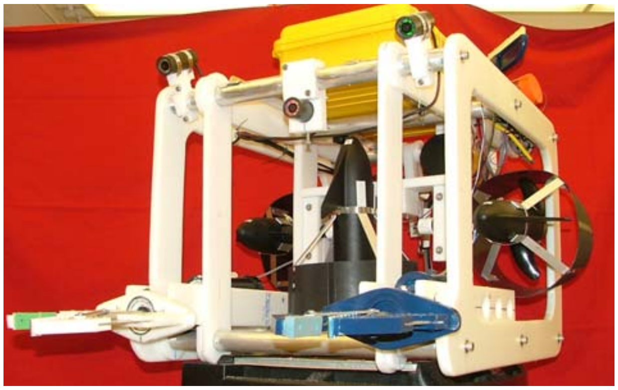
"THE 13TH HOUR"



TECHNICAL REPORT

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SITE 3 ENGINEERING

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I. Abstract

A three-year veteran of FIRST's (For-Inspiration-and-Recognition-of-Science-Technologies) robotics competitions, the Jesuit Robotics Team (Figure 1) had little trouble transferring from land to water. In our second year in the MATE competitions, we were given the opportunity to step up to the Explorer class, and we graciously accepted this new challenge.

Drawing on our experience from previous years, we began looking into how we would build our ROV. We modeled our ROV in SolidWorks and were able to prevent design flaws in the process. We also looked into stronger, more flexible and advanced technologies. Instead of using PVC, we used high-density polyethylene (HDPE). HDPE was great for us because it was sturdy, neutrally buoyant, and readily available to us and easy to work with. Also we reached our goal of a more versatile control system, specifically the use of the Innovations FIRST controller. This new control system allowed for better control and more powerful motors. In addition to this we water proofed two linear actuators that were used in our claws.

Among our training regimen was the ***Discover Scuba Program***, construction of our own indoor test pool and countless hours of large pool testing in order to bring our ROV up to our own high standards. Through the ***Discover Scuba Program***, our entire team learned the basics of scuba diving. We learned the importance of neutral buoyancy, and we were better able to understand the environment surrounding our ROV would be in.

Figure 1: Our Team 2007

II. Pictures of ROV

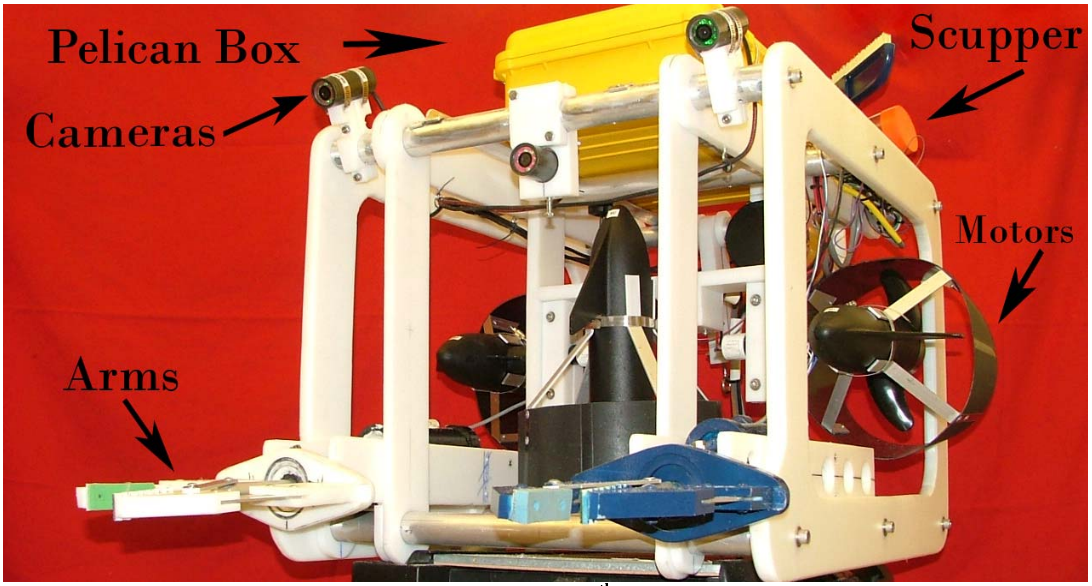

Figure 2: "The 13th Hour"

