MAOS ROV Club
Ranger Team
"The Ninety Dollar Miracle"

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2008 MAOS ROV Club

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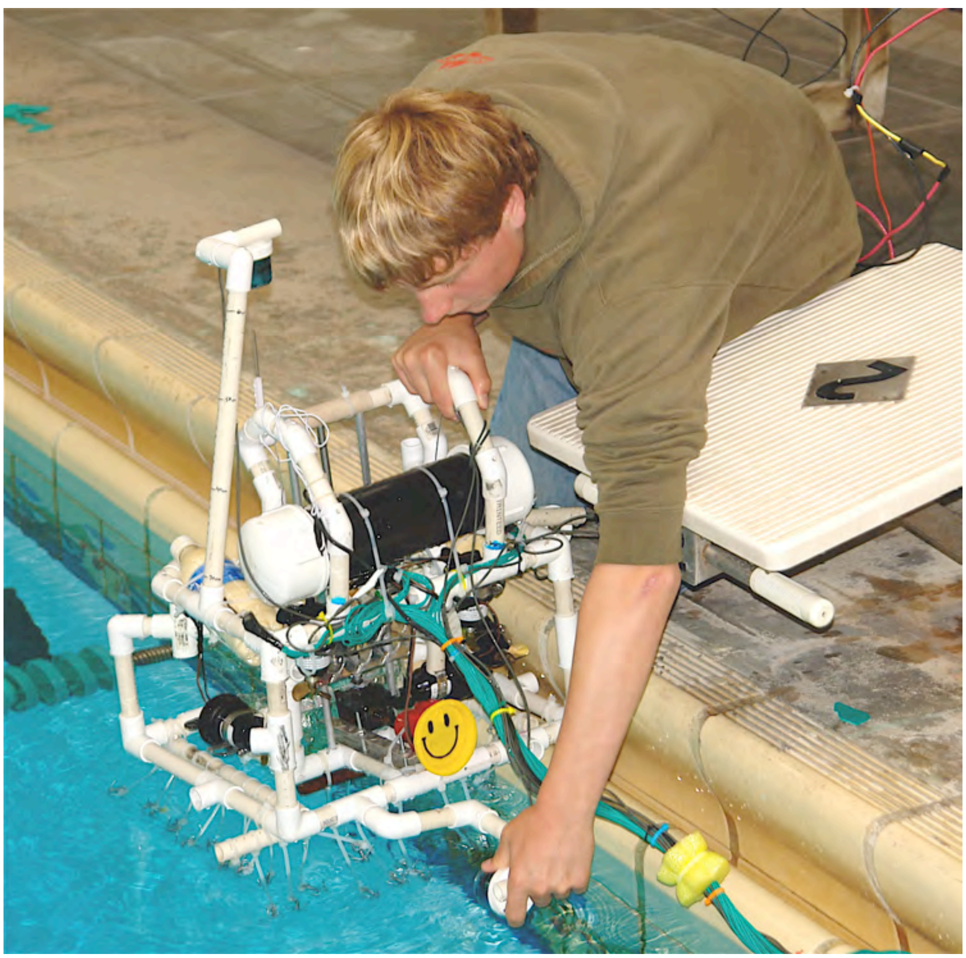
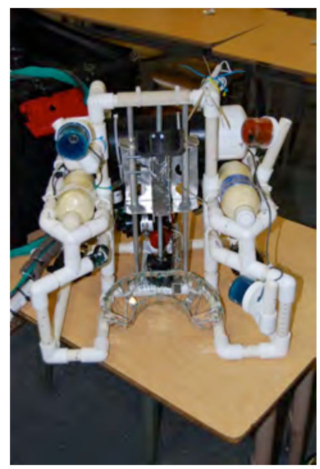


