7th Annual Marine Advanced Technology Education (MATE) Center International Remotely Operated Vehicle (ROV) Competition

Diving to the Deep:
Uncovering the Mysteries of Mid-Ocean Ridges

Technical Report

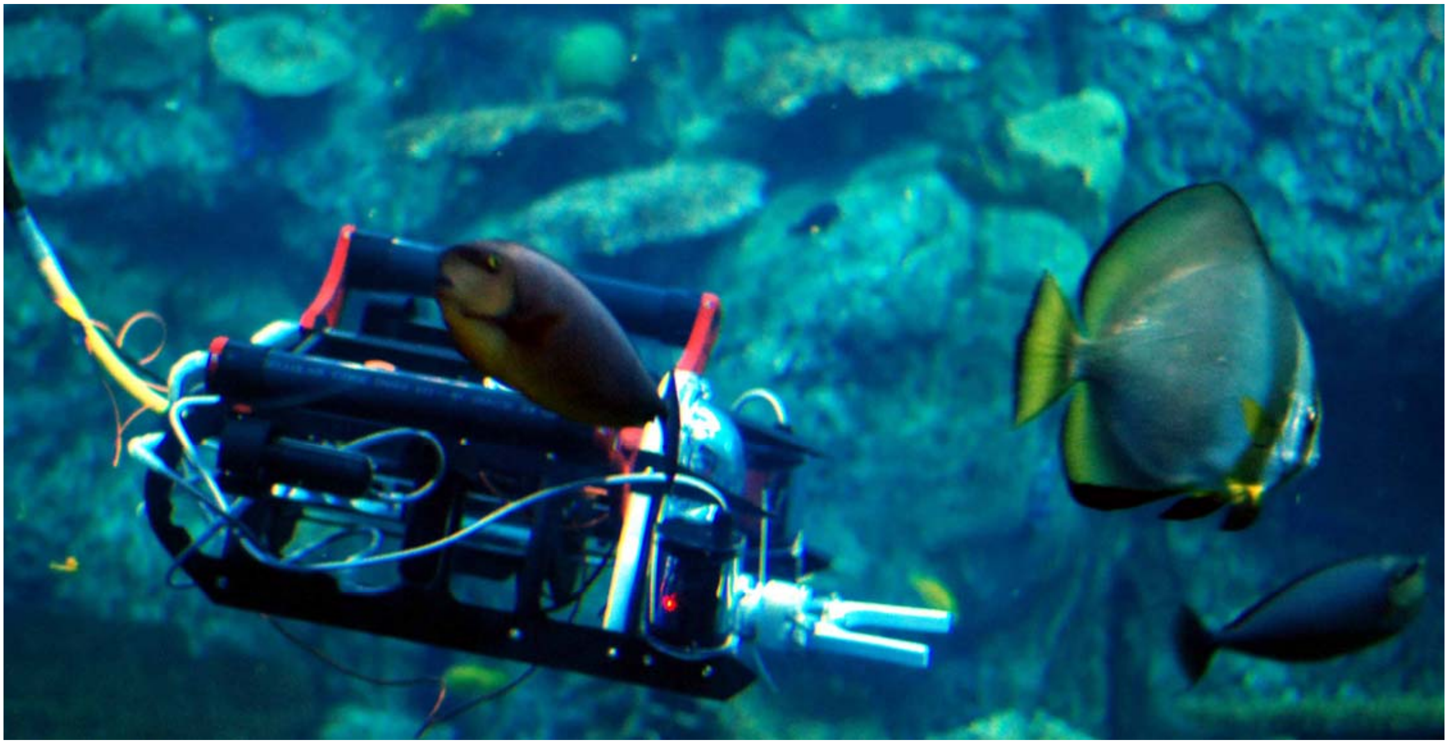
Long Beach City College ROV Team
Long Beach City College
Long Beach, CA

Team: Viking Explorers

ROV Name: Viking SABER