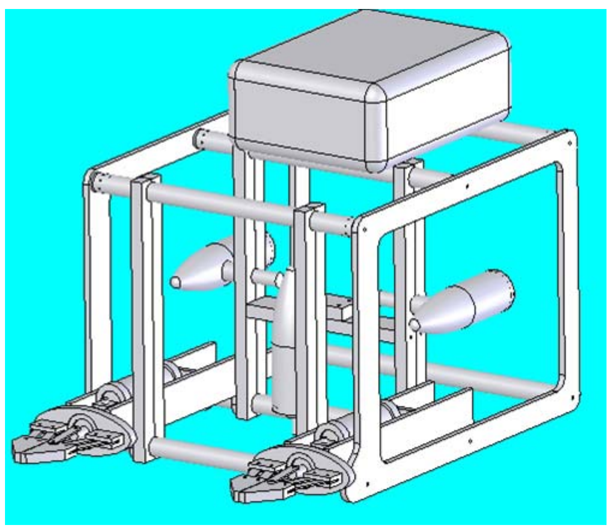

Figure 3: CAD Model

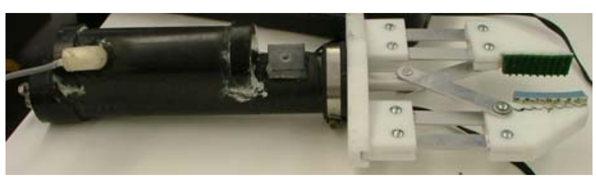

Figure 4: ROV Arm

III. Team Organization

Team organization and a diversity of skills on the team were crucial to our success. Our captins managed the entire operation and work was delegated to "specialists" to complete tasks requiring different talents. In order to complete a task, everyone would need to be involved and organized. For example, when we were in an advanced prototype stage we had to split up the tasks to maximize our efficiency. Some members would be working on the arms, some on mounting cameras, some on adjusting our buoyancy, and so forth, but they all talked together and organized into a team.

