Lamphere Robotics

Lamphere High School
The Lamphere School District, Madison Heights, Michigan
Robotics Team
Remotely Operated Vehicle
MATE National ROV Championships

Team Members:
Dawn Bezanson, Arthur Campbell, Jonathan Mansoor,
Brett Reichart, Matt Savela, Brian Shuman, Patricia Thompson

Teacher Coaches:
David Holstein, Melissa Cragg, Bill Ray

Abstract

De cnidarian mobile (the jelly fish moves)

Our ROV, Al, built by the Lamphere High School ROV team was engineered to fulfill the requirements of the 2005 Ranger class competition. Our ROV is based on the principles of operation of the Innovation First Control System. We opted to use trolling motors on our ROV instead of bilge pumps or other propulsion devices. With the analog control system it was more logical to use trolling motors because it gives us a greater range of motion. This being our first competition we are excited to get out in the field and gain experience.

Two of our team members, Jon Mansoor and Arthur Campbell, get the robot ready for testing after the first coat of paint.

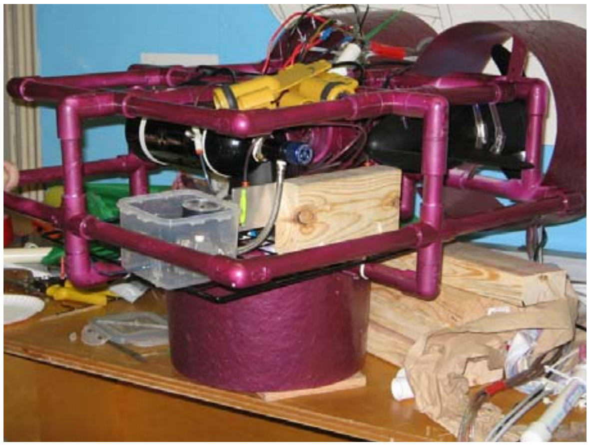
Design Rationale

Our first objective was to create the chassis for our ROV. At our first meeting, the team decided unanimously to use 1.27cm diameter PVC tubing because it is light-weight, easy to cut and connect, and it helps with buoyancy control. The shape of the chassis was not decided upon as easily. This decision took much debate and experimentation before we decided on our current design. Al weighs 30.2 kg with the tether, and 24.3 kg without. The rectangular shape gives us plenty of room within the chassis to contain our cameras, motors, and other devices, while also maximizing surface area at the top and bottom so all devices can be securely anchored. This design also offered us the advantage of building supports into the frame which surround our trolling motors, ensuring that they will stay in place in any situation.

Mentioning the motors brings up the second objective of our design, propulsion. We opted to use trolling motors on our ROV, rather than bilge pumps or other types of thrusters, because of their high power relative to their size. Our ROV uses three motors: two facing the stern of the robot, for horizontal propulsion and steering, and one aligned vertically in the center for depth control. Ideally we would have at least six motors for symmetry and power, but practicality (from the directions of budget, buoyancy, and space) dictates that we work for a balance between ideal power and maximum maneuverability.

Another key feature of ROV design is the camera. We chose to use two cameras so that the drivers could view the ocean from the bow and below the ROV, if you'd like to get into the spirit of the competition tasks.

The cameras we're using were designed for ice fishing, so they are adapted for underwater video (meaning we didn't have to waterproof them, which was a big consideration when we were developing our design) and each has a ring of LEDs around the lens to illuminate the image. We have two small LCD monitors completing our video system, which work quite well in the tests we have done.