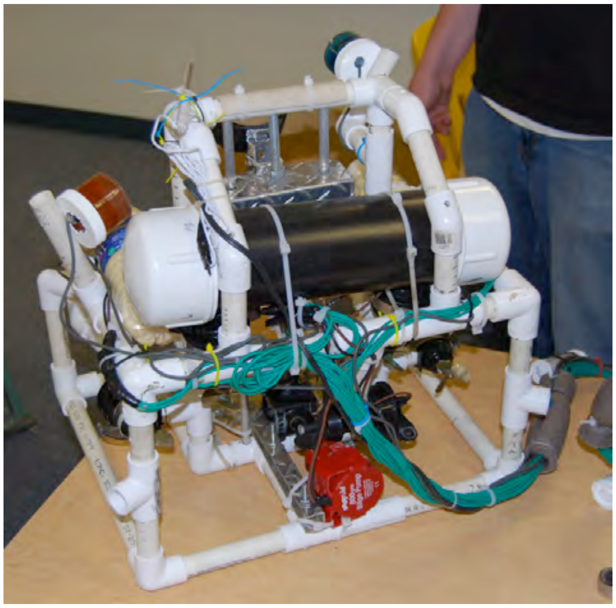
Abstract

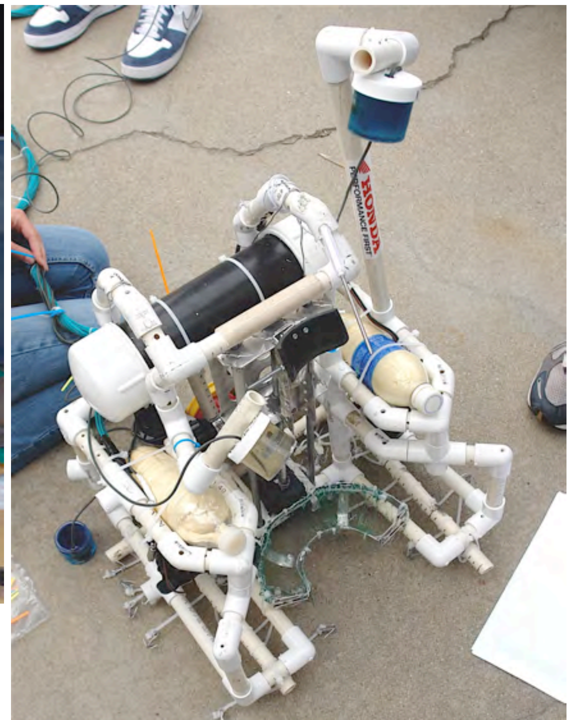
The MAOS ROV Club has designed and constructed an ROV for the 2008 MATE International ROV Competition. This ROV, named the "Ninety Dollar Miracle" because of its low cost, has been designed to achieve this year's competition tasks. Unlike all previous MAOS ROVs, the Miracle is taller than it is long, and is dominated by a mechanical rock scraper in the vehicle center. The vehicle also features a large number of hooks dangling below the frames bottom to catch crabs, and a temperature probe on top for measuring the temperature of water coming out of hydrothermal vents. The control system operates the five propulsion motors using two joysticks. Three video cameras provide the ROV pilot with views from inside, above, and behind the vehicle. The ROV design has proven successful in completing all of the tasks in practice. The MAOS team's design philosophy of simplicity, reuse of materials from past years, and focus on the competition tasks have resulted in a uniquely low cost yet capable entry to the competition.

Introduction


The Ninety-Dollar Miracle

The MAOS ROV club was founded on the common interests of its members in the fields of engineering and ocean sciences. The Monterey Academy of Oceanographic Sciences is a program within Monterey High School that provides a broad education with particular emphasis on mathematics and science, organizing quarterly science-oriented fieldtrips and facilitating student organizations like the ROV club. Last year MAOS competed in both the regional and international competition. The 2008 team began by examining and modifying last year's vehicle, developing an improvement-based construction strategy that has produced an economic and unusual vehicle. We brainstormed on methods and designs for a vehicle that would be able to accomplish the competition tasks. At first we thought about making a new vehicle and using the old vehicle, Nereus, to test ideas and hone piloting skills. After much debate among the club members and mentors, the team decided that it would be best to focus our energy on a single vehicle. We all agreed that the best way to perform successfully was to keep everything as simple as possible, a concept that has since pervaded every aspect of our design. As we assembled and attached systems to sample rocks, crabs and water temperature the vehicle evolved into a colossal chimera. Every person in the club helped with some part of the vehicle; James Caress designed and built the control system, while Joe Fernandez, Richie Henderson, and Brian Hoover all designed and built the rock removing system. Brian, Joe, and Richie spent hours taking measurements to calibrate the temperature sensor. From the long hours, sleepless night, and meticulous toil emerged a miraculous vehicle, one perfectly tailored to this year's objectives and inhumanly efficient at achieving its purpose, a machine bred of collaboration, adaptation, and frustration and manufactured for the amazing price of $90.89—the Ninety Dollar Miracle.

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Budget and Expenses

Our ROV, the Ninety Dollar Miracle, is so named as a testament to the large quantity of supplies and numerous vehicle components that have been recycled from past MAOS machines. As indicated by the table below, multiple key systems are derived from reused parts. The salvaged components include an array of cameras either purchased and assembled in previous years or won as prizes at the regional competition, a frame modified from the 2007 vehicle, Nereus, a differential salvaged from an RC car, a tether woven for Nereus and transplanted onto the Miracle, and motors that were similarly transferred. Finally, we followed a MAOS tradition by using a set of propellers whose origins stretch back so many years that none of the current team members or advisers knows when the four-bladed bronze heirlooms were cast.

