Great Lakes ROV Team

Presents

T-1 Ichthyoid

Team members (left to right)

Benjamin Ford	**Co-Captain**
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Stephanie Oatley	**Buoyancy Control**
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Team Mentors
Cary and Mary Ford

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Abstract

The T-1 Ichthyoid is a surface controlled, powered, and monitored remotely operated vehicle (ROV). Our ROV is designed to collect data and perform tasks while underwater. During the 2008 MATE ROV competition, the ROV is required to complete a mission which simulates collection of data at the site of a hydrothermal vent. Mission tasks include taking the temperature of a hydrothermal chimney and retrieval of a sensor unit trapped on the ocean floor. The unit is trapped by placing 0.91 Kilograms of dive weights atop the sensor. Three dive weights which represent lava rocks must be returned to the surface for further analysis.

Design Rational

Our team spent several months brainstorming design rationale. We agreed that our ROV had to be more compact, lightweight and durable than the Great Lakes 2007 ROV. We also wanted all of the electronics components to be visible without disassembly. To achieve ocean floor depth for readings at a hydrothermal vent we all agreed that the frame needed to be sturdier than PVC pipe would permit. The T-1 Ichthyoid needed to be maneuverable to be able to pull up close to a hydrothermal chimney without damaging it, and yet the equipment should be modification-friendly and easily adjustable (preferably without the need for tools). Finally we decided we wanted to have our ROV look more organic in the water and glide smoothly like a manta ray. Thus the T-1 Ichthyoid was conceived.

Frame

We decided to make our ROV depth friendly using stainless steel tubing for the frame. Not only is stainless steel strong, but it also doesn't rust or corrode like other metals. The tubing is lightweight in water, and the silver soldered joints seal in air. This makes the frame weigh only 2.54 N in water, rather than a possible 20 N. We welded six tabs on the frame to mount everything to it we would need. The horizontal thrusters were bolted to two sliding plates centered on both sides of the frame. This design allows us to change the location of the thrusters at any time, and gives us almost infinite ability for adjustment.

Electronic Cases

The electrical components of the ROV must remain airtight. Lots of effort and testing went into achieving this airtight goal. The result are two waterproof cases that although different in function still utilize the same design.

The first case houses the ROV's two DC to DC converters. It is composed of a 10 centimeter long 15 x 8 centimeter rectangular aluminum tube that has 0.63 centimeter walls. Each end is sealed by a rubber gasket under pressure from a 1.3 centimeter aluminum plate. Pressure is provided at each tab using a stainless tension rod. Since the plates are 13.8 centimeters wider then the rectangular tube this allow the tension rod to be located on the outside of case preventing them from having to be waterproofed.

We determined it would be very helpful to be able to see into our main electronics case. Not only could we see if there was any water infiltration but, since our speed controllers have indicator lights it would allow us to see which ones are functional. We constructed the main electronics case from a 17.8 centimeter piece of 15.2 centimeter diameter 0.63 centimeter wall cast acrylic tubing. The ends are sealed much as with the DC converters case using a total of six tension rods. Electrical wires enter both cases by use of waterproof pin connectors.

Buoyancy

One of our goals with our ROV was to construct a machine that could travel to a depth of three-hundred feet. This required that we use a durable material that would not crush under the pressure of such depths. After consulting numerous experts in this field, we were advised to use syntactic closed cell foam. Syntactic foam is made of glass beads mixed with epoxy, compressed, and heat cured. The result is a material that can withstand the pressures of depths while maintaining its full buoyancy. We utilized 0.07 cubic meters of foam on our machine which provides 368 Newtons of positive buoyancy. Although this provides T-1 Ichthyoid with 73 Newtons more than is required to achieve neutral buoyancy, this allows for the addition of future components such as the manipulator arm and tray. Our low mounted ballast, increases T-1's stability.

The organic shape of the syntactic foam not only provides aesthetic appeal but, reduces horizontal drag while increasing stability. Repairs and inspection of the foam are easy thanks to our quick removable design utilizing thumb knobs for mounting.