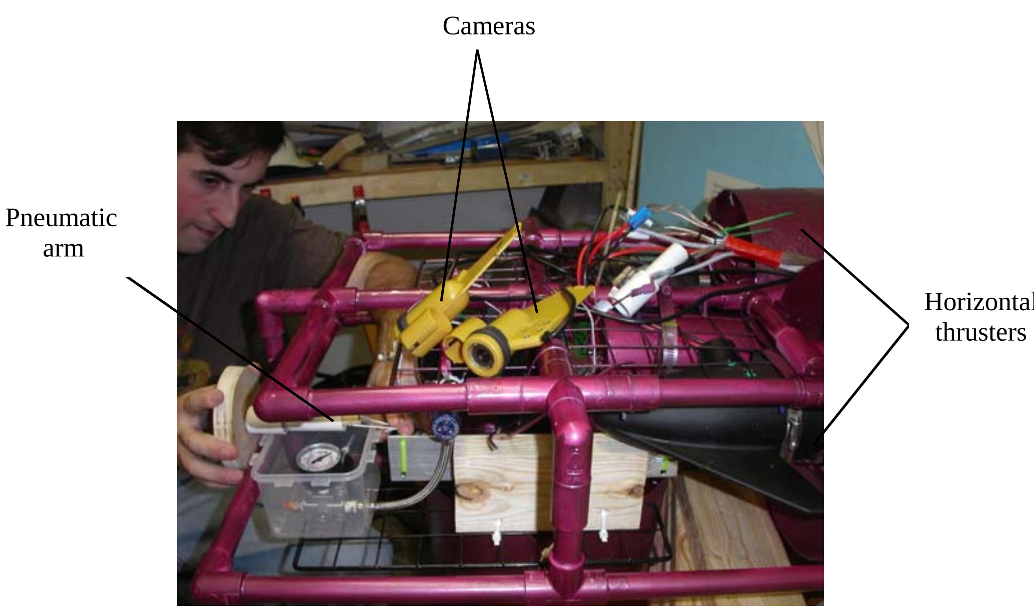


Al is finally complete!!!

Design Rationale, Con't.

The next basic element of our ROV is its manipulator. In the interest of simplicity, we decided not to build an arm, which would make for complicated engineering (with a lot of opportunities for error) and result in problems with balance and inertia. Instead, we have a small pneumatic cylinder with a PVC attachment powered by a canister of compressed carbon dioxide. This allows us to fulfill the two mission tasks that require such control.

The last of our ROV's main features are the three fiberglass motor guards. In addition to providing safety, they keep our unwieldy tether from getting caught in the propellers and shredded into small useless pieces. The ring on the vertically-aligned motor also provides an effective support for the robot when it is transported or enhanced. The fiberglass rings also increase and direct the thrust from our motors.



Brian Shuman experiments with the places to attach the instrument module to "Al".

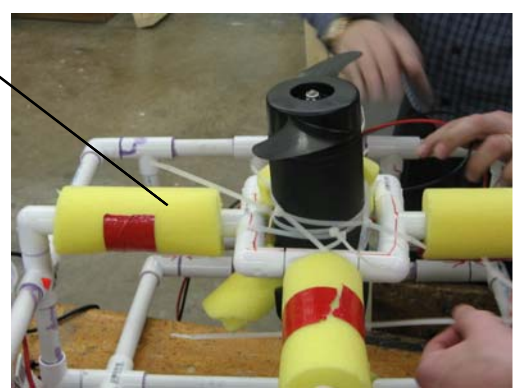
An Interesting & Unique Challenge

Like any other group of people with a task to accomplish, Lamphere's ROV team has faced quite a few challenges over the time we have worked together. And like any good team, we have met these obstacles head-on, to become a more unified, successful team.

One of the problems our team has faced while working on our ROV has been organization. No team is complete without a leader, and we know that well - so well, in fact, that everyone in the team has decided at one point that they are the leader. Such a strategy may work, had we not all decided to try it at the same time. Doubts and constructive criticism had no chance to be voiced, and the team ended up nearly working backwards for a time before authority was sorted out. Through this process, we learned to make concessions and compromises without taking them as affronts to our authority.

Another challenge that we have faced and are still in the process of overcoming is the familiar problem of timing. Our team is composed of a group of students who each take every opportunity to get involved in school and community organizations, and also who have dedicated time from their busy schedules to attend to their studies in a variety of advanced classes. Especially nearing the end of the school year, it is difficult to find enough balance between everyone's activities and the time-consuming, deeply involved project like our ROV. Conflicts with school sports have led to some team members being present at fewer than half of our meetings, which ties in with the organization problem again. Schedules and meetings have been reconciled, and all the students (not to mention our wonderful coaches) have made sacrifices in order to help our team be successful.

Closed cell foam module



This is the finished product of one of our two possible designs. We are mounting the motor and getting ready to test it out in our pool.

Future Improvements

Our ROV is still a work in progress. Since the Alpena Regional Competition, we have worked to improve our ballast system. Our first design included PVC pipes with caps attached to the port, starboard, and below the horizontal thrusters. This design was not as applicable as we had originally planned because the stern was pulled downward and our motors were not powerful enough to level it out. Our second design worked out better. Our ROV relies on closed cell foam modules as well as two PVC pipes with caps on the port and starboard to achieve neutral buoyancy. We are currently testing out our ballast system by allowing water into one of the tanks to control stability.

In theory the ROV would start with empty ballast tanks creating positive buoyancy. A valve would be opened allowing water to fill to the point of neutral buoyancy. Once we reach “PONB” we could then use the trolling motors to control the robot until the objective was complete. After the objective had been completed, the CO_2 would be used to blow the water ballast. The ROV would then become positively buoyant and rise to the surface. We will start experimenting for next year.