The club raised funds by selling food at four school food fairs. These sales raised $350, of which $90.89 was spent purchasing supplies for the ROV construction. Once we qualified for the International Competition, the Friends of MAOS foundation contributed $1000 towards our travel to San Diego.

Item/s	**Price ($)**	**Quantity**	**Total ($)**
1/2 in PVC	.80/ft	3ft	2.40
1/2 in PVC	Salvaged*	20ft	Salvaged*
1 /2 in PVC Fittings	Salvaged*	misc.	Salvaged*
3/8 in Alum. Tubing	4.50/ft	6ft	27
3/8 in Alum. Bar	3.50/ft	3ft	10.50
3/8 in All Thread	3.75/ft	4ft	15
600G/H Bilge Motor	Salvaged*	5	Salvaged*
800G/H Bilge Motor	Salvaged*	1	Salvaged*
3/8 in Couplings	.69	2	1.38
Diamond Plating	Salvaged*	2sq ft	Salvaged*
3in PVC End Caps	3.14	2	6.28

PVC Glue	3.99	1	3.99
Large Zip Ties	Salvaged*	100	Salvaged*
Small Zip Ties	Salvaged*	100	Salvaged*
Digital Thermometer	12.99	1	12.99
Tether Wire	Salvaged*	600ft	Salvaged*
Differential and Housing	Salvaged*	1	Salvaged*
Universal Joints	Salvaged*	1	Salvaged*
Differential Drive Shaft	Salvaged*	1	Salvaged*
Cameras	Salvaged*	1	Salvaged*
Control Box	Salvaged*	1	Salvaged*
Toggle Switches	3.99	2	7.98
1/8in bolts	.43	3	1.29
Hook Wire	Salvaged*	15ft	Salvaged*
Netting Mesh	Salvaged*	5sq ft	Salvaged*
1/8 in Rivets	.4	25	1.00
Motor Props	Salvaged*	5	Salvaged*
Fender washers	.26	4	1.08
			Total= $90.89

Table 1: 2008 MAOS ROV Club Equipment Expenses

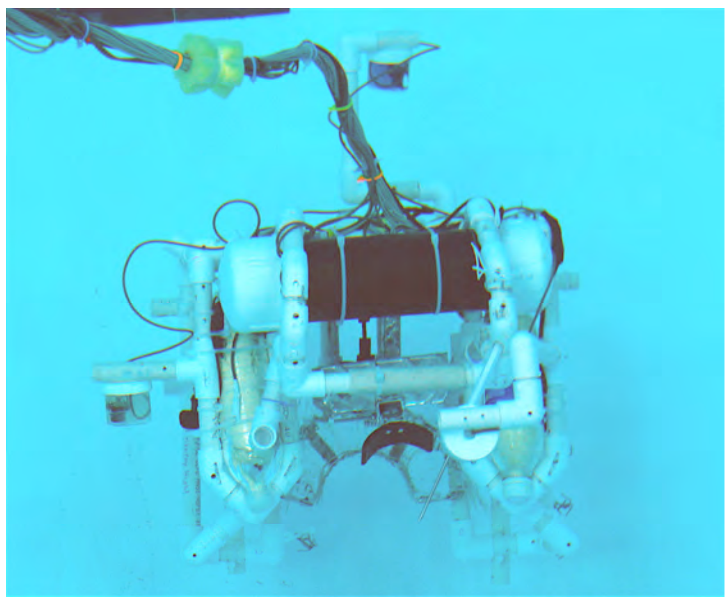
*Salvaged- Items used but not purchased this year because they were donated by students or left over from previous years of ROV construction.

Design Rationale

The Ninety Dollar Miracle was designed and built exclusively for the tasks of the 2008 competition. Every aspect of the vehicle is tailored to accomplish the three missions and all innovations were conceived and constructed with the smoker, the rocks, or the crabs in mind. From a frame that wraps around the smoker to a scraper that runs the full height of the Miracle to rows of hooks arranged specifically to trap and tangle pipe cleaner crabs, the explicit and narrow focus of our objective yielded a machine fully capable of completing the missions and unique from all previous ROVs that MAOS has produced.