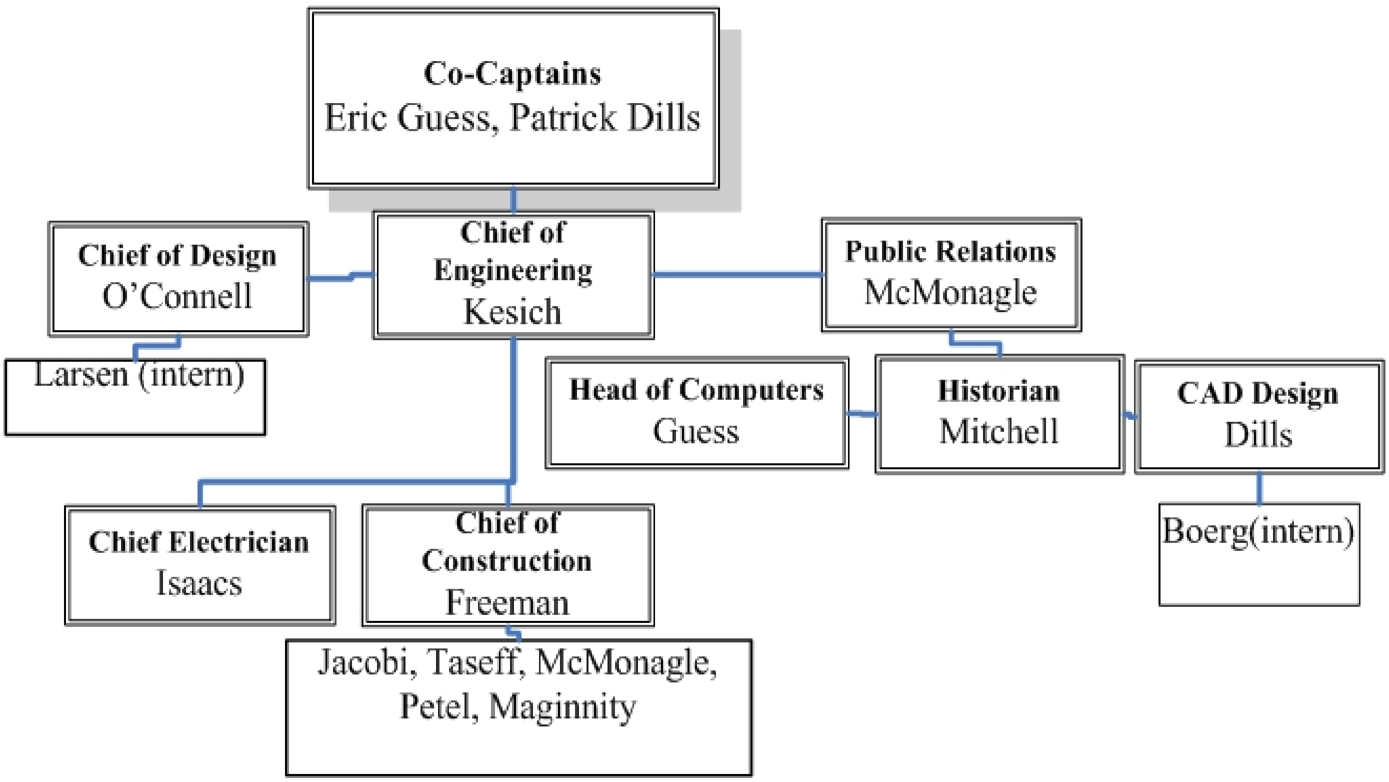

Figure 5: Team Organization

IV. Design Rationale

A. Design Methodology

Like all great creations our ROV originated on the drawing board. Our brainstorming phase was made up of many hand drawn sketches and cardboard prototypes. Once these prototypes were created, tested, and refined, we were able to use solid works to create our final ROV design (Figure 6). Once the final design was built a few more changes were made. In retrospect it would have been better to spend more time in the design process so we could have avoided these late changes.

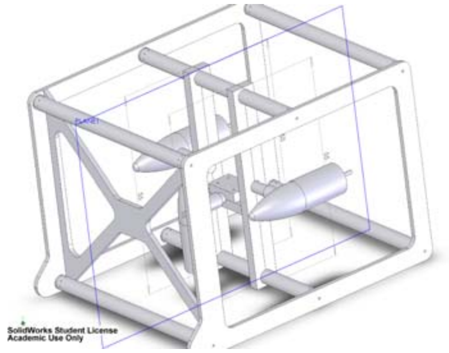

Figure 6: CAD Model

B. Frame Construction

We built our robot out of HDPE (High density polyethylene) with aluminum crossbars (Figure 7). We used HDPE because we did not want to make our ROV from PVC and wanted it to look professional. We researched what materials professional consultants were using to construct their ROVs One material that grabbed our attention was HDPE . We found HDPE to be relatively affordable, easily attainable, good impact resistance, light weight, very low moisture absorption, and high tensile strength, chemical resistant, not a good candidate for gluing but easily mechanically fastened. HDPE has a tensile strength of 4550 psi and a maximum temperature of 248°F/120°C

Figure 7: A cut frame side from HDPE

C. Thrust Motors

In order to maximize our efficiency , we used commercially available trolling motors (Figure 8), ranging from 28lbs to 32lbs of thrust. The trolling motors were modified and mounted on the ROV. Our ROV utilizes a total of three motors. Two horizontal motors were used for tank drive and a more powerful vertical motor. This operating system gives our ROV mobility in tight situations, and if necessary a great amount of speed and power.

Figure 8: A 28lb thrust Trolley Motor

D. Arm Construction

Our arm (Figure 9) design incorporates two arms. This design will be extremely useful when working in a current, and when working with tiny objects underwater. While creating these arms we had to keep in mind the environment that they would be surrounded by. This led us to encase our motors in a case that would protect them and keep them dry.

Figure 9: Final design for our arm

E. Scupper

The scupper (Figure 10) is designed to go along the underside of the ice sheet and suck down the ping pong balls. This motor is controlled from the surface so that we don't waste any unnecessary power.

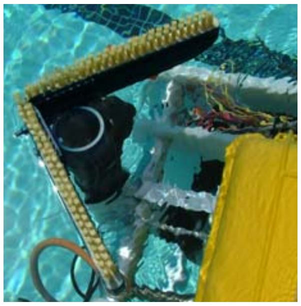

Figure 10: The scupper

F. Cameras

We went with a three camera (Figure 11) design so that we could have better vision in the water. These cameras are infrared which will help in the environments that have low lighting levels. These three cameras are set up with two at the top of the ROV and one center mounted with easily adjustable mounts. The two top cameras will give us a binocular like view of the water, and the center mounted camera will let us see the grabbers.