Although our robot works well, there is enormous room for improvement. One aspect we chose not to tackle this year is to have the ROV controller on the robot instead of having it inside of our main box on land. This idea was partially sparked by trying to figure out ways to make the tether lighter. It was thought that having the box with a spare battery on the ROV would decrease the amount of wires that we would need to route through the tether. The reason we moved on was because we could not risk damage to our controller or contamination of the pool by the spare battery. Next year, we may spend time to figure out other ways of protection rather than using epoxy and relying on air pressure to keep the water out.

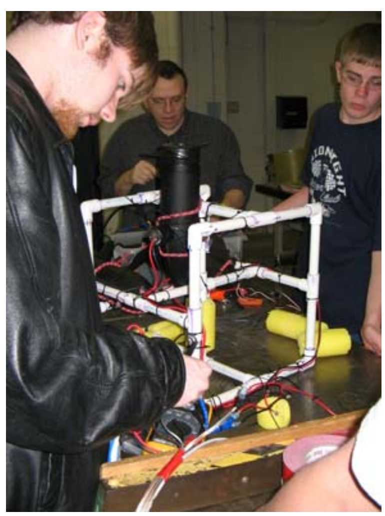
Our coach, Mr. Holstein, is showing Patricia Thompson how to lay up a Fiberglass shield for our motors.

Future Improvements, Con't

At the moment we are using trolling motors which are quite heavy and hard to position. Next year we would like to experiment with the idea of using bilge pumps instead of the trolling motors. If we decide to go with the bilge pumps then there will need to be 8 of them increasing the weight of the tether therefore we would need the onboard box idea to be implemented in order to keep the tether from being bulky. Attaching the bilge pumps is another challenge since there are 8 of them it will be harder to find places to mount them.

During the Alpena competition we used the default program that was loaded into our controller. After that first competition, we wanted to experiment with combining two joysticks into one. In the past, one joystick controlled the port motor, and one controlled the starboard motor. With the new program that Mark McLeod, Alan Anderson, and Allan Cameron helped us create, we combined the motion of two joysticks into one.

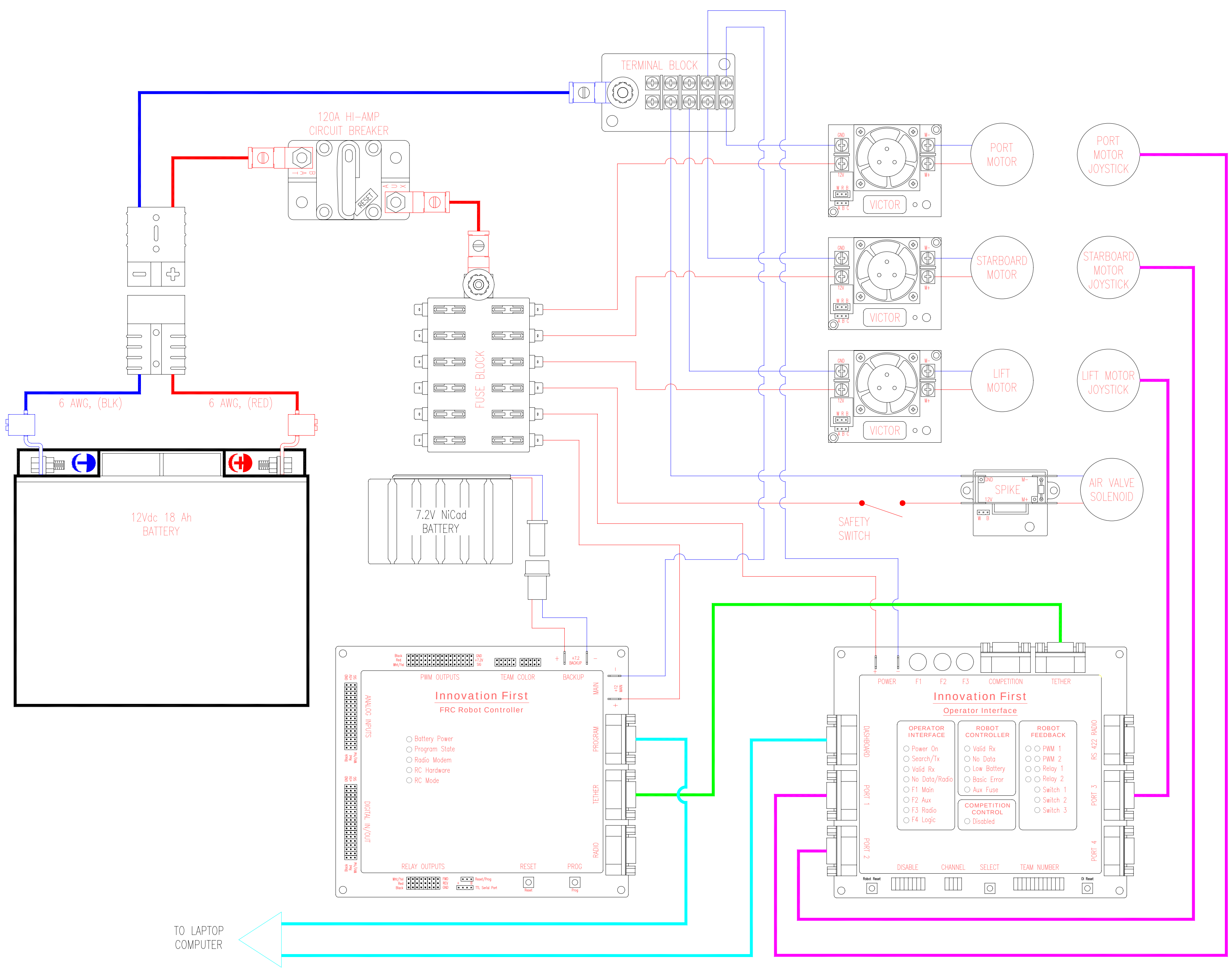
We are using two 7-inch LCD monitors to currently view what is in front of the robot. With the goal of increasing depth perception, we would like to research a computer program, called Callipygian3DCam, that combines both video signals into one signal using one monitor, like human sight. This would allow us to get a better view of what our objective looks like so accuracy and precision are easier to achieve.