Frame Configuration

The Miracle's frame was designed with the intention of completing the tasks with which we were faced. The final design of the frame was influenced by the addition of task-specific tools. One example is the forward cut out on the vehicle, made so that the ROV can fly up to the black smoker and "hug" it, scraping the rocks off as we take the temperature of the water that comes out from the top. Another reason for the abnormal shape of our ROV was the centering of the scraper's weight in relation to the vehicle so as to preserve the Miracle's balance while extracting rocks. Our team decided to make the frame out of ½ inch PVC pipes and fittings. The team decided to make the ROV out of these materials because we had a lot remaining from previous years, and because PVC pipe frames can be easily altered during development and testing.



Overhead View of Wrap-Around Frame

We drilled holes into the ½ inch pipe in order to allow water to fill up the frame.

Buoyancy/Ballast

We started off this year with the grand idea of using variable buoyancy. We designed a system of valves that were connected to a compressed air tank. We used two ball valves, one to allow air to flow into the tank and one to allow the air to escape. We found that this system allowed us to sink and float the vehicle rapidly but it was difficult to maintain a constant depth. After practicing with the system on the vehicle we found that it was more efficient to use static buoyancy. The vehicle's current system of buoyancy consists of one ABS pipe of length 35cm and diameter 9cm with an end cap on either side centered in the rear and two coke bottles filled with expanding foam. We decided on the amount of buoyancy more through trial and error than a specific calculation. We used extra flotation on the top of the vehicle with the intention of adding ballast weight to bottom. Our ballast weight is a wrench donated by the Monterey High swimming team. This separation of buoyancy and ballast makes for a very stable vehicle.

Design of the Trawling Bars

The mission of collecting crabs was a difficult one for our team, mostly because much of our time was spent building the frame and other mechanisms that have gone into our ROV. We came up with an idea at first to build a platform at the bottom of the vehicle to be surrounded with netting— this would retain the crabs after a wedged bottom layer, perhaps made of Plexiglass had scraped them up. After seeing how some of the other vehicles performed at the 2nd pool practice we realized that the platform idea was not working to what we were expecting. Our sole purpose in our vehicle is utility, and this platform would post too many dilemmas for our already complicated vehicle. One of our team members suggested a series of hooks, that when driven over the crabs would entangle the pipe cleaner arms, and trap the crabs in a mess of tangled barbs. Everyone was skeptical of the idea, but he was encouraged to make a mock up. He came in the next day with about twelve hand-made, four pronged barbs that worked beautifully. So we gave him the task of making more barbs for the bottom of the ROV. These barbs are attached to a piece of ½ inch PVC pipe with wire ties. These pieces of PVC have now been strapped to the bottom of the ROV to do their duty of entangling anything in their paths.

Trawling Bar

Design of the Rock Scraper

As a team, the MAOS ROV club decided that the most efficient way to tackle the task of retrieving rocks from the black smoker was through the use of a scraper and a basket. The scraper was designed to have a wedge-like blade that uses a vertical movement to peel the rocks off the smoker. Our wedge is attached to a cart that moves vertically on a pair of rails. The drive train consists of a threaded rod of aluminum passing through a series of nuts in the center of the cart. The aluminum rod is attached to a differential which gears down and changes the directional power of the drive motor from horizontal to the vertical power necessary to drive the cart. We designed the cart to be versatile, allowing us to easily change and position the blade. We did this through a mounting bracket on the front consisting of a bent

Rock Scraper

piece of diamond plating with a series of holes drilled in it. During our tests we found our original blade angle and shape to be effective. We were very pleased to have designed a system on which we could rely during practice. Hopefully it performs as well during the competition.

Placement and Modification of the Thermometer

The temperature task baffled our team for a long time, posing the question of whether to use an analog thermometer with a camera to view it or a digital readout thermometer. After deciding upon the latter and finding the ideal candidate on eBay, we were lucky enough to get the item donated by a parent. We had a slight problem though. Our tether was very long and the cord for our digital thermometer was very short. Thankfully our tether had an unused wire running up that would be perfect to lengthen our cord. We spliced the cord into the tether and immediately ran into a new problem: the readouts on the digital display were much larger than the true temperature. Lengthening the cord had changed the amount of current running in and out of the temperature probe. We then set up a test to see just how off we were; we took down control temperatures from an analog thermometer and compared them to the readouts on the display. We then recorded the data and made a statistic plot on one of our graphing calculators. A linear regression gives us a very good estimation of what the readout would say at both high and low temperatures.

