Technical Report

Ranger Class

Mission College Prep High School

MCP Robotics Team

The Anaconda ROV

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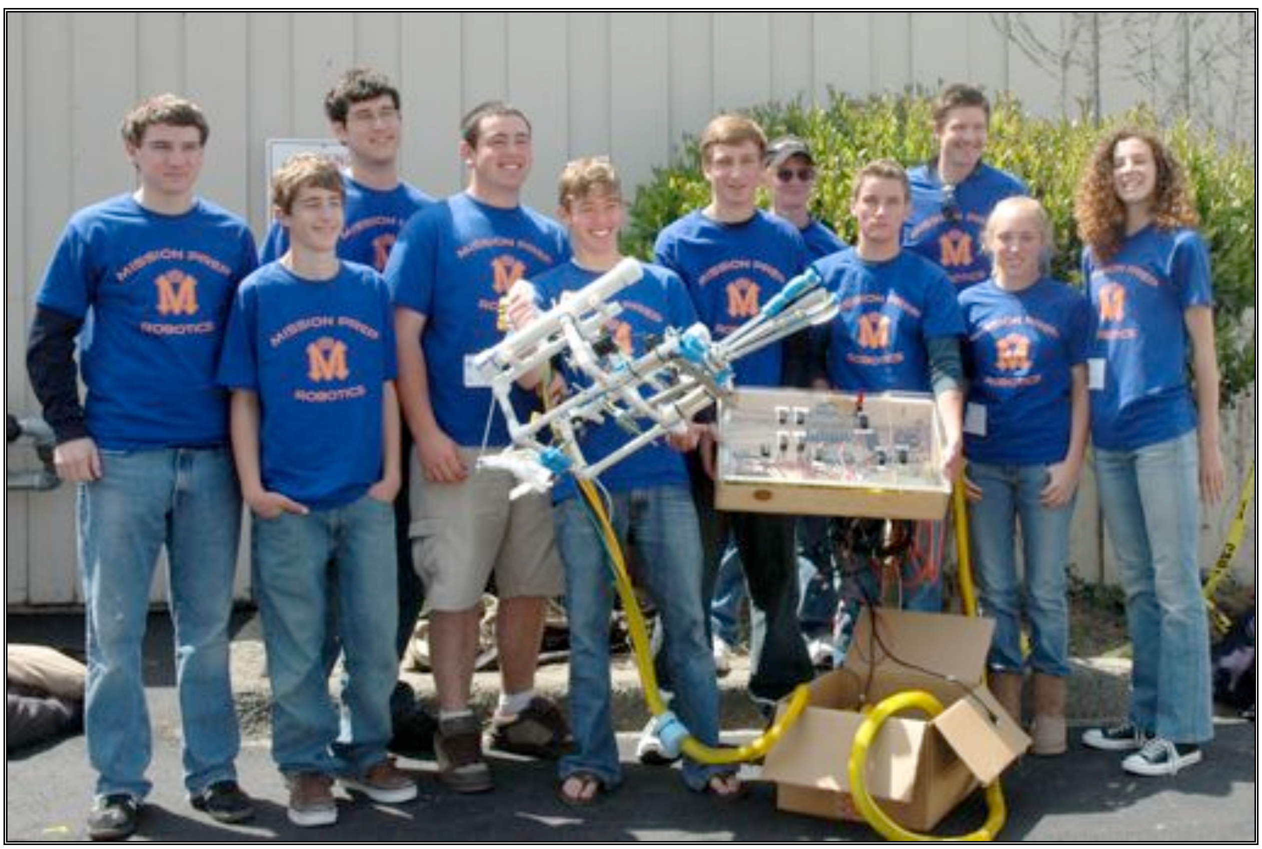


Abstract

The following is a technical report on the Remotely Operated Vehicle (ROV), the *Anaconda*, designed, built, and operated by the Mission College Preparatory High School Robotics Team of San Luis Obispo, California. Over the course of the 2007-2008 school year, the team worked together to produce an innovative, robust ROV that could complete the mission tasks of the 2008 International ROV Competition, coordinated by the Marine Advanced Technology Education Center (MATE).