Arthur Campbell and Matt Savela are prepping one of our original designs to be tested in the pool.

Lamphere Robotics

Electrical Schematic



12 Volt power is sent to the control box through a 25 amp circuit breaker. Power is divided between all of the electrical circuits through a 10 gang fuse block. All electrical devices are grounded to a dual binding post. Power is sent to each device through our operating system.

The operating interface our team uses is very adaptable to the Ranger class competition. We are using the Innovation First Control System. Our team has previous experience using this control system in the Oakland County Competitive Robotics Association (OCCRA). The Control system consists of two parts: The Robot Controller and the Operator Interface. Joysticks are connected to the interface, which sends signals to the controller. Electrical relays called spikes and Victors are found on the robot controller, which are used to control various aspects of the robot's movements.

Spikes are relay modules. They act like remotely controlled electrical switches. They enable weak electrical signals from the controller to turn on or off the large current that is sent to the pneumatics solenoid. Only one spike is needed to control both actions of the pneumatic cylinder.

Victors are also relays. A victor controls each thruster. Victors control the speed and polarity of thrusters. Unlike the spike relays, which are either on or off, victors can output a range of power values. Victors adjust the amount of power they deliver to the motor based on the signal they receive from the controller. The position of the joystick determines this signal. The victor then acts like a water faucet regulating the flow of water through a garden hose. This controls the speed of the motor. If the joystick is moved to the reverse position, the signal to the victor has a reversed polarity. The victor then makes the motor spin in reverse. Victors can allow infinite speed control as well as reverse and forward motor direction. They are very versatile.

Troubleshooting Techniques

When part of our robot does not work, we fix it. Our team has developed a system for troubleshooting that we follow whenever there is a problem.

We use the troubleshooting checklist whenever there is a problem. First, we start out by making sure our electrical boxes have power. We then check that the fuses, the joystick cables, etc. are plugged in firmly in the controller. This is where many of our problems originated.

If they have power and there is still a problem, then we check the wiring between the box and the Victors/Spikes. A broken PWM wire could be the cause of the problems. We use PWM wires to connect our motors to the controller. If that is the problem, then we just replace the PWM wire. We used a volt ohm meter for checking circuit continuity.

A broken Victor/Spike could also be the problem. To check this, we test a connection that we are sure works with another Victor on the Victor in question. If the connection we are testing does not work on the Victor in question, then we have to replace it.

Lastly, our controller shows us what it is receiving information from and what it is not. There are LEDs on the controller than indicate that the item on a PWM input is working. If nothing is showing up next to the light for that PWM input, then we try it on a different PWM input.

There is a picture of our controller on the attached page. There are three different columns, *Operator Interface*, *Robot Controller*, and *Robot Feedback*.