Method of Propulsion

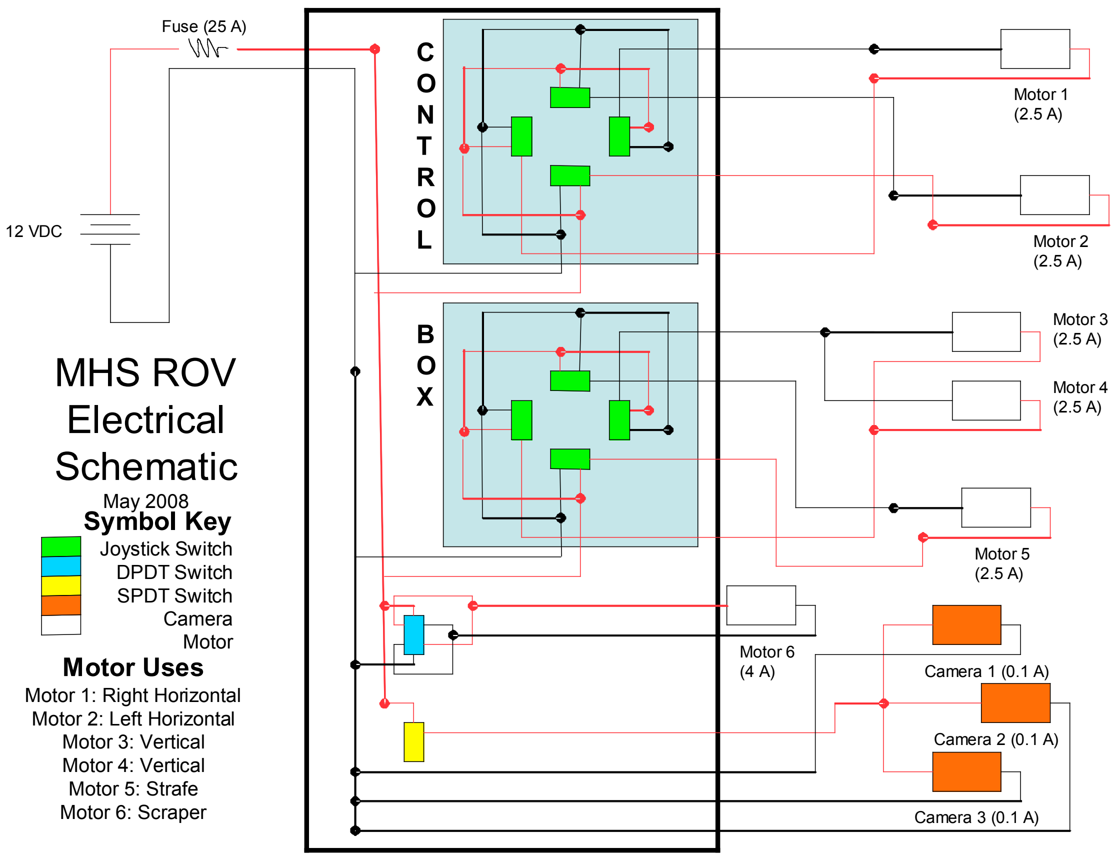
Five bilge pump motors propel the ROV; each is rated to pump 600 gph (2271Lph) and fitted with a bronze propeller. Using the propellers in water, each motor draws 3 amps. Two motors control forward and reverse propulsion, two motors drive vertical propulsion, and one motor causes the vehicle to strafe. All motors are contained within the frame, which serves as housing for them and makes it so that we did not have to add extra appendages to the ROV to cover the motors. The ROV is a strong vehicle and moves quickly through the water.

Design of the Control System

In sharp contrast to previous control boxes, none of which required more complexity than a bundle of double pull double throw switches, this year's control system was inspired by one of the team's many science room discoveries. The majority of this project was completed while Mr. Von, our teacher adviser, was moving from one classroom to another, resulting in a working environment that, while unstable, provided for the unearthing of salvageable materials. One such excavation included an old control system with joysticks. The Miracle's controls are wired around these two joysticks, each one composed of four switches with two pathways (normally open and normally closed) running through a common ground. Opposing switches—those located on opposite sides of the joystick—are wired to a single motor with consideration for the fact that such a configuration prevents both switches (those wired to the same motor) from activating simultaneously. The horizontal axis of movement is wired to the right joystick while the left joystick interfaces with the vertically oriented and strafe motors, the former including two vertical motors wired into the same circuit. A separate DPDT switch controls the motor responsible for driving the rock scraper and a SPDT switch protects the cameras from power surges associated with plugging and unplugging the system.

The power leads connected to the battery include a 25-amp fuse. The five propulsion motors draw 3 amps each, the rock scraper draws 6 amps, and the three cameras draw about 0.4 amps overall. So, the maximum current draw of our ROV is 21.4 amps, well below the contest limit of 25 amps.