Thrusters

Without a doubt, the Seabotix Btd 150's are the best choice for this machine. These thrusters are powerful, capable of handling 28VDC using a maximum of 4.5 amps. With that much power, each can produce up to 6.4 pounds of thrust at a depth up to three-hundred feet. We mounted them on adjustable brackets which allows them to be moved to any horizontal or vertical location necessary. The vertical thrusters are mounted in a vertran ("V" pattern as viewed from the front) configuration. By giving one of the vertical thrusters full power in one direction, and the other vertical thruster full power in the opposite direction, we can maneuver our ROV sideways. By reversing power, we can then propel our ROV in the opposite direction. The speed of sideways movement can be adjusted simply by varying the angle of the vertical thrusters.

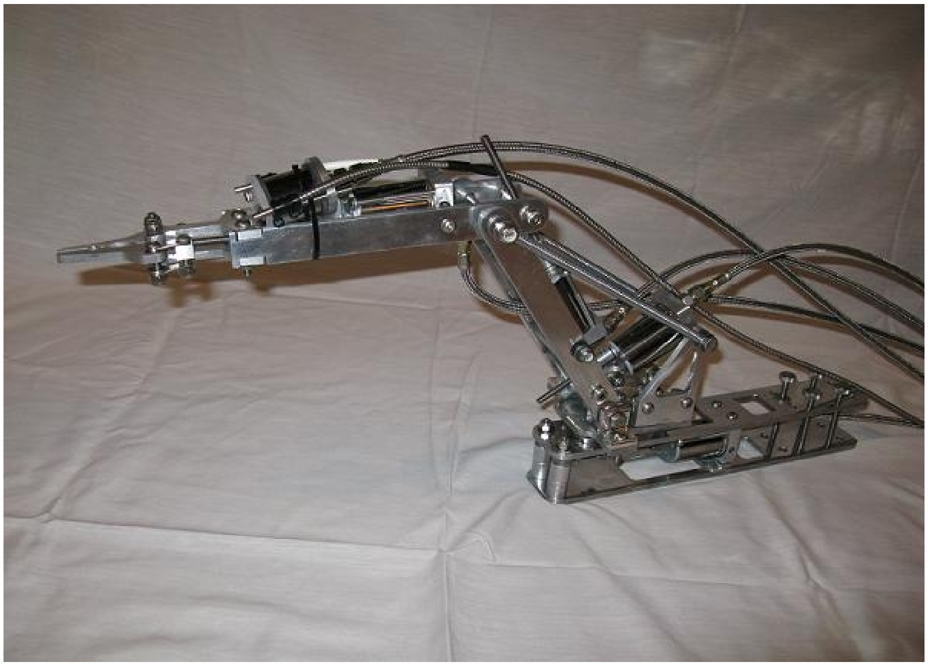
Each thruster receives its power from its own 24VDC digital proportional speed controller. These allow very precise control of each thruster.

Robotic Arm

The 2008 MATE competition requires a manipulator that can be extremely versatile. Our team's first thought was to modify our original claw from last year. We realized however, that a stationary manipulator would not complete these tasks as effectively as we wanted. Our new design has two hinge points, and a rotating base to allow for more than enough maneuverability to complete all the tasks. Power comes from four 20:1 gear reduced 24VDC electric motors. Each motor was first waterproofed by encasing the body in an aluminum tube filled with epoxy. The output shaft was sealed using double o-rings. Each motor can easily be removed using quick disconnect connectors, rubber sealed within each motors end case. Wires running from each motor to the electronics case are protected and waterproofed by running them through braided stainless steel lines.

Two methods of power transmission are used on the arm. The first is the use of a miter gear to provide rotation of the whole arm assembly. Secondly, acme screws are used to extend and flex the arm as well as to open and close the claw. The claw has enough strength to carry up to 33 kilograms.

Mounted above the arm and just behind the claw is a dual fiber optic cable for lighting, and a camera. We felt that this camera and light near the claw would improve T-1's manipulator accuracy.



Items collected by the arm can be transferred to a a conveyor belt mounted under the ROV. This device allows for payload to be moved to a central mounted collection bag. In this way any additional weight is easier to carry as the ROV remains in a more stable state. The conveyor is constructed from a vinyl gutter equipped with a roller at each end. The rear roller is attached to a 24VDC gear reducted motor. As the motor turns it rotates a rubber belt formed from an innertube. The belt is supported by a portion of metal wire grate from a refrigerator rack.