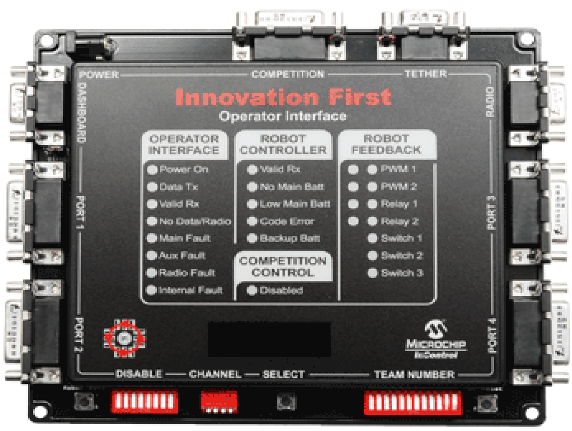
In the *Operator Interface* column, it tells us if the controller is powered and whether it is transmitting/receiving a signal It also indicates if the data packets received are bad, and if there is a main, an auxiliary, a radio, or an internal fault.

The column labeled *Robot Controller* tells us if the controller is receiving intelligible information, if there is a connection problem with our battery, and whether the battery attached to the robot controller is below 9V or 7.1. Lastly, it tells us if there is a coding error.

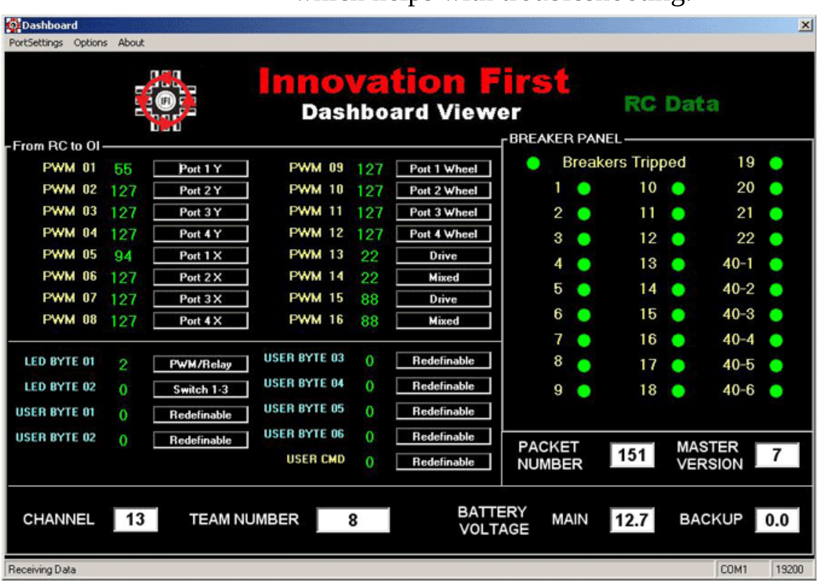
The column labeled *Robot Feedback* tells us if the PWMs, relays, and switches are working.

Troubleshooting Techniques, Con't.

There is a free program that may be installed on a computer than receives information from the robot controller. This program is called *Dashboard Viewer*. This program can tell you detailed information about what is going on inside the robot. This is useful to make fine tunes to the motors. You can see what breakers are tripped, or have tripped in the past to help stop those problems from happening again.



This is a picture of our operator interface, which helps with troubleshooting.



This is a screenshot of *Dashboard Viewer*, which is currently showing information about tripped breakers and PWM inputs.

Troubleshooting Techniques, Con't.

TRIAL	YES/NO	TEST 2	TEST 3
Is there a 12 volt power supply connected?			
Is the circuit breaker open?			
Is the fuse blown?			
Is the robot controller unit on?			
Is the user interface on?			
Are the PWM wires connected?			
Are the joysticks connected?			
Are there any loose wires?			
Are all connections secure?			
Check with multimeter for continuity			

Impact of ROVs

ROV's have opened a whole new world into the past and the unknown. They are used as a window into our history, to make expeditions safer, and to better understand the world beneath the water's surface. As the thirteenth National Marine Sanctuary, Thunder Bay is the first National Historic Landmark located entirely within state waters. As a team from Michigan, Thunder Bay has helped provide us with information and guidance to succeed in our first year. Thunder Bay has used ROVs for several revolutionary applications such as exploring and mapping historic shipwrecks in ways that had never been thought possible.

The idea for Thunder Bay to become a sanctuary began in the 1970's when the community considered the possibility of an underwater park dedicated to the shipwrecks in the area. The idea continued to develop, and in 1981 the park was created as Michigan's first Great Lakes Bottomland Preserve, and soon became a candidate for recognition by the National Marine Sanctuary. With the help of the state, a 15-member Sanctuary Advisory Council, and interested citizens, the National Oceanic and Atmospheric Administration (NOAA) published the Environmental Impact Statement that detailed the criteria for the establishment of the sanctuary. On October 7, 2000, after 45 days of review by the Michigan governor and congress, the park was officially designated as a sanctuary.