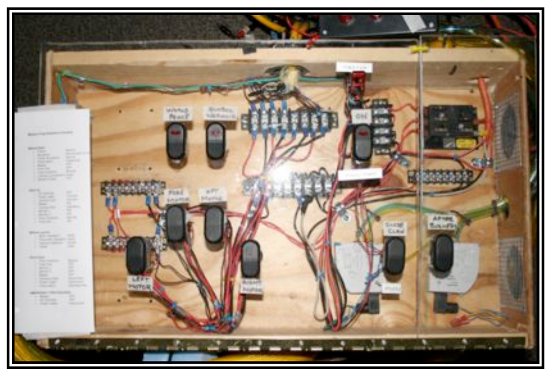
The 2008 International ROV Competition is being hosted by the Scripps Institution of Oceanography—UC San Diego, which researches the unique ecosystems found in and around deep-ocean hydrothermal vents. In order to best investigate these harsh environments, ROVs must be designed in an original and intuitive manner. The mission tasks of this year's competition are modeled off of the challenges that face ROVs in these environments. The *Anaconda* was designed over the course of the school year to be able to complete this year's mission tasks in an efficient manner.

The report includes detailed design rationales behind our unique payload tools and systems, diagrams of our electrical and pneumatic systems, a profile of on-going research on hydrothermal vents using ROVs, the personal reflections of team members, summaries of the lessons we learned, as well as the challenges we faced and overcame, our well-honed troubleshooting techniques, our designs for future improvements to the ROV, a summary of our expenditures and incomes, an acknowledgement of the generous donors who made our work possible, and a references list.

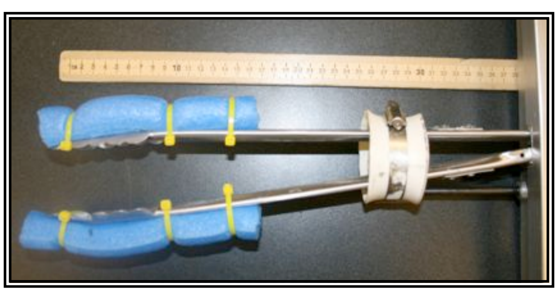
Design Rationale

Frame: The ROV frame is constructed out of a combination of one half inch (1.3 cm) PVC and aluminum bars. The PVC was chosen for the ease of modification and was used as the basis of the original frame, while the aluminum was added near the end of the design process to provide a sturdy platform for mounting the pneumatic claw, and other mission tools.

Tether: The tether consists of two lengths of negatively buoyant cable, each containing three #24 gauge pairs and one #20 gauge pair. The wires are stranded to allow flexibility, and covered in a jacket of Mylar, Kevlar, and yellow polyurethane which protects the wiring from any potential damage. In addition to the cables, the tether contains two air lines and three video cables, one for each camera. All lines are bundled in a yellow hollow braid, which keep the entire tether in one neat and organized line that is easy to coil and handle, while also having the advantage of being easily visible underwater.



Control Box: The wooden control box (63x40x14 cm) has a clear 0.63 cm polycarbonate top. The top has a piano hinge along its length, which we added to allow easy access to the control box for modifications and diagnosis of problems. This design was chosen for simplicity and visibility of the interior system, while allowing us to easily house the pneumatic controls, motor controls, and power distribution busses. Conduit entrance fittings are used to reduce stress. The control box is simple, versatile, and can easily be modified to fit our needs.



Pneumatic Claw: Our pneumatic crab catcher consists of two barbecue tongs bolted together using aluminum plates, then attached to a pneumatic cylinder using a short heat-molded PVC sleeve and a hose clamp. After testing various PVC-hinge combinations, we settled on this simple yet robust design, which combines the pneumatic operator with the claw while preserving the claw's range of opening, which allows us to pick up items using only one arm of the claw. We also attached foam flotation to the end of the claw to improve the ROV's balance and stability.

Rear Scraper: The operation tool used for collecting rocks is a passive "rock scraper," consisting of a piece of heat-shaped plastic with a net riveted and epoxied to it. This allows us to make the optimal shape for scraping rocks off of the black smoker, and catching them effectively. The custom shaped plastic allowed us to mold its shape into a form that is easily attached to the ROV and that can be readjusted if necessary.