Tether

The T-1 Ichthyoid's tether is much more advanced than our 2007 ROV's design. The idea behind our design is quite simple, smaller is better. The smaller our tether is, the less drag our machine will encounter. Because our ROV no longer uses pneumatics, we could eliminate all of the air lines on the tether, however we didn't stop there because our goal was to create the smallest tether possible. The Coaxial 6 cable has been replaced with RG 176, which is almost a third of the size of our previous line. We used 22 gauge wires for relay and camera signals. In addition, the tether contains type K thermocouple wire. The 30 meter tether is encased within highly flexible clear shrink wrap. Neutral buoyancy of the tether is achieved by using 10 centimeter long by 2.5 centimeter diameter syntactic foam floats.

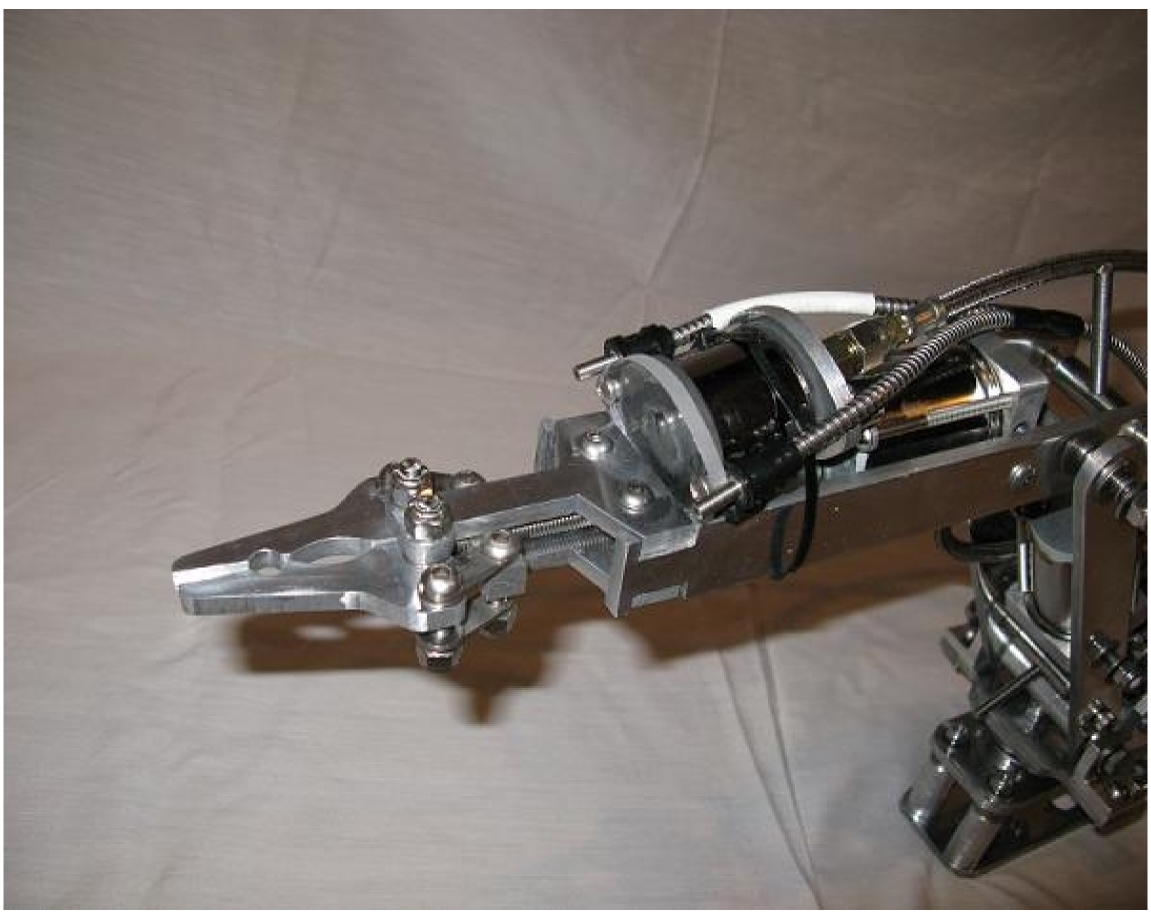
In order to make moving and shipping of the ROV easier, the tether can be removed from the ROV using waterproof pin connectors.