The sanctuary located in Thunder Bay spans 3,000 square kilometers in Lake Huron. This magnificent historic site is estimated to contain 116 shipwrecks though only 40 have been located and mapped. ROVs have helped the Thunder Bay Marine Sanctuary by exploring the shipwrecks in areas where it is dangerous for SCUBA divers to travel. ROVs have captured pictures and brought back samples from the ships, allowing us to identify the age of the ships and most times the specific history of that vessel.

Thunder Bay's marine sanctuary has allowed us the opportunity to expand our knowledge of Michigan's nautical past. It is an ideal facility for education and research and will contribute to our appreciation and awareness of the noble history of Great Lakes seafarers for years to come.

Sources: http://preserveamerica.noaa.gov, http://thunderbay.noaa.gov

A picture taken by an ROV of the many shipwrecks near Thunder Bay.

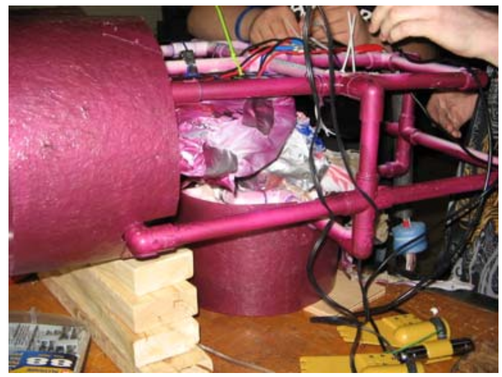
Skills Gained

Our robotics team has overcome many difficult problems in the past, but the most difficult task we have ever received was to build a robot that can swim! Our team learned long ago as part of the OCCRA (Oakland County Competitive Robotics Association) that no matter how smart one individual is, they cannot build a robot alone. Through the ROV competition, our team has acquired numerous abilities, most importantly those that allow us to work effectively as a team. Each individual on our team is capable of coming up with great ideas, but unless they can share those ideas with the rest of the team, we cannot work them into our robot. From the beginning of our first meeting, we have been learning how to better communicate ideas to our teammates and coaches, in preparation for our final presentation to ROV competition judges. By keeping each other up to date, and combining our ideas, we are able to overcome just about any obstacle that is thrown our way. It is easy to tell when you walk into the lab if someone has had a breakthrough idea because you can see them up at the drawing board making a diagram.

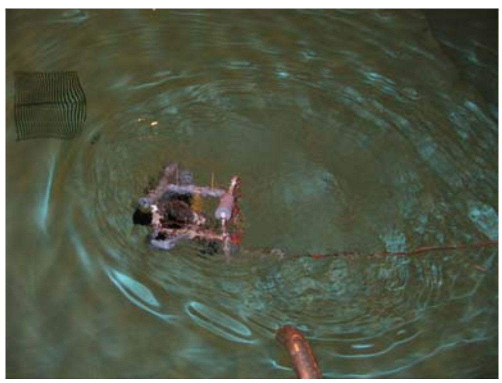
There are many skills that our team has also learned that are useful in our every day lives that most high school kids no longer get to learn in school due to the higher focus on computer technology rather than physical skills. There are many examples that would relate to everyone on the team. Twenty or so years down the road when we have our own homes and encounter a problem with our plumbing, we will not be stuck relying on a service company to repair it. With our experience in working with metal piping and PVC, properly soldering or gluing a section of pipe onto a pre-existing one with a connector coupling is not a difficult task for anyone on the team. Another example of how far-reaching these skills are, one of our team members has now made it his future goals to attend MIT to become an engineer. Learning these skills gave him the confidence he needed to make this dream within reach.

We are testing out our new program.

Photographs of " Al"

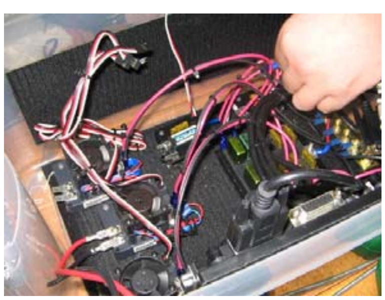


(Above)
This picture was taken when we had just finished attaching our tether to the robot for the first time

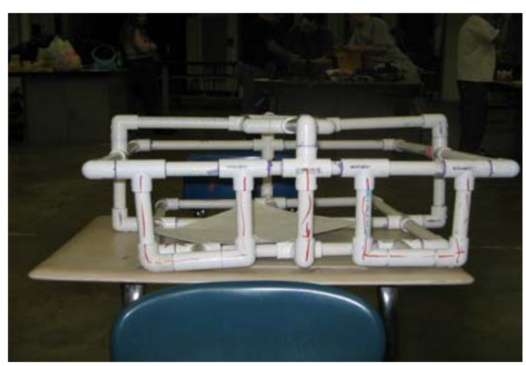


Testing one of our designs

(Above)
Conducting experiments to determine where we should place the pneumatic for the best results