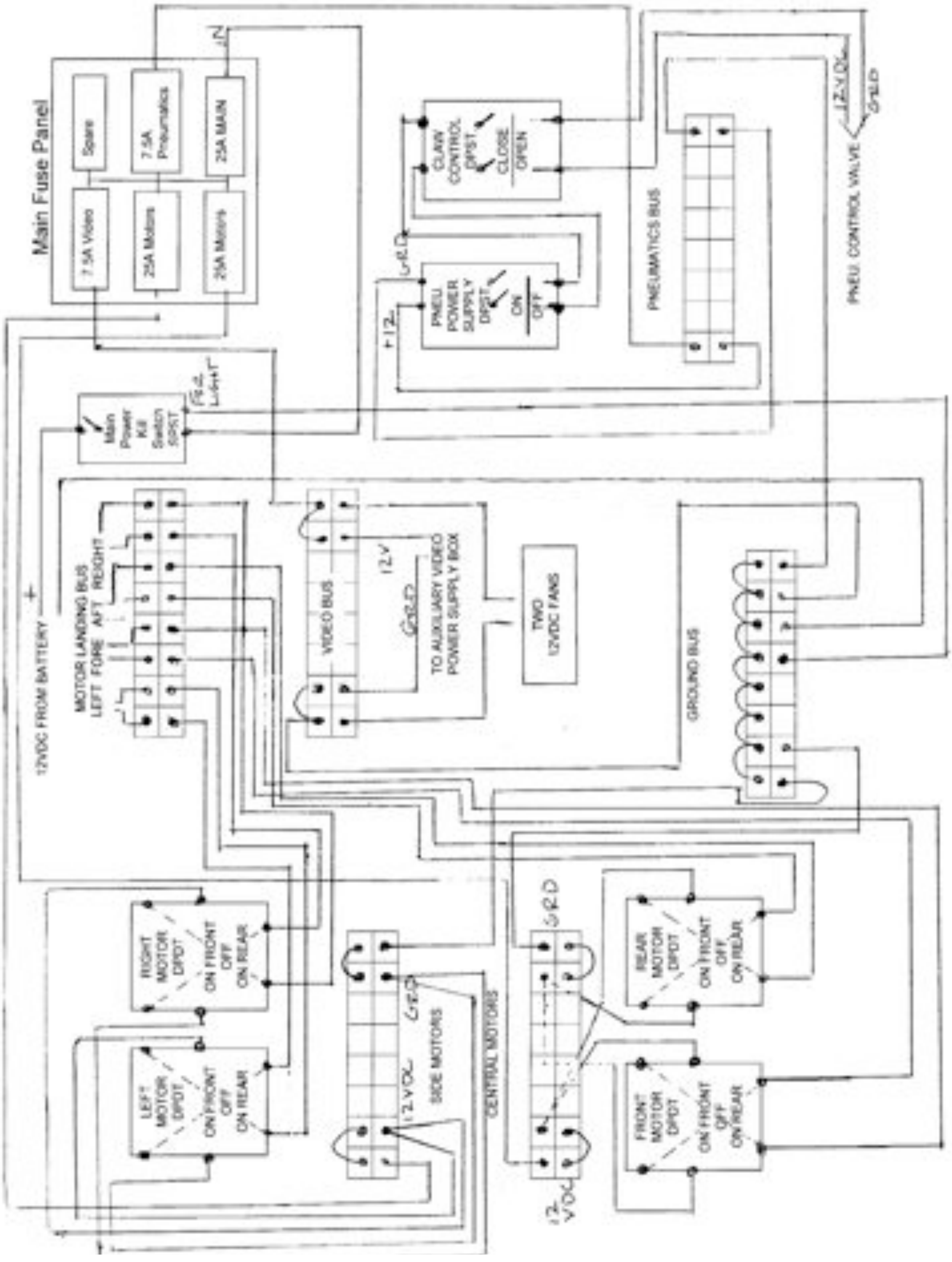
Temperature Mechanism: Our temperature mechanism consists of a digital, self-powered thermometer attached to a funnel with an opening of the same size as the black smoker, which centers the thermometer into the opening of the vent. This thermometer-cone set-up is then attached temporarily to the front of the rock scraper, allowing us to switch between the two tools manually. It relies on the principle that the hot water, which is less dense than the cold water, will rise and collect within the thermometer cone and stream past the sensor, which reliably obtains the correct temperature of the venting water.