Temperature Sensor

Temperature Sensor readings are a critical tool for scientists who wish to measure activity of a hydrothermal vents. The T-1 Ichthyoid has been designed to provide these readings accurately, yet as quickly as possible. Readings come from a waterproof type T junction grounded thermocouple sensor mounted on a retractable arm. The data travels to the surface along type T 18 gauge insulated wire where it is attached to the digital thermometer. This system has an accuracy rating to a tenth of a degree, and has a range of -60 to +400 degrees Celsius.

Cameras

While submerged at three-hundred feet, it is critical that the operator be able to see. A poorly designed camera system would mean failure of the entire mission. In many applications, a black and white camera system cannot deliver enough detail, especially when trying to identify marine life. The two cameras mounted on T-1 Ichthyoid have many impressive features. The first feature is that camera have both color and black and white modes. Color can be used when there is ample lighting in the location. Black and white kicks in when the lighting is dim. Both cameras have an infrared mode for when the lighting becomes too dark for even the black and white to see. One of the cameras is mounted centrally inside the main electronics case just behind a 10 centimeter acrylic dome. It is attached to a micro servo which allows the operator to move the camera in a 90 degree vertical arc to pan left/right and up/down. The other camera is mounted on the robotic arm allowing for a continuous view of the claw operation.



Lighting

An ROV without proper lighting would only be effective in clear, shallow water. Our machine has been outfitted with three high-powered lights for maximum visibility. The two main lights are heavily modified Mag Light flash lights mounted on adjustable brackets. Each light contains a 6VDC crypton bulb. The robotic arm gets its light from a 6VDC crypton bulb mounted inside a waterproof case. The light then passes from the case through a fiber optic cable mounted to the arm. As the cable reaches the claw it splits into two cables with one providing light above, and one below the claw. Both the main and claw lights can be turned on and off using a relay controlled from the surface. As a special aesthetic feature and a power indicator, the eyes of T-1 Ichthyoid are equipped with red L.E.Ds. These really look great! All wiring used on the lights passes through braided stainless steel hoses.

Surface Controls

One of the most important things the Great Lakes Team had to consider was how to control it our ROV. We chose to use a Hi-tec Laser 6 six channel digital transmitter. This gives us fully digital control, allowing for the most precise maneuvering possible. The transmitter also allows for the control of a servo mounted to the main camera. Two 15 inch LCD screens provide excellent viewing of the data from both cameras mounted on the ROV. The robotic arm motors are controlled by two side mirror switches removed from late model Ford trucks. Two Pelican 1550 cases protect everything listed above from water and impact during transport.

Troubleshooting Techniques

Troubleshooting by definition is the systematic approach to problem solving. In order to prepare for possible electrical issues, we first developed an electrical schematic. In this way, we could then write a check list of possible problem sources if any were to arise. As fate would have it, the first time we tested the ROV's thrusters, all systems failed. It was time to use that electrical schematic and checklist.

We learned that it is beneficial to be able to see into electronic equipment in order to check for possible water infiltration. Having constructed many of our components from transparent materials, we were then able to quickly determine that water was not the source of the problem.

Referring to our checklist, we began to test each component on the ROV for it's required voltage. It became immediately apparent from our electrical schematic, that all components after our board 48VDC to 24VDC converter were not working, while items like relays that receive voltage from the surface were fine.

A test of output voltage of our converter confirmed that the converter was bad. The resulting comparison of it's wiring with the electrical schematic revealed that two wires had been crossed during installation. To add insult to injury, the wires were hooked up correctly according to how they were labeled, however they had been labeled incorrectly.

The costly mistake was easily repaired as many of our components are removed and installed using hand fasteners and plug together wire connectors. Lesson learned: Check, recheck, and have someone else check!

Challenges Faced

This is our second year of involvement in the MATE ROV competition and we learned a great deal from last year. A major challenge last year was ensuring that each team member completed the tasks they had volunteered to perform. This in turn resulted in undue stress on the remaining members and reflected on the team's overall performance.

This year every effort was made to insure that each member of the team was committed to the project and would follow through with his/her assigned task. The only problem was the travel distance between members. Two of our team members live 300 kilometers in opposite directions from the team base in northern Michigan. Fortunately the individuals of the team truly enjoy working together and were willing to devote their time e-mailing, phoning and even on the road to work on the project.