Inside of the electrical box

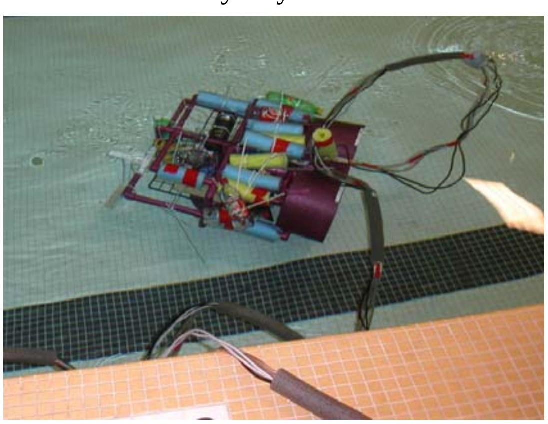


Prototype of our current design

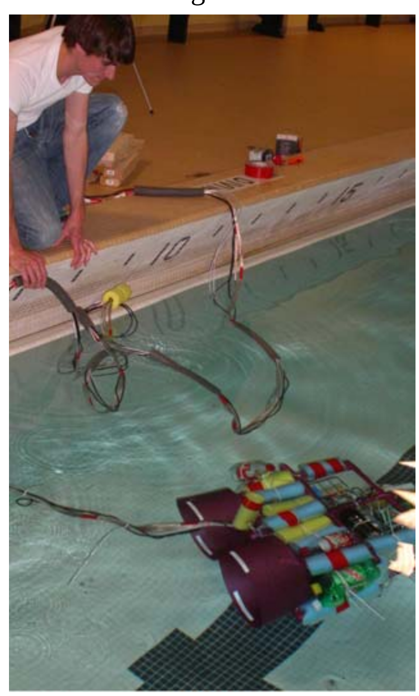
Photographs of “ Al”

(Above) Brett Reichart, Jon Mansoor, and Brian Shuman discussing buoyancy.

Matt Savela perfecting his driving skills.



Our tether and robot are complete in this picture, and we are adjusting buoyancy.



Experimenting with buoyancy

Lamphere Robotics

Lab Journal

January 26 First Meeting Discussed potential design ideas	**February 2** Researched shapes and designs Began keeping photographic records
February 7 Discussed designs Seperated into groups to develop designs	**February 9** Group research session: propulsion, advantages and disadvantages, basic principles
February 23 Small groups and design discussions Worked on preliminary aspects of technical report	**March 9** Started work on electrical control box Discussed and made final decision on structure of tether
March 16 Set up a shared online server for pictures Voted on body designs Assembled tether	**March 21** Attached all available design components to frame Attached tether
March 23 First test run in Lamphere's swimming pool	**March 25-April 3** Spring Break
April 6 Modified design based on first test run Waterproofed components	**April 13** Started making fiberglass propeller guards Re-wired motors and control box
April 18 Attached and tested pneumatic devices Discussed improvements to video system	**April 25** Compiled budget report Troubleshooting workshop: wiring
April 27 Designed template for tech report and design modifications	**April 29** Troubleshooting workshop: electronics Birthday party for new sponsor
May 2 Edited submissions for tech report Modified camera arrangement Dry-tested all functions	**May 5** Tested robot in preparation for Alpena
May 9 Experimented with buoyancy Loaded new program	**May 12** Tested new program in pool
May 16 Experimented with lasers	**May 18-19** Finished ballast system