Cameras: The ROV carries three on-board cameras mounted on a camera tower overlooking the entire unit. Two of the cameras are Harbor Freight black and white cameras with dedicated video monitors. The cameras are guaranteed to be waterproof up to eighteen meters, but after one early waterproofing failure, we sealed all of the crevices with silicon and reduced their size by cutting off unneeded plastic casing. The two cameras were rewired to receive 12 DC power from the control box. The Harbor Freight cameras have a 70° viewing angle. Each camera requires two watts of power and each monitor requires another eight watts. The third camera is an Anaconda X10 video camera that was modified to be waterproof. The camera has a 60° viewing angle and is wired to run off of the marine battery power supply through the control box. The Anaconda X10 camera is also connected to one of the Harbor Freight monitors. The Anaconda X10 camera is viewed by switching to Camera 2 mode on the monitor. The camera is adjusted to focus at twenty centimeters, allowing a clear image of close and far objects. The original X10 wire was replaced by a CAT 3 outdoor cable for its stronger insulation to withstand physical damage. The X10 camera wiring that connects to the CAT 3 wire is sealed and secured within a waterproof PVC pipe. All three cameras are on PVC mounts that can easily be adjusted to change the viewing perspective, allowing the most flexibility possible.

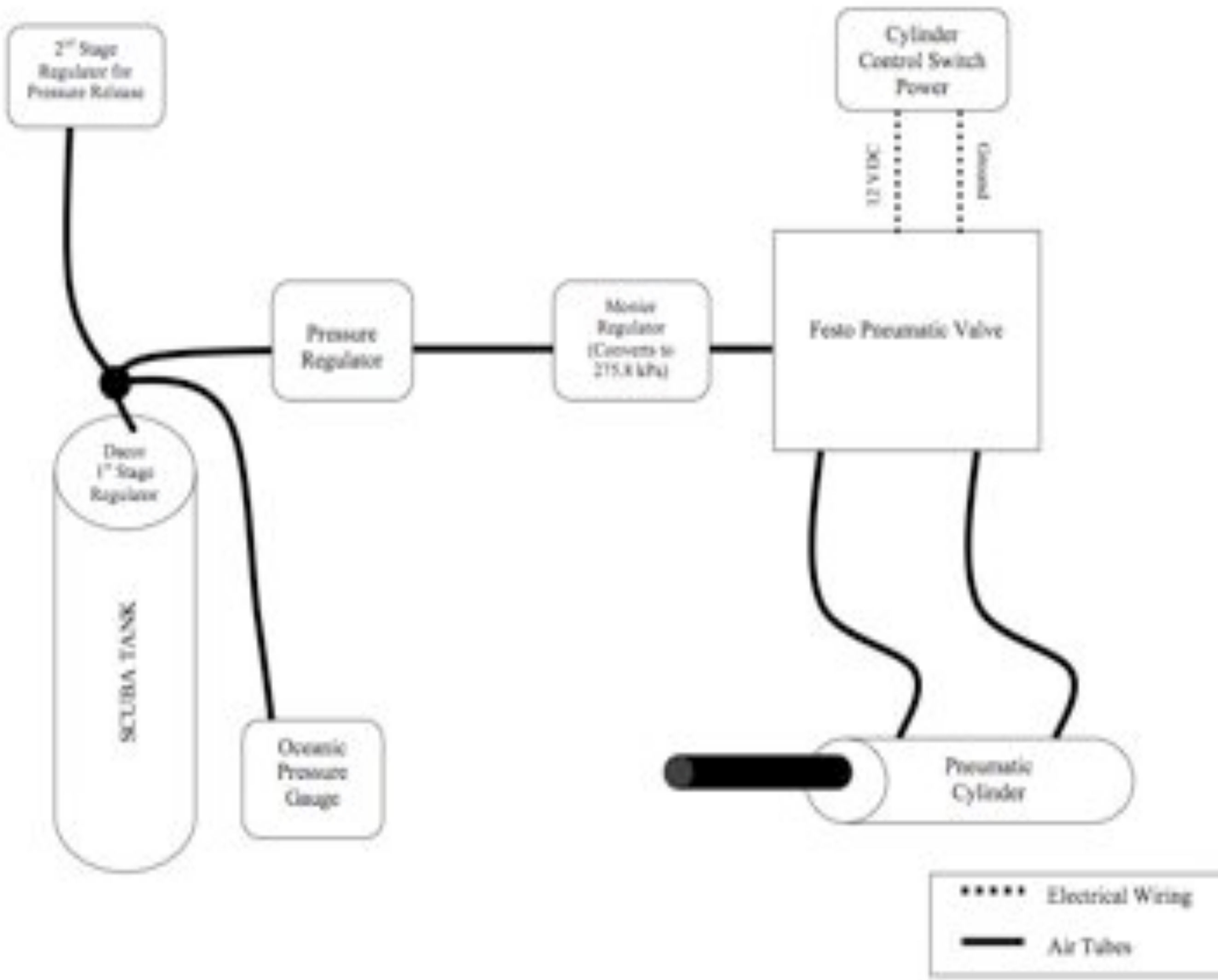
Pneumatic System: Our crab-catching system includes a pneumatic cylinder, which actuates a PVC-sleeve attached to the claw. The pneumatic system is operated off of a 14,478.9 kPa scuba tank (2100 PSI). From the tank, air flows immediately to the first stage regulator, which splits the flow between three things: the oceanic pressure gauge, the second stage regulator for pressure release, and a pressure regulator which reduces the outgoing flow to 275.8 kPa (40 PSI). The regulator feeds through air lines rated at 1206.6 kPa (175 PSI), to a Festo pneumatic valve mounted inside the control box. The Festo valve controls the outflow to the pneumatic cylinder using a wired double-pole switch. This design was chosen because no electrical components were required to be in the water, which was recommended to the team by a veteran robotics instructor from another local high school.