In accordance with our guiding principle of "reuse and recycle", the new control system was integrated into a twenty-four-pin computer plug complimentary to the connector that caps our tether. The tether is a remnant of last year's Nereus vehicle, woven to improve flexibility and stability and composed of the twenty-four leads linking the joysticks to the motors (some circuits are wired through multiple strands to allow optimal current flow) as well as the camera wires. Several foam floats are attached to the tether, making it positively buoyant near the vehicle and roughly neutrally buoyant elsewhere.



ROV electrical schematic.

Video Cameras

The ROV has three X10 Anaconda video cameras, each of which has been waterproofed by being potted into a plastic housing using epoxy. The cameras are attached to the frame using adjustable arms, allowing us to adjust the view angles as needed.

Overcoming Adversity

In the course of constructing the ROV, a great deal of brainstorming and modification occurred, with successful ideas speaking for themselves and criticism arising from failure during testing more often than from malicious complaint. Because the value of a vehicle component was generally determined by its performance in the water, most tools were either beneficial from the start or rapidly recognized as implausible and ineffective. The Trawling Bar innovation serves as a notable exception to this rule of consensus, with its proposal sparking immediate debate amongst the team members. Several other methods of crab catching had preceded the trawling strategy—ideas ranging from clasping claws to scooping baskets to trailing fish nets—and each had failed spectacularly, prompting a certain degree of skepticism at the concept of glorified fishing lines. The criticism disappeared once the member in question had built a prototype, complete with four-pronged wire hooks attached to long zip ties and secured in a row along the bottom of a ½ inch PVC bar, and the team saw how deftly and securely the trawling method ensnared unsuspecting vent crabs. A similar philosophy of simplicity and functionality has guided all of our designs and troubleshooting.

Issue #1- Binding of the Rock Scraper

Once the plans for the scraper had been drawn up and the team began to form a simple frame and guide system, the issue of binding became an immediate problem. The MAOS team did not have the precision CNC tools to drill and cut exact measurements. All the work had to be done by hand, so we simplified the problem by allowing the aluminum rods that guide the scraping apparatus to float freely within larger holes in the frame. This simple fix eliminated the binding issue of the rod inside the guide tube while allowing the scraper to flex more and move more smoothly.

Issue #2- Binding in the Differential

The differential, which was salvaged and constructed from leftover remote-control car parts, was not meant to work in water without grease. We repeatedly had difficulties with rusting and binding inside the gearbox, a problem that hindered the functionality of the scraper so dramatically that a solution became essential to the vehicle's success. We took each part of the differential and impregnated the metal with wax so as to decrease friction and prevent rust.

Issue #3- Camera Angles

Our camera angles have always been a problem, with the pilot often finding the number and variety of perspectives to be insufficient for navigating the vehicle. We simply could not get a view wide enough to encompass the task and the ROV without the cameras themselves becoming cumbersome and awkward. In order to compensate for each camera's narrow view, we outfitted our vehicle with four cameras and mounted them at various places on the vehicle. In order to compensate for the refraction of light through water (a phenomenon that amplifies the image perceived by the camera and distorts the pilot's view), the cameras were adjusted and positioned while both they and the vehicle were submerged.

Issue #4- Temperature Gauge

The temperature gauge on the ROV was modified from a simple cooking thermometer, but extending the thermometer wire to 30 feet—an attempt to accommodate the tether—greatly increased the resistance within the wire. This skewed the temperature displayed on the readout to varying degrees, distortions that, when plotted, take the form of a regression graph ranging from 0-80. The temperatures were approximately 10 degrees off at the high end of the graph and 20 at the lower end on a constant curve. In order to remedy this problem, the team plotted points and calculated a regression formula to solve the temperature. Whenever we receive a temperature reading from the thermometer, we plug it in to the x variable and the regression formula solves for the actual temperature.

Lessons Learned

Although each member derived personal meaning from the experience of collaboratively building a ROV, as a team we learned some important and resonant lessons about teamwork and perseverance. This vehicle would not have been completed if not for the cooperation, compromise, and conflict resolution practiced by team members who often disagreed. We found out (sometimes the hard way) that a team working together accomplishes much more than a group of people arguing over each and every detail. With the intense brainstorming sessions and barrage of ideas that meetings often included, listening to each other's perspective was crucial to progress. Because our team developed and implemented unconventional designs, redundant testing and perseverance in the face of utter failure became valuable assets toward ensuring the ultimate performance of the Ninety-Dollar Miracle. The practice of trial and error played a substantial part in the team's design process and patience was key when, during the course of testing, error was much more likely than immediate success and excessive frustration would only waste time.