Mission Description

Our pilot will first need to find both the hydrothermal vent as well as the OBS sensor. Our first task will be to measure the temperature of the simulated hydrothermal vent. For greatest accuracy, it is imperative that our reading be taken within the stream coming from the chimney. After the temperature has been recorded, we will then release the OBS sensor covered with simulated lava rocks on the pool floor. This task will require us to remove and collect (3) 4.4 kilogram weights off of the sensor. Remaining weights will need to be removed in order to release the OBS. The OBS has a positive buoyancy of 1 newton, so once the weights have been removed, the OBS will float to the surface on its own. The mission time will stop when all of our team members touch the ROV with all three weights on board.

Lessons Learned

One of the important lessons we learned came from last year's MATE ROV competition. We decided that we needed to have a group of like-minded individuals on the team who worked together well as a team. Technical expertise while important, is not as critical in completion of a mission as is team effort. With this premise in mind, the captains set out to recruit team members with team attitude as a foremost requirement.

Another important lesson we learned was to keep copies of all our design drafts. One of our technical feedback resources within the community was laid-off from his position and left the area due to the lagging Michigan economy. When he left his position, he kept our design drafts. It caused us lost time and sleep to recreate what we had already designed in detail.

Lastly, we have been overwhelmed with the giving nature of individuals who assisted us as team mentors, donors and competition volunteers. It has been a very tough year financially in Michigan with foreclosures, plant closings, bankruptcies and family hardships for our supporters and resources. Through all their difficulties our team contacts have remained willing to assist us with their time, expertise and support. It is a humbling experience which will always be remembered. We hope to someday pass this selfless lesson along to others when the opportunity arises.

Future Improvements

We began designing our machine in November of last year, so we had enough time to incorporate almost everything that we wanted into T-1 Ichthyoid. We originally wanted to mount a depth probe to the T-1 Ichthyoid. However, budget and time constraints kept us from completing this goal. If our team had been able to fund raise more than three thousand more dollars, we would have been able to upgrade our thrusters to brushless models. These thrusters have the capability to produce up to eight pounds of thrust, rather than our units which produce 6.4 pounds of thrust. None of these modifications would require any cutting or drilling on our machine so if funding becomes available before the competition, we will try to install everything that we can.

The other improvement we would have liked to improve upon is that our current ROV requires 2 operators. Ideally we would have liked to make the T-1 Ichthyoid capable of single operator use by using a computer controlled system. Unfortunately incorporation of a computer controlled system was too cost prohibitive for our team this year.