Figure 11: Underwater camera

G. Tether

The tether (Figure 12) consists of three power cords, one communication line, and three camera leads. Having power on the surface was important because it allowed us to reduce space and weight on the ROV, avoid recharging and replacing batteries, and manage our power source on land. In addition, if something were to go wrong we would be able to fix the ROV's power from the surface.

Figure 12: Our tether

H. Control System

We have two joysticks (figure 13) that control the left and right motors. We are using a potentiometer in our control box to control the vertical thruster. We went with the potentiometer so that we could leave it at a certain power level without holding a spring-loaded joystick. The claws are controlled by the triggers and buttons on the main joysticks. The bilge pump motor and the lights on the system are operated by switches in the control box.

Figure 13: Control system

I. Sensors

Two sensors are used on the ROV to sense the environment. These devices will allow us to monitor our moisture and heat. Both of these factors are very important, because if moisture reach high levels in the pelican box our control system may become damaged or destroyed. The thermal sensor will ensure that our robot is still within the temperature range it was designed for.

The moisture sensor (Figure 14) will be placed in the pelican box and inform the pilots if water flows into the box. In the event water enters the box, the sensor will help us make an attempt to rescue the ROV before any critical damage is done to the control system.,

The thermal sensor (Figure 15) also has a large significance, and will play a central role in our operations. Depending upon the temperature, the ROV will be operated in different ways in order to maintain the temperature below maximum operating temperatures. If the temperature reaches extremes, the sensor will inform the pilots who will be able to prevent temperatures from damaging the control system, rescue the ROV, and remain in the competition.

Figure 14: Moisture sensor

Figure 15: Thermal Sensor

V. Challenges

A. Waterproofing Motors

Working with underwater robotics, we ran into many issues with electronics. One of these major issues was the motors. Last year, we started off easy with bilge pump motors that were already waterproofed. This year, we only used one pre-waterproofed motor. For our drive motors, we used three trolling motors. These motors are pre water proofed on the shaft side, but on the side where the wires came in, we needed to fill them with gasket maker in order to prevent water from leaking into the housing. For out claw motors we had linear actuators, which had no waterproofing at all. For these, we had to build custom housing for each with PVC, lexan, HDPE, silicone, o-rings, and lots of Mr. Sticky glue. The tricky part about this waterproofing job was that we needed to allow a rod to go in and out of the housing without leaking. For this, we created a dual layer seal. This seal consisted of two HDPE discs that were separated by another piece of HDPE. The two outer pieces were each slightly larger in diameter than the shaft but stuck inside each of them was an o-ring fit to the shaft.

B. Cords Into and Out of Pelican Box

Because we decided to house all our electronics in a sealed waterproof Pelican Box, we were required to run wires into and out of this box without it leaking. This problem was solved by one of our members who works with pumps and generators. This member suggested we used the compression fit cable entry and exits that are used on pumps and control panels at his work. To do this, we measured all our cable sized and ordered compression fit entry's to fit them. To use these, we had to carefully drill holes into the sides of the Pelican Box and bolt them in with an o-ring on either side. The cables ran through these hollow entry's and were clamped in when the end was screwed on compressing the rubber seal inside onto the cable.

C. Mounting the Pelican Box

Once we had waterproofed our Pelican Box, we were challenged with how to mount it. The box would need to be secured, but also accessible in order to do any required maintenance on the control system. Realizing how buoyant the box is, we understood that it would be prudent to have it high up on the robot in order to prevent tipping. To add to the control of the robot, we decided to make the Pelican Box longitudinally adjustable so that we can balance the robot to sit flat in the water.

D. Scupper Design

Thinking about how difficult it would be to grab ping pong balls off the ice, we decided it would be smart to suck them off the ice. To do this, we took a 2000 gph bilge pump motor, ran a PVC pipe off the suction end to a cone on top where the balls would be sucked in. After that, we put in a plastic fence mesh to keep the balls from being sucked into the bilge. Above that, we put a splitter with a clear plastic cup on one end. This cup would catch the ping pong balls when the pump was turned off so they didn't float out. To keep the balls from just going back out the way they came, we put in a one way plastic flap that would fold down for the balls coming in and pop back out in the way on their way out.