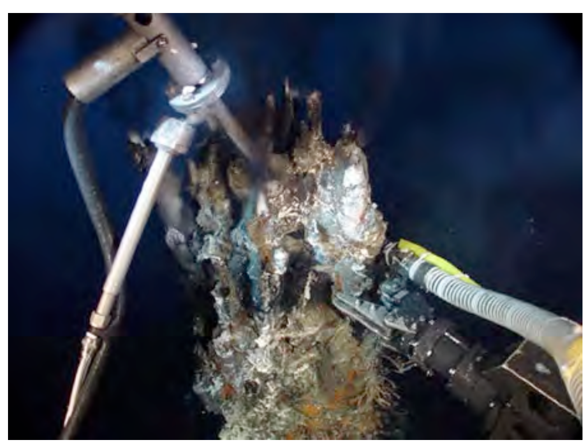
Future Improvements

With any project, future improvements are necessary. Our vehicle has many areas that can be improved. However none of them are needed for it to work to a decent standard. With any underwater project, we always need more as well as higher quality camera angles. The next largest obstacle we have encountered is maximizing the energy efficiency of our motors. Our motors, originally intended for bilge pumps, and our propellers, manufactured for model boats, have been handed down to us from past teams. We would need to do extensive research to see how efficient our propulsion setup is and how we could better our efficiency with less effort from the motors. On another note, our frame is entirely made of PVC pipe. PVC has a great leading edge for going through the water, but a horrible trailing edge on the rear side. If we could find a way to make a lightweight triangle-shaped trailing edge that would direct the water in a certain direction and cut down on the number of vortexes being made behind the pipe, we would utilize it. Another place for improvement would be to implement variable speed controls on our joysticks. Variable speed would aid in our attempt to make our vehicle the most mobile vehicle in the water.

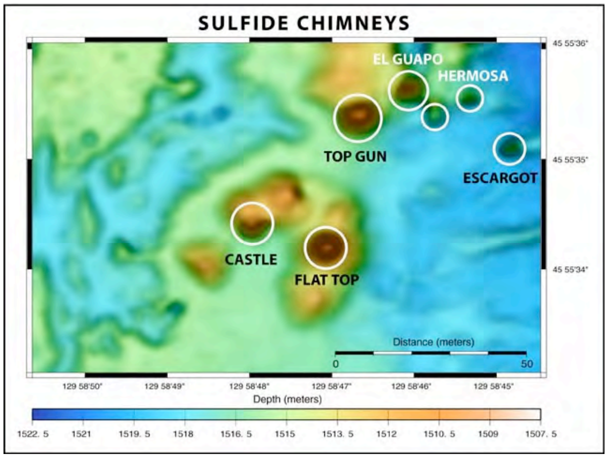
Mid-Ocean Ridge Research

Mid-ocean ridges, often found in the deepest, darkest, and harshest marine environments, represent rare blooms of life amongst the barren wasteland of the ocean floor. Submarine hydrothermal vents, cracks that spew water as hot as 403°C, often characterize these volcanic ridges, in some cases producing thick, chemical-rich clouds. These latter vents, commonly called black smokers, form chimney-shaped sulfide mineral deposits and create perfect habitats for the proliferation of organisms unique to this unusual environment, a plethora of creatures ranging from chemotrophic bacteria to tubeworms to crabs. With such opportunities for discovery and scientific advancement awaiting any scientist to come across a hydrothermal vent, one can imagine the excitement experienced by researchers associated with the New Millennium Observatory when they recently discovered new vent sites.

The New Millennium Observatory (NEMO) project involves ongoing research concerning mid-ocean ridges, a study conducted by the NOAA Pacific Marine Environmental Laboratory. For the past fifteen years PMEL has conducted annual surveys and explorations of Axial Seamount, located off the coast of British Columbia along the Juan de Fuca Ridge, with the expressed purpose of studying volcanic eruptions and hydrothermal vents. Employing a small army of remotely operated vehicles, autonomous underwater vehicles, and manned submersibles, the PMEL



El Guapo hydrothermal vent on Axial Seamount. The vent water is being sampled and measured by ROV ROPOS.