Real Life Uses

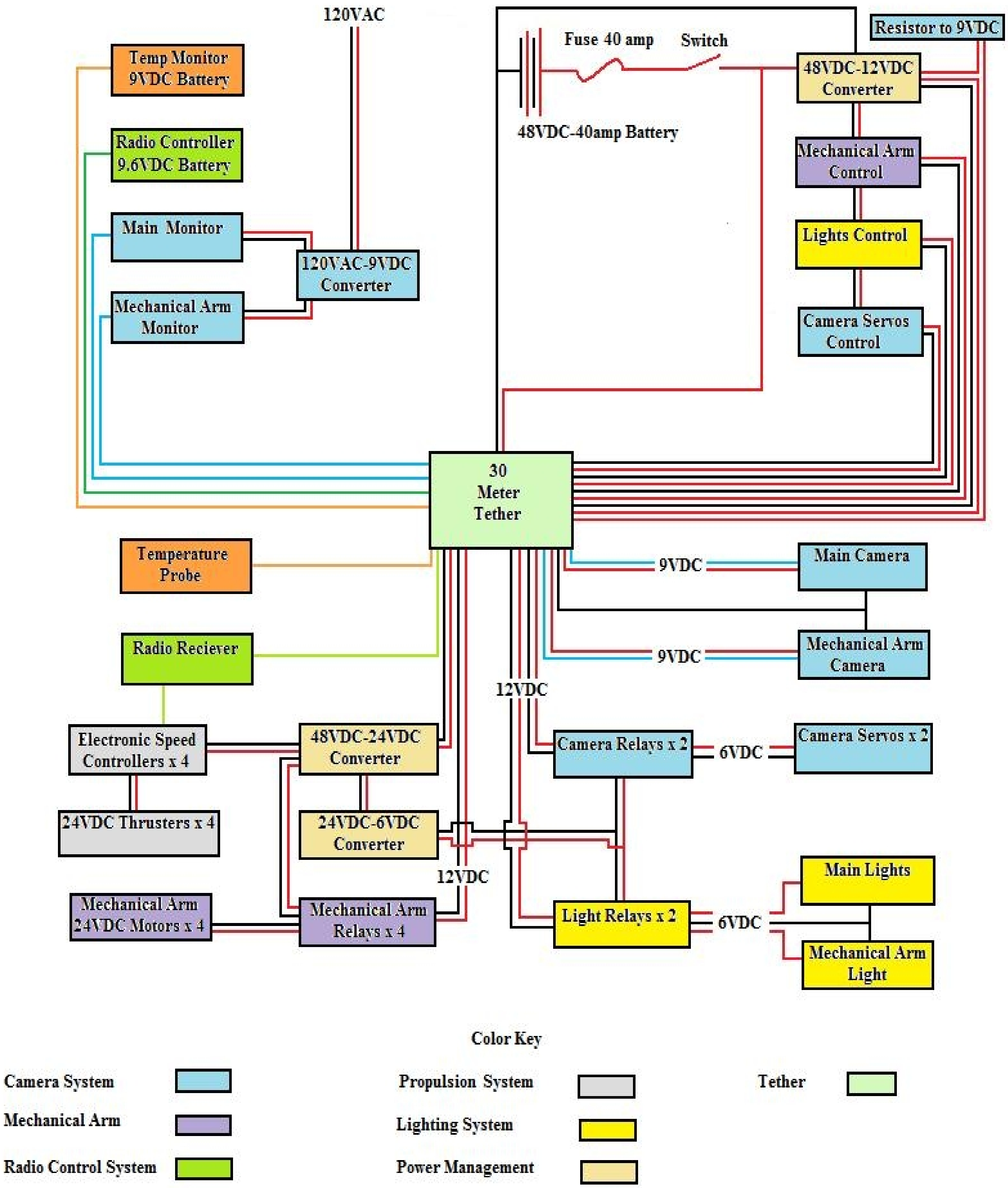
The T-1 Ichthyoid has been built to perform missions in water as deep as three-hundred feet, and is capable of handling both fresh and salt water conditions. We have enclosed all of it's electronics as possible inside the main waterproof case, to reduce to chance of leaks. This feature allows our ROV to operate in water that is below freezing without any problems. The vertical thrusters have been mounted in a Vertran design. This gives the operator the ability to maneuver sideways with ease, allowing the ROV to follow a pipeline or retaining wall with ease. The T-1 Ichthyoid's temperature sensor is capable of reading up to 400 degrees Celsius Equal to temperatures sometimes found at hydrothermal vents.

Expenses/Donations

T-1 Ichthyoid Expense Report			
Source	**Items Bought**	**Cost of Items**	**Use of Items**
Tonix	Team Shirts	$330.00	Team Shirts
Big Lots	LCD Monitor	$117.98	Control for ROV
Car Quest	Terminal Pack	$2.97	Power for ROV
Digi-Key	Heat Shrink Tubing	$58.94	Tether
Seabotix	ROV Thrusters	$1,550.00	ROV Thrusters
Hitec	Receivers and Crystals	$100.00	Power/Control
Great Lakes Pipe	Bronze Bushing	$3.07	Electronic Case
GTR Rubber	O-Rings	$16.63	Electronic Cases
Radio Shack	Electronic Supplies	$21.64	Electronic Cases
Aurthur's	Car Mirror Switches	$15.00	Arm Controls
Allacrilics.com	Acrilic Tubes	$54.00	Electronic Case
Ebay.com	Electric Motors	$32.99	Manipulator Arm
Frontier Airlines	Plane Tickets	$2,500.00	Flight to California
Meals and Lodging	Room Rental/Food	$800.00	Room Rental/Food
Rent-a-Wreck	Car Rental/Gas	$298.00	Trasportation
Elmer's Ham Shack	Coaxial Cable	$36.04	Tether
Habitat for Humanity	Fiber Optic Cables	$4.00	Lighting for ROV
Diver Down Scuba	2 Lb Diving Weights	$19.50	ROV Testing
Reid Supply Co.	Knobs	$122.23	Electronic Cases
J & M RC Hobbies	Micro servos/Misc.	$49.50	Camera Movement
Power Glide Inc.	Dc-Dc Converters	$250.00	Power for ROV
Buyheatshrink.com	Heat Shrink Tubing	$54.00	Tether
Totals			
Total Expenses			$6,436.49