E. Safety

Working around chemicals, electricity, and heavy power tools, safety is always a big issue. Keeping everyone wearing safety glasses and ear protection is a key issue. Because accidents happen and that's exactly what they are, accidents, it's hard to predict everything. So we try and keep the place neat and clean, tools organized and put away, and the floors swept in order to prevent what accidents we are able to.

VI. Troubleshooting

Our design maximizes troubleshooting and part replacement with easy access to controllers and thrusters. We have taken advantage of this set up on several occasions, especially in the final rush hours.

As far as troubleshooting the controller goes, we would first open the pelican box and make sure that everything was connected and receiving a signal. The indicator lights on the controller, victors, and spikes will help us diagnose this. If everything was connected, we would most likely check or re-download the programming to the controller.

In order to fix any broken parts we will come prepared with a plan of action. This plan includes how to repair the pelican box, how to gain access to the motors, and being able to quickly and effectively repair a connection. In having a plan of knowledge when we are face to face with something that might endanger the mission success, we can face it head on and move on.

The final component of our troubleshooting plan is to bring extra parts. In addition to the standard set of tools we will be bringing extra motors, fastening items, and possibly spare cameras. In doing this we would be preventing a possible crisis, and ensuring that we are able to compete. It is very important that we arrive prepared. By being prepared we will be ready to face any situation we are brought into, and will be able to do any necessary add-ons as well.

Figure 16: A Freshman being a Freshman

VII. Future Improvements

The Jesuit high school robotics team knowledge and technical experience has increased exponentially in the two years that we have participated in MATE competitions. Although our system is fairly advanced in comparison to our previous year's ROV, there is still plenty of room for improvement.

For example, a fiber optic (Figure 17) tether would not only be lighter, but also able to carry more information in a smaller gauge cable, simultaneously enhancing both the maneuverability and capability of our ROV. In addition, a high definition camera with an HD video recording device on the surface would enhance our ability to see underwater, as well as record practice sessions for later retrieval and analysis. We also looked into a dual-camera system that would give the operator depth perception when driving the ROV. In addition to increasing depth perception, having two cameras would allow for peripheral vision. These cameras would be able to move, which would also increase our visibility, especially to the sides of our ROV.

Figure 17: Fiber optics

Another idea for next year is variable and moveable ballast. This system will allow us to better control our pitch and mobility in the water. If this system works we could also save the added weight and cost of our vertical motor. To do this we would have rails upon which our system would move and alter the center of gravity.

Onboard power is also in the Horizon. In having onboard power we could keep our tether thickness to a minimum. By having a smaller thickness we could better manipulate the tether and also increase our ROV's mobility. Onboard power is also more efficient because we minimize the amount of amperage lost going down the tether. Therefore, we have more power to operate the ROV with.

Going from 12 volts to 48 volts is also a helpful improvement. This added power boost would allow us to run more devices at once on the ROV. This added ability will maximize our productivity and minimize the time it takes to complete the given task.

Our final future improvement is the use of hydraulics (Figure 18). Using hydraulics would allow us to have more control of our motion. Hydraulics are able to stop halfway in the range of mobility, which would give our pilots more ease-of-use when working with tight or compact situations.

Figure 18: Hydraulics system

VIII. Polar Civilizations

Karl Weyprecht14, the founder of the international polar year in 1882, has exposed the truth about global warming. In founding the IPY, Weyprecht (Figure 19) has promoted awareness and allowed the general population to become educated on this pressing issue.

Figure 19: Karl Weyprecht

One of the central goals of the IPY is to show people how our pollutants are affecting the life style of the polar inhabitants. One of these polar civilizations is the Inuit population (Figure 21). These intuits, formerly known as Eskimo's, inhabit the northern tip of the globe, and live anywhere from Canada, to Greenland, and even to the northern regions of Russia.

Figure 20: IPY Logo

Figure 21: Inuit family

The Inuit culture is heavily influenced by their environment. They have recently acquired territory in Canada in which they have full rights to all wealth there. Upon this land the Inuit's lead a life that is mixed with old values and newer technologies. For example, the Inuit's still fish for their food, but some buy from the local grocery store. Another example is that most Inuit's still heat their homes with the traditional fireplace, however recently Inuit's have begun to use heating systems.