Topography measured by the MBARI AUV on Axial Seamount. The map shows the previously known Castle and Flat Top vents, and also newly discovered vents nearby, including El Guapo.

team has been able to conduct detailed and thorough research into the geology of hydrothermal vents as well as sampling the marine life and the water itself. AUVs employ sonar to collect bathymetry data to be converted into detailed maps of the ridge topography that also indicate unsual or unanticipated geographic formations. ROVs, with their cameras, sampling devices, and heavy carrying capacity, serve as pioneers into unknown and potentially dangerous environments. Once the unmanned vehicles have examined the vent sites, scientists conduct further observations from behind the glass of deep-sea submersible Alvin. The latest of these surveys, a collaboration between PMEL and MBARI, yielded some unexpected data. When MBARI's mapping AUV, a bright yellow torpedo of a machine called D. Allan B., was scanning the seafloor, its sonar data included an irregularity that, when investigated by the ROV ROBOS, turned out to be a previously undiscovered group of hydrothermal vents. In order to take advantage of this valuable find, PMEL intends to return to the new vents with Alvin, the manned submersible belonging to the Woods Hole Oceanographic Institution (WHOI). Exploring a new cluster of black smokers is certainly a fitting task for Alvin, the same submersible that participated in the first hydrothermal vent discovery off the Galapagos Islands in 1977.

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Personal Reflections

Joe Fernandez: I had a great time working on our ROV. I learned a lot about underwater vehicles and how they work. I had the opportunity of doing custom metal fabrication and welding on the vehicle, which is my pride and joy. I will always remember staying up until 3 am the night before the regional competition to get a working vehicle.

Jacob Paoletti: I really enjoyed completing the ROV. I learned a great deal about how to make it so that everything is waterproof and functions underwater. It gave me a chance to go somewhere after schools on Mondays and make new friends at a new school. Also it allowed me to help express my interest in working with designing and then controlling something I helped build.

James Caress: Helping to construct the ROV we call "The Ninety Dollar Miracle" has been an wholly gratifying and worthwhile experience, a vehicle and a team that stand out as among the best on which I have had the opportunity to work. The members of this year's team collaborated with a greater degree of cohesion than previous Monterey teams and every member brought unique and innovative ideas to the table. I believe the success and high quality of the Miracle—a powerful and versatile vehicle tailored specifically to the competition's tasks and well-equipped to accomplish those missions— are due almost entirely to this creative diversity and the continued teamwork displayed by our club should lead us to success at the international level. My favorite aspect of the assembly of the Miracle was the design and wiring of a joystick-based control box that far exceeded the sophistication of control systems I have designed in the past. The completion of this new box also represents the most valuable lesson I learned; this wiring system showed me that exploring greater complexity in electronics is not a challenge of which I should be afraid.

Richard Henderson: The ROV team has given me a great outlet for my engineering creativity. The hours we have spent on Monday nights and other random late night weekends have been enjoyable and have tested our motivation. Though some days were frustrating and some problems were difficult we have overcome all of the obstacles. I look back on the ROV club and I am glad to have participated. The team has supplied me with a great experience, which has built friendships and skills. All in all I regret nothing and I am thrilled to have been part of such a driven team that has again progressed to Internationals.

Brian Hoover: This year has been a lot of fun. I have spent many hours working with both old and new friends. Joe, Richie and I have spent a few nearly sleepless nights working on getting the ROV ready for pool practices and the local competition. I have learned a lot about car differentials, the wiring of joy sticks, and the time and effort needed to design and build a working vehicle. I plan to use this knowledge I obtained as I continue my education in the field of Mechanical Engineering at UC Irvine.

Chelsea Hoover: This year we had a great ROV team. We put all our ideas together to create a vehicle that will hopefully beat all the competition. Each member had their own responsibilities and for the most part completed them. If we had to do something different however, I think we should have fine-tuned our vehicle in advance rather than so close to the competition. I also think that although we got pool practices in, our team could have used more practice still.

Tera Hoover: This ROV team has been a great experience for me. I have learned a lot of new things and hope to learn more as we prepare for the international competition. It has been fun working with the team every Monday night and hope there is more fun to come.

Acknowledgements

The team would like to express sincere gratitude to all those who facilitated the Ninety-Dollar Miracle with time, dedication, donations, and just a little faith in our abilities. We want to thank our mentors, Mr. Caress and Mr. Hoover, for their guidance and patience through the long months and late nights and Mr. Von, our teacher adviser, for opening his room to us, persevering with us through the rough times, the crunch times, and transition from science classroom to portable classroom. Thanks also to Mr. Hare and Mr. Woods for devoting their time to facilitating our crucial meetings.

Special thanks must also be extended to organizations that have made our journey possible, MAOS for the plethora of opportunities they have given us and MATE for coordinating this exciting and unique competition.

MAOS placed second at the Monterey Regional competition!