Motor System:
Our motor system consists of four Mayfair bilge pumps: two 1890 liters/hour pumps and two 2840 liters/hour pumps. The smaller pumps provide the horizontal thrust, while the larger pumps provide the vertical thrust. This was chosen to account for the extra weight of collecting crabs and rocks during the mission tasks. All four motors used a thrust adaptor collar to mount the propellers. The smaller pumps used 50 mm diameter propellers, while the two larger pumps 55 mm propellers. All the motor wiring connections were attached to the tether wires using a waterproof marine heat shrink.

Electrical Schematic



Pneumatics Schematic



Victor 6000: Exploring the Deep

Humankind has an enduring fascination with learning about the edges of our universe, both in the stars and under the sea. Until recently, we have had a limited amount of knowledge regarding the deeps of the oceans below depths that people could dive to, or fish could be pulled from. The advent of ROVs has opened a whole new world of knowledge.

The discovery of hot hydrothermal vents tremendously changed our understanding of the conditions necessary to support life. It was previously believed that life could not survive at boiling hot temperatures, and the hydrogen sulfide environment was thought to be poisonous.

One institution working in this field is IFREMER, the French Research Institute for Exploitation of the Sea. It began in 1984 to work on the exclusive exploration of the RMS Titanic. IFREMER has since grown to specialize in the research and enrichment of ocean life and seafloor resources. Thus, IFREMER has evolved into a well-funded, equipped and respected scientific institute.

In the 1990s, marine scientists began to use ROVs. Average dives could reach between 1000 and 3000 meter depths by the end of the decade. In 1999, LFREMER introduced its first ROV, the Victor 6000, shown below. This vehicle was designed to reach a revolutionary depth of 6000 meters.

Victor 6000 (www.lfremer.fr)

After having undergone significant technical upgrading over the years, today the Victor 6000 features advanced technology. It is instrumental in numerous diving missions along the mid-Atlantic oceanic ridge and can perform many tasks at extreme depths. Victor 6000 has a sampling module that is able to collect a wide variety of rocks and seafloor minerals. This base compartment can store a maximum payload of 600 kilograms.