John Franklin made one of the first attempts at exploring the Arctic coastline. This expedition was regarded as one of the most technologically advanced expeditions of the time. The goal of Franklin's adventure was to map out 500 miles of unexplored coast. Franklin left with 134 men from England to make a stop at Greenland. There, five men left the ship and Franklin made his final departure from Greenland. After this point the expedition was lost. Franklin's wife demanded a rescue search, but because the expedition left with enough food for three years, the rescue mission was postponed. When the idea was resurrected a 20,000 pound reward was offered. It was later discovered that after exhausting their supply of food and livestock the crew resorted to cannibalism.

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IX. Lessons Learned

The Jesuit High School Robotics team learned many things in our process of building our underwater ROV. These lessons helped us to shape the building and operation of the ROV.

We learned many things about the process of machining our robot. The machining refers to the machining of specialized parts and the construction of the robot. We learned that if one machines a part by trial and error won't work most of the time. Knowing this we recognized the important of precise measurements. Often parts would not fit in the areas they needed to and we learned to 'measure twice and cut once'. In machining parts it helps to use the correct tool. Through this process we were able to produce a well built machine.

Our team also learned things in designing. One lesson was in the important prototyping of our designs. We found that prototyping with card board helped with the placement of real objects such as the arm, scupper, and camera. Also the program SolidWorks helped us to make sure parts would fit correctly and bolts wouldn't cross each other without actually building the pieces. Both of these things helped us to incorporate the entire teams designs into a working machine that all fit together.

We also attained knowledge about electronics. In the beginning of the year we decided to use the innovation first controller in order to broaden our design possibilities. But this blessing came with a curse. We had almost no knowledge of programming but this curse was soon lessened with the help of our mentor Mr. Pelochino Also we learned how to solder with only minor injuries thanks to our safety precautions.

Although these lessons were important safety lessons were probably the most important. With our safety goggles and gloves on, we saw the dangers of the machinery that we were using. We learned how to keep ourselves safe when working with powerful and dangerous equipment.

X. Reflections

This year was a great experience for the team. From early mornings to late nights, we always had the support of our team parents. On top of that, our refrigerator was always full, so our stomachs were never nagging us during work. We learned a lot about ROVs and teamwork this year, and we hope next year we will increase our knowledge even further.

We also learned many valuable lessons, in which teamwork and cooperation are included. By breaking up into smaller groups with specific tasks we were able to accomplish more. In the decision making process we found that sometimes it was best to just accept someone else's decision and to follow directions. The greatest lesson learned is that constructive criticism is valuable to a certain point, however after that point a plan must be followed.

Another great part of this year was creating a mentoring environment for the new team members. In creating a fraternity spirit more was accomplished and goals were reached faster. This year was a lot of fun, and we hope next year will be even better!

XI. ROV Specifications

Table 1: Specifications

Materials	HDPE & Aluminum Frame
Dimensions	78 cm W x 88cm L x 34cm H
Weight	493 Newtons (50.3 Kg.) Calculated with digital force sensor
Weight in Water	1.5 Newtons Negative Buoyancy. Calculated with digital force sensor
Power Requirements	12 (13.1) volts max 34 amps =408 watts (445.4W) @Max Pwr. Pwr. run thru a 18 m. 10 ga. Stranded cable With flexible coupling connector. Loss rate At length is less than 8%.
Motors DC Trolling	Two (2) drive (125 newtons (12.7 Kg.) ea.) Total: 250 Newtons One (1) vertical thruster 150 Newtons (15.4 Kg.)
Motor Control	Full range control thru 0-100% power. Thru the

	Innovatiopns First control system
Control System	Innovation First control system. PWM Modulation of motors and relay control thru A single communications cable. With pressure-tested connectors.
Manipulator Arms	Two (2) DC Linen Rotators connected to The claws. 5:1 ratio (120W Force) Four (15.25m) and six (25.4cm) stroke 12 volt DC 1 Amp. Enclosed in a water-tight case. Single axis Claw movement Stroke time approx six (6) sec.