T-1 Icthyoid Donation Report			
Donators	**Items Donated**	**Value of Donation**	**Use of Donation**
Home Depot	$782.89 in Parts	$782.89	Construction of ROV
Castle Creations	Speed Controllers	$636.00	Construction of ROV
Seabotix	50% off Thrusters	$1,550.00	Propulsion for ROV
Big Lots	30% off Monitor	$35.39	Control for ROV
Gaylord Machine	Materials	$75.00	Case/Frame Materials
Syntech	Flotation Foam	$1,028.00	Buoyancy
M-Tech Kirkland	Machine Work	$250.00	Case/Frame Construction
Golden Auto	Batteries	$200.00	Power for ROV
Solid Works	3D Graphics software	$400.00	3D Graphics and Charts
Uni-Pro	ROV Frame	$500.00	Frame for ROV
Power Guide	DC-DC Converters	$500.00	Power for ROV
Mid-State Bolt	Random Hardware	$150.00	Assembly of ROV
Otsego Sportsplex	Use of Deep Pool	$1,000.00	Testing of Machine
Reid Supply Co.	Knobs	$30.56	Electronic Cases
Applied Industries	Bushings and O-Rings	$19.40	Robotic Arm
Total			**Amount**
Cost of Items Donated			$7,157.24

Electrical Schematic



Reflections on the Experience

The Great Lakes ROV Team had an great time designing and creating the T-1 Ichthyoid. At first we thought our design ideas were unachievable. We purposefully set our sights high and wanted our ROV to perform as well as commercial models. We had several weeks of brainstorming what the ultimate model would be capable of. We thought we were being too idealistic, however the more we talked to our resources, the more we wanted the ultimate ROV and felt it might be attainable.

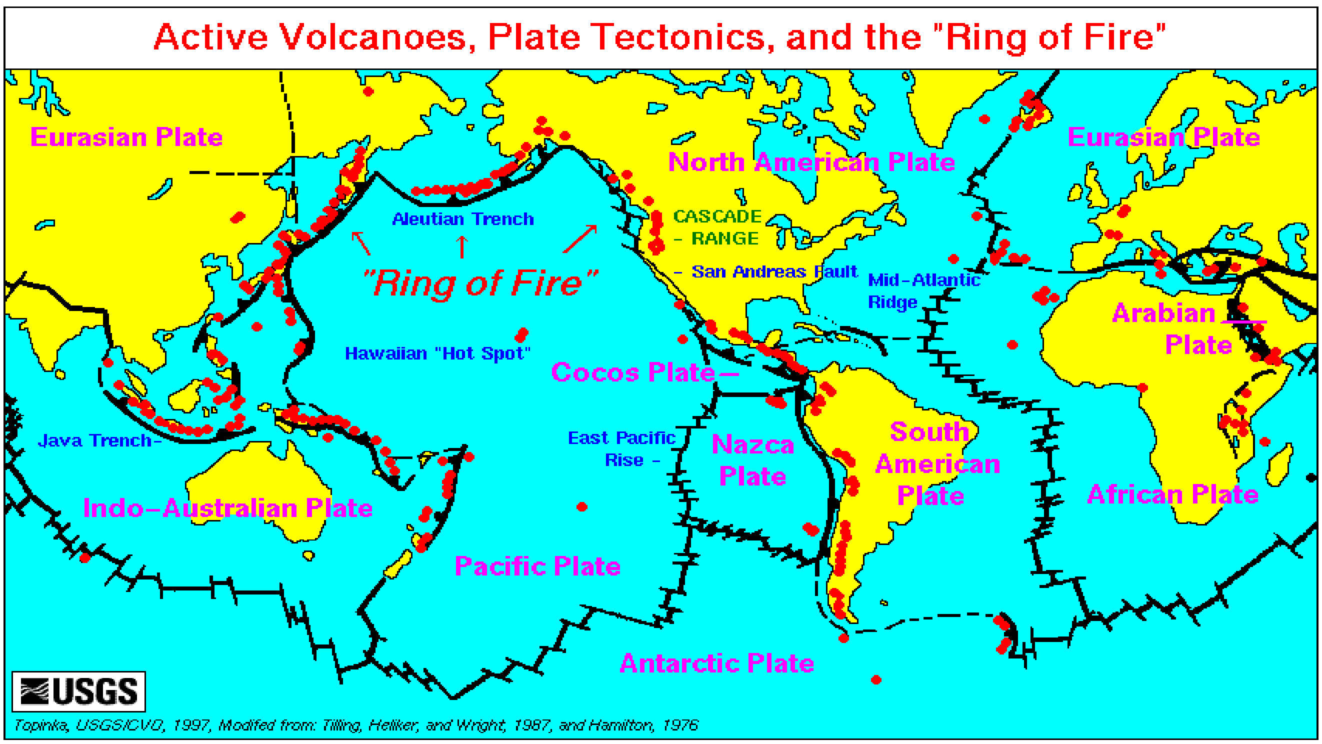
Our research of the hydrothermal vents had us spending hours online and at the libraries. We learned about not only hydrothermal vents, but saw the grace of the manta rays and decided that we had to go organic in our design.