Budget

Item	Qty	Unit Price	Cost
1/2x10' PVC	6	2.48	14.88
PVC Connectors	2	3.97	7.94
PVC Fittings	60	0.19	64.8
1/2" Tee S X S X S	72	0.19	13.68
1/2" 45° Elbow S X S	3	0.36	1.08
1/2" 90° Elbow	17	0.21	3.57
1/2" 45° Elbow S X S CPVC	18	0.31	5.58
1/2" Tee S X S X S CPVC	36	0.21	7.56
1/2" Cross S X S X S X S	16	1.1	17.6
1/2" 90° Elbow S X S CPVC	18	0.21	3.78
7.2" TFT LCD monitors	2	124.94	249.88
SC-420 color underwater camera	2	99.99	199.98
Fiberglass mat	2	4.68	9.36
Fiberglass resin - gallon	1	23.97	23.97
Coupler	1	1.59	1.59
Ring Terminal	1	1.59	1.59
Junction	1	3.49	3.49
1/8"x600 Nylon Rope	75	0.09	6.75
Five minute epoxy 2 in 1 tube	1	3.59	3.59
Resin roller	1	7.49	7.49
Battery Clips (copper)	1	1.09	1.09
36-Piece Heat-shrink Tubing Set	1	2.59	2.59
Lighted Flip Switch	3	2.99	8.97
Dual Inline Banana Plug	1	3.99	3.99
Gold-Plated Banana Plug	1	6.29	6.29
Chassis-Mount Dual Female Binding Post	1	4.99	4.99
12VDC Toggle Switch with Safety Cover	1	4.99	4.99
5-Gallon Bucket	1	3.98	3.98
Epoxy Adhesive	1	2.97	2.97
Endura Transom Mount Trolling Motors	3	91.39	274.17
Ancor Battery Cable	8	1.39	11.12
Insulated Ring Terminals - Funnel Entry	2	1.39	2.78
ATO Style Fuse Block - 10 Gang	1	19.79	19.78
Nylon Disconnects - Full Insulation	1	6.89	6.89
Thermal Circuit Breakers Panel Mount	1	28.59	28.59
Universal Fill Adapter	1	23.58	23.58
20oz. CO2 Tank	1	33.02	33.02
7in. Stainless Steel Hose	1	11.32	11.32
8 oz. All Purpose Cement	2	3.97	7.94

Budget, Con't

Item	Qty	Unit Price	Cost
PVC Cutter	1	9.97	9.97
Duct Tape 2in X 60yds	2	5.89	11.78
Blue Duct Tape	1	3.27	3.27
Duct Tape	2	8.27	2.98
1Gal. Krystal Kleer Solvent	2	1.19	2.38
Brown Plug	3	1.93	5.79
White Plug	3	1.93	5.79
Speaker Wire	1	43	43
Quickwire Ivory	8	0.48	3.84
24-4 PR5 1FT	130	0.15	19.5
1/2" Full Port Threaded Ball Valve	1	6.97	6.97
1/2" Male Adp. MTXS CPVC	2	0.3	0.6
1/2" - 1/4" Heat Shrink Tubing	1	1.95	1.95
3/4" - 3/8" Heat Shrink Tubing	2	1.74	3.48
Spray Paint	1	11.42	11.42
Lock N Lock Watertight Containers	1	5.99	5.99
Fiberglass Mat	4	2.97	11.88
Pipe Insulation	1	6.36	6.36
1/2" PVC 40	2	1.39	2.78
1 1/2" x 10' PVC	1	4.28	4.28
Colored Zip Ties	1	2.97	2.97
Fitting	16	0.12	1.44
1-1/2 In. Slip X Slip PVC Coupling	3	0.47	1.41
Fitting	3	0.22	0.66
5-Pack of Tape	1	3.98	3.98
5/16" x 3" Large Screw	30	0.35	10.5
Miracle Beam Aquarium Laser System Module	3	11.04	33.12
Heavy Duty Rivet Tool	1	9.99	9.99
1/8" Long Aluminum Rivet	1	7.99	7.99
1/8" Steel Washer 40pk.	1	1.89	1.89
Mending Plate	4	0.99	3.96
Hose Clamps	12	1.34	16.08
12VDC Regulated DC to DC Selectable Converter	4	3.95	15.8

Total: $1,391.33

Sources of revenue: Lamphere Board of Education Donation (Total of $3000)
Nathaniel Bezanson ($80 worth of zip ties)
Boat US (at cost purchases)

Acknowledgements

- Boat-US
    - Discount on building materials
- Mrs. Melissa Cragg
    - For her ongoing help and support. Mrs. Cragg really pushes us to do our best and her trust in us never waivers
- Mr. Bill Ray
    - For his ingenious ideas, filling in for one of our sponsors at the last minute and we know we can always count on him
- Mr. David Holstein
    - For getting our team started here at Lamphere. We wish the best of luck
- The Lamphere Schools
    - Supporting us financially and academically
- Audrey Marshall
    - Incredibly awesome lifeguard
- Mr. Mark McLeod, Mr. Allan Cameron, Mr. Alan Anderson, (Team programmers for Oakland Country Competitive Robotics Association)
    - For help with programming issues
- Mr. Brad Lyon
    - For your guidance and inspiration to create one of the best schematics we have ever designed
- Thunder Bay National Marine Sanctuary
    - $1500 donation towards travel expenses
    - Sponsoring Michigan Regional Competition
- Alex Calverley, Corey Allison, Andrew Quinn, (Lamphere High School Students)
    - Help making schematic
- Mr. James McCann, Superintendent of Lamphere Schools
    - Supporting our team throughout the year
- Mrs. Jeanne Berlin, Technical Communications Specialist
    - Computer support