Thruster Dynamic Testing

Power	Max current out of water 17 amps Max current submerged 34 amps
Claw Motors	1.6 amps
Rated Thrust	All thrust measurements with digital Force sensor(s). Forward: 56 net newtons Reverse: 30 newtons Vertical (up): 50 newtons (down) 25 newtons
Turn Radius	@ Max Differential Thrust: < 1.3 meters
Max Submerged velocity:	1.0 + meters/second

Time Trial measurement – 5.0 meters

Buoyancy compensation:	Pelican box (173.5 newtons positive) and SCUBA led shot

XII. Electrical Schematic

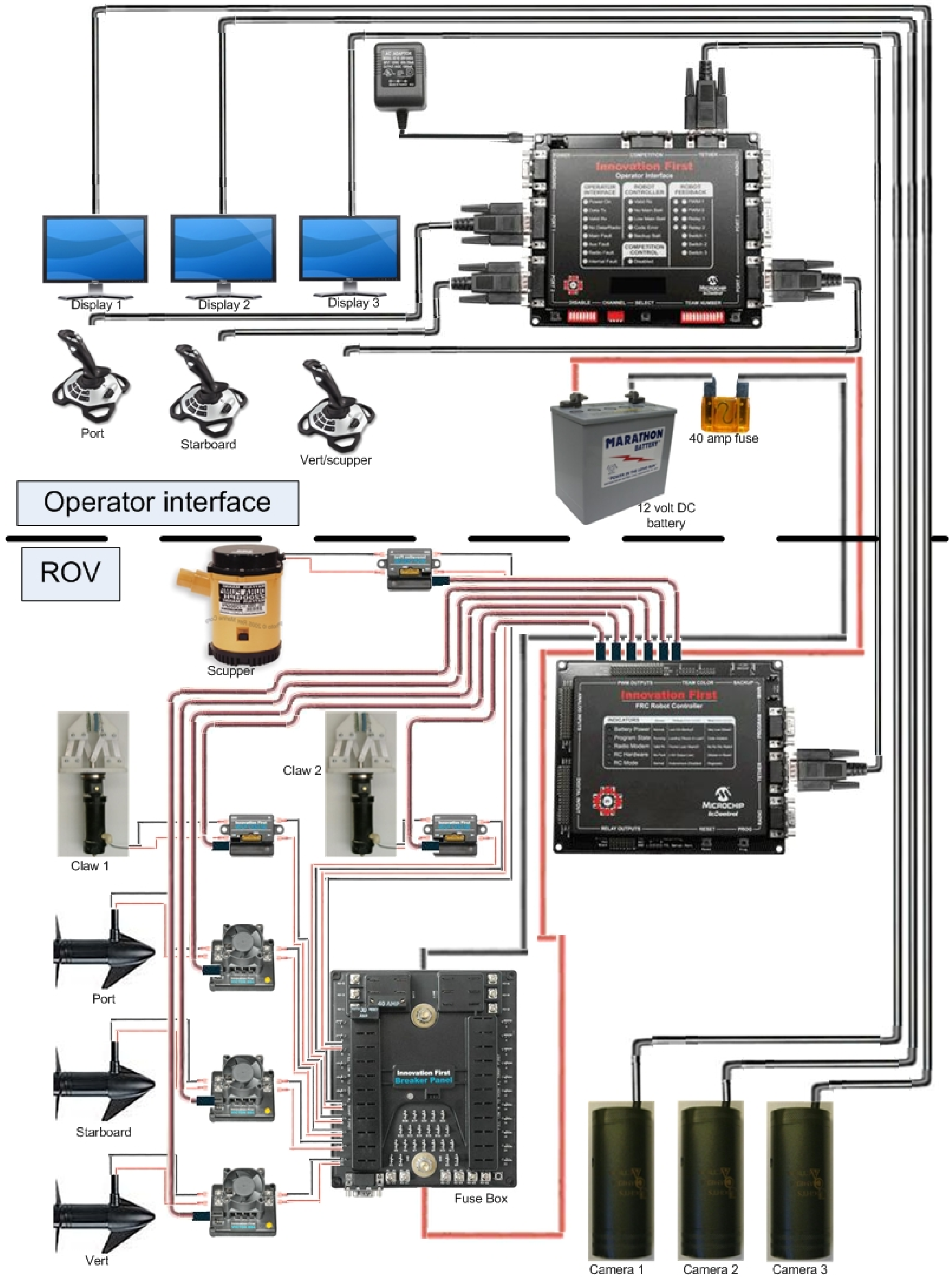

Figure 22: Electrical Schematic

XIII. Software Flow Chart

Programming was an essential part of our ROV this year. With the implementation of the Innovation First Controller we were able to increase our performance in the pool. Using the programming language C we learned the “inns and outs of outs” of our system.