We took college courses to help design our ROV, learned how to cut and shape syntatic foam as well as stainless steel and became adept at stripping wire insulation without damaging the wire.

In all, it has been a busy but great 6 months. We look forward to the 2008 MATE competition.

Hydrothermal Vents

First discovered in 1977 off the coast of South America, hydrothermal vents are cracks in the ocean floor that emit superheated mineral-rich fluids and have spectacular communities living on them. To better understand hydrothermal vents, it is helpful to first understand plate tectonics. The earth's surface or crust is broken up into large plates called tectonic plates which float on the earth's molten magma. As these plates move in relation to each other, boundaries are formed. These can be either convergent boundaries where the plates move together, or divergent boundaries where they move apart.



Divergent boundaries allow hot magma to rise up between tectonic plates, resulting in the creation of new sea floor. As the tectonic plates are pulled apart, cracks form in the plates which allow cold sea water (2 degrees Celsius) to seep in and come into contact with hot magma (1400 degrees Celsius) under the sea floor.[1] As the water is superheated, it evaporates and is forced up to the sea floor while carrying dissolved minerals with it. As the water erupts through the sea floor, the minerals precipitate out forming a structure called a black smoker chimney.

The MATE ROV competition missions simulate research conducted on the hydrothermal vents. Collection of lava rock samples and temperature readings are currently being conducted to better understand the key features of hydrothermal vents. Using "Jason" the ROV, geochemist Susan Humphris has collected chunks of black smoker chimneys and gathered lava rock from the ocean floor.[2] Susan has found that the rocks contain hydrogen sulfides (H2S) and iron monosulfides (FeS). These compounds in turn react to form pyrite (fool's gold) and hydrogen gas. The hydrogen gas provides the energy that microbes at the vent sites need to grow. Microbiologist Anna-Louise Reysenbach grinds the rocks collected by Jason in order to extract microbial DNA to determine what bacteria live on the chimneys. Of particular interest is that while our food chains based on the energy of the sun, these organisms are supported by the heat and minerals of the hydrothermal vent, allowing them to flourish in the dark, at high pressure, and in low temperature. Microbes capable of doing this are referred to as chemolithoautotrophic.[3]

Bacteria form the base for the vent food web and all vent animals ultimately depend on the bacteria for food. In addition to bacteria, other organisms populate vents. Those that feed directly on bacteria include limpets, clams and mussels. Vent crabs act as scavengers while octopi are predators. Perhaps most interesting of all are the tube worms. These animals form a symbiotic relationship with the bacteria. The bacteria live within the worms and in turn provide food for the worm.[1] Tube worms get their name from the chitin tube they produce and live within. Some species can reach lengths in excess of 3 meters.

Photo with permission from Woods Hole Oceanographic Institute

Collecting temperature readings has become much easier as a result of Dr. Albert Bradley's efforts. Dr. Bradley of the Woods Hole Oceanographic Institution developed the Temperature and Inductive Coupled Link (ICL T-probe) making it possible to get data into and out of an instrument in the deep ocean without a cable.[4]

Hydrothermal vents are among the most dynamic and astonishing places on earth. As more vents are discovered and research collected through the use of ROVs, new ideas and understanding of these extreme environments and life forms can be achieved.

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