Victor is a proficient explorer and has on occasion worked directly with the Ocean Drilling Program to examine sediment and mineral concentrations on the seafloor. Its most valued work takes place along the mid-oceanic ridge. During its cruise along the Azores ridge, Victor recorded evidence of heavy hydrogen formation due to compound exchange between the earth's mantle and the ocean. Chemists and microbiologists attribute the formation of bacterial populations to this chemical phenomenon.

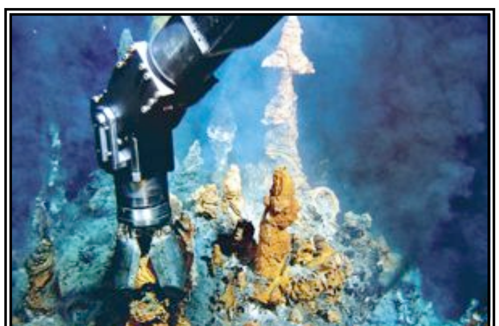
Victor 6000 is no amateur ROV. It has two distinct, multi-function arms, a long duration dive capacity, records real time data, and carries a modular section at its base that allows flexible planning once placed at its mission location.

The subject of oceanic study that most captures the interest of marine scientists is the deep-sea hydrothermal vent. Hydrothermal vents ("black smokers") were first noted in 1977, and were discovered on the seafloor of the Pacific, just south of the Galapagos Islands. They are known to be the most toxic fissures on earth, emitting a fluid made of sulfide and hot metallic minerals. Due to the contrast between cold saltwater and hyper-heated chemical matter, tall chimney-like structures tend to form at vent sites. The Victor 6000 is frequently used for sampling depository material from hydrothermal vents. Chimney fragments are rich in polymetallic sulfides and consequently have some commercial value.

Black smoker located at the Logatchev vent field along the Mid-Atlantic Ridge(www.noc.soton.ac.uk).

Hydrothermal vents, in addition to producing valuable minerals, are known to sustain benthic organisms, living in the lowest levels of the ocean. Victor is a very capable and popular instrument in the act of collecting micro-benthic animals. A typical procedure entails not only safe transport of the specimen, but also extensive evaluation of the ecological environment it inhabits. This is allows experimentation in a simulated environment to take place so that the specimens collected can survive outside their natural habitat. To meet the standards of this extensive procedure, Victor must do a number of things such as utilize both temperature and pH probes and to record micro-scale video imaging of benthic assemblages.

Oceanic exploration is an emerging industry. Project scientist Ron O'Dor of the Census of Marine Life recently said, "we know about 10 percent of what lives in the ocean". Machines like the Victor 6000 are constantly in operation, bridging the gap between human knowledge and the deep-sea habitat. O'Dor and his colleagues expect a great many breakthroughs in the near future.



Victor 6000 collecting samples from the chimney of a hydrothermal vent (www.gizmag.com).

Lessons Learned

Among the many lessons learned this year, by far the most important for the Mission Robotics Team was the value of camaraderie.

Early in the build season, the team had many differences of opinion over the best design for the ROV. This often led to friction between members, with unproductive meetings and arguments over topics including camera placement, motor placement, and other essential parts of assembly. In addition, new members did not understand the technical aspects of our ROV, such as camera wiring and pneumatic functionality. The lack of knowledge of some of our members, combined with the competing opinions about design, were aggravated by outside demands and responsibilities placed on our team members throughout the school year that limited their availability for working with the team. The result of this multitude of factors was that little work was accomplished during the first three-quarters of the build season.

The team finally learned to work together only as the time before the regional competition ticked away. With little time left, the team was able to overcome the problems presented only by realizing that leadership was needed to pull the team together. To this end, all team members endeavored to become specialized in one aspect of the ROV, and by doing so become the final voice in matters concerning their area of specialty. By the competition, the entire team had learned to look to *one* person when it came to a specific aspect of design; while the entire team could give input on a system on the ROV, it typically came down to one or two people who made the final decision. This allowed for the compression of the build season into a two-month time span.

Over the course of the school year, the team members greatly increased their ability to work well together, and as a result developed a feeling of camaraderie that served us well in our competition efforts.

Challenges Faced

This year the Mission Robotics Team had its fair share of challenges. The main factors of our troubles involved over-all attitude, scheduling, and technical design.

At the beginning of the year, morale was high and nearly every person showed up to meetings with a positive and productive attitude. We grew in arrogance after a very successful first pool day. The fact that we had allowed complacency to enter our mentality led to an erosive lull in the improvement of the robot. This greatly contributed to our stressors later when we saw that there was still much work to be done under much less time.

Another major challenge that the team faced was establishing a high turnout-meeting schedule. All members were occupied with school and extra-curricular activities. Some were even employed. Consequently, there were few occasions where the team was together at once.

Designing a claw that fit the satisfaction of everyone was a challenging and time-consuming dilemma. Due to conflictions between members and differences in opinion, the supposedly simple task of engineering an arm for our vehicle really turned out to be a stressed necessity.

Overall, the team acclimated to its most critical challenges. The Lessons Learned section describes in depth how the team optimized the challenges it faced.

Reflections

Will Buckingham- In robotics I learned that each time you rebuild something, all those little changes lead to that final product which makes that part what you needed it to be, and that the process just takes patience. I learned an amazing amount about PVC piping and how much you can do with it: I discovered its uses in buoyancy, structures, and all the things one can do with it once it is heated.

Rainer Fiege-Kollmann- Throughout this years events I have learned that the planning process has a major part in final perfection. The effort that comes with team communication and cooperation has a large impact on team efficiency and influences the productivity level of the team. The experiences of continuous trial and error have allowed me to realize that patience has a growing impact on others and on the team's ability to work on a common task. The experiences I received with hands on work gave me the opportunity to gain engineering and building process skills that I would not have gained without the robotics program.

Paige Czarnecki- I had to realize the complexity and challenge of constructing a functional robot. I was introduced to many new insights in electronics and pneumatics and learned to value the attributes of precision and patience.

Matthew Kudija- Along with the general experiences of learning to work effectively with a team to accomplish a common objective, I learned specifically about basic pneumatics and how they operate and are implemented into a system such as our ROV, and how cameras, controls, and motors are integrated and wired.

Josh Erskine- Through my work on the control box, I learned about proper integration of the different electrical components. We had challenges with the pulse width boards, and opted for a simpler design that still allowed for precise control of the ROV underwater.

Connor Pozdolski- I learned how pneumatics function with regards to PSI and directional control of their moving parts. In addition, the value of having a build schedule and STICKING TO THAT SCHEDULE was made very apparent, as our design process went through trial and error, with the focus on the error. Additionally, I learned how important it is to have team members with specialties rather than having the entire teamwork on everything at once.

Connor Fourt- In my first year of robotics, I learned a great deal about basic camera and motor operation. I was impressed with the versatility of our design and how we were able to implement many different parts into the final design to achieve the desired objective.

Jake Mather- I have learned a lot this year building the robot. I have learned the effectiveness of a tea when each person is working on what they are best at. I have also learned a lot about pneumatics, which as something new to me. I can now say I know how to set up a simple pneumatics system and put it to work.

Amanda Ford- I learned what a black smoker is and why they require advanced equipment to explore and study. Additionally, I the experiences working with other team members under stressful conditions gave me a level of confidence that I had not experienced before.

<u>Troubleshooting:</u>

The development of our troubleshooting technique was vital to our design and development process. First, after designing and constructing a portion of a payload tool or ROV system, we would perform a dry-test in the classroom. If the system worked under dry-test, it would progress to wet testing in a fish tank. If it did not pass the dry-test, we would collaborate as a team and make a list of the possible sources the failure arose from. We would then order this list from most likely to least likely, and use that order to go about finding the cause of failure. This methodology was particularly helpful in the early stages of development of the electrical system, where our troubleshooting technique allowed us to identify quickly with a voltmeter the cause of a wiring short or other failure.

While this troubleshooting technique works well for our electrical and pneumatic system, we used a time-tested method of trial and error when working with our buoyancy, ballast, and temperature measurement systems. In these cases, we would build, attach, or otherwise modify the system in question and then observe the effects of our efforts. In this way, our buoyancy system evolved over time as payload tools were added to the ROV. Similarly, we continually redesigned our temperature system until we were satisfied with the outcome.

Future Improvements:

Future improvements to our ROV fall into two categories: short-term improvements that are within our reach, and long-term improvements that we would like to do if we could gain the expertise needed. The team expects to accomplish all of our short-term improvements before the international competition date. First, we will be modifying the ROV frame to include an aluminum bar across the rear face of the robot to mount the rock scraper more securely. Second, the shape of the rear rock scraper will be further heat-modified to conform to the shape of the black smoker, which allows us to more effectively remove the rock samples from the side of the smoker. In addition, the team will be researching the effectiveness of Kort nozzles to increase the efficiency of our thrusters.

Long-term goals for the development of the *Anaconda* include the integration of the temperature sensor with the rest of the ROV, making a more condensed and efficient payload tool, rather than the effective but structurally wasteful design we currently use, which limits the ROV's ability to accomplish both the rock sampling and temperature sensing tasks without returning to the surface for modification. Another improvement would be the design and construction of a joystick operating system for the motors of the ROV, which would allow us a greater degree of control and maneuverability during the competition.

BUDGET				
date	**company**	**product**	**Income**	**Costs**
2/15/08	Stroebie Welsh Engineering		500.00	
4/10/08	Franke Family		500.00	
3/20/08	Absolute Auto Tech	marine battery	137.00	137.00
2/12/08	SOSI	underwater cable (est $10/meter)	300.00	300.00
4/3/08	Arroyo Grande HS Eagle Robotics	pneumatic parts	400.00	400.00
4/19/08	Atascadero HS Greyhound Robotics	two pneumatic valves	100.00	100.00
4/5/08	Depth Perceptions Diving	various fittings and tank	100.00	100.00
2/10/08	SolidWorks	software	200.00	200.00
4/20/08	Doria Family	pool time	100.00	100.00
1/31/08	Noah Doughty	borrow underwater camera	100.00	100.00
1/31/08	Mission College Prep	borrow underwater camera	100.00	100.00
TOOLS				
1/31/08	Amazon.com	Hot Air tool kit		34.99
3/27/08	Blake's Inc.	taper cutter		8.03
3/11/08	delcity.net	4 rocker switches		18.84
MOTORS AND PROPELLERS				
2/1/08	Cabela's	motors		137.82
2/4/08	Tower Hobbies	8 prop adapters		32.73
3/13/08	Race prep hobbies	plastic props		38.38
1/30/08	circuit specialists	2 motor speed controllers		43.52
MISC. HARDWARE AND PARTS				
3/15/08	Pacific Home/garden	parts		83.72
3/15/08	dollar tree	parts		7.54
3/13/08	tech instrumentation	thermomenters		55.92
3/3/08	Delecity.net	parts		141.22
3/16/08	Michaels	parts		3.54
3/21/08	Farm Supply	parts		98.39
3/21/08	Home Depot	parts		132.94
3/21/08	Radio Shack	parts		78.42
3/24/08	Kragen	marine terminal		5.92
3/27/08	C.E.D.	parts		14.42
4/5/08	Wal Mart	weights/net		15.21
5/8/08	Kragen	blade fuses and misc.		13.99
5/8/08	zip ties/hardware plates	Home Depot		38.62
4/16/08	Home Depot	Air hose parts		21.20
DISPLAY BOARD				
5/8/08	Longs Drugs	Photo Processing		11.85
5/5/08	Longs Drugs	Photo Processing		9.62
5/5/08	display board	Staples		15.07
		Total		**2,596.88**

Acknowledgments

Along the way to San Diego, the MCP Robotics Team received assistance from a number of organizations, companies, and individuals. We could not be where we are today without these contributions. Our heartfelt gratitude and thanks goes out to:

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Absolute Auto Tech
Depth Perceptions Diving Services
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Doria Family
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Robotics Team Families, for their patience and love

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