When the ROV is powered up, the program initializes itself, resets outputs, sets variables, and starts communication. It then enters a loop in which it reads the input values from joysticks and switches, and outputs these values to the victors and spikes.

Finally, the program sends feedback using lights and the display on the controller.

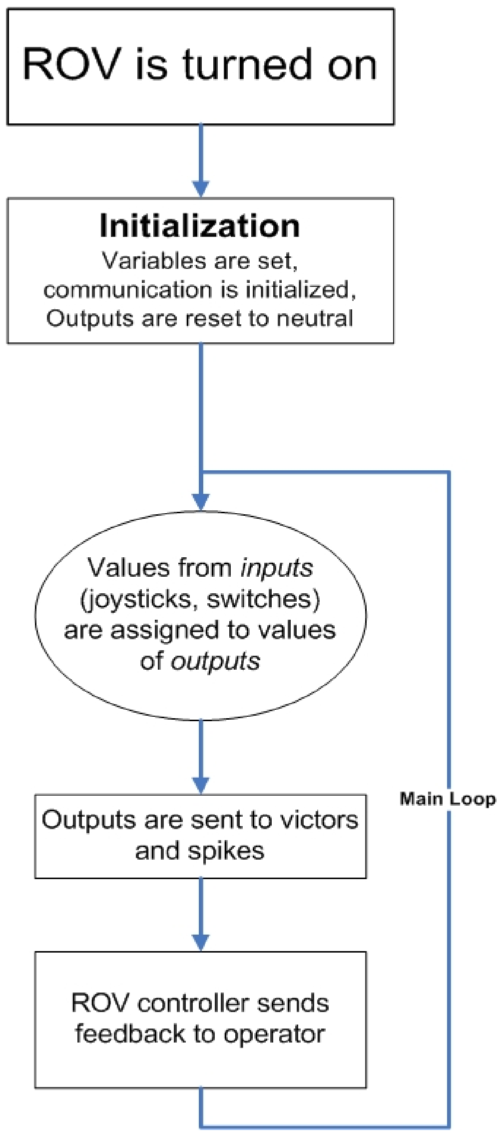

Figure 23: Software Flow Chart

XIV. Bill of Materials

Table 2: Expense Sheet

Item Description	Quantity	Unit	Cost/Unit	Total Cost	Reused
HDPE 1"	1 Sheets	EA	$135	$135	
HDPE 3/4"	3 Sheets	EA	$100	$200	
HDPE 1/2"	1 Sheets	EA	$70	$70	
Lexan	2	EA	$120	$240	
Aluminum Supports	6	EA	14	$85	
Solid Bar Caps	12	EA	3	$35	
Trolling motors	3	EA	90	$270	
Wiring	NA	EA	NA	$120	
Assoc parts	NA	EA	NA	$90	
2 Jack Screw Motors	2	EA	80	$160	
Copper Fittings	2	EA	5	$10	
Small Pelican box	1	EA	65	$65	
Large Pelican box	1	EA	107	$107	
ABS Pipe	3	EA	12	$48	
Controllers	1	EA	1000	NA	$1000
Victors	2	EA	110	$220	
Cable delivery	1	EA	50	$50	
Camera	3 (1 New)	EA	225	$225	$450
Shrouds	3	EA	8	$25	
Warning Labels	3	EA	5	$15	
2000 gph pump motor	1	EA	50	$50	
Spare parts	NA	EA	NA	$87	
Power	1	EA	55	$55	
Wire wraps	NA	EA	NA	$25	
Mechanical fittings	8	EA	7.5	$60	
Heat shrink	12	EA	1.5	$20	
Glues	NA	EA	NA	$100	
Stanless steal screws	120	EA	0.8	$100	
Avg. Daily meal	NA	EA	80		$80
Poster	1	EA	20	$20	
Total				**$2,687**	**$1450**

XV. Acknowledgements

- MATE Center
  For providing us with a unique challenge and competition

- McMonagle Family
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- SolidWorks
  For providing free SolidWorks Student Design Kit 2006-2007 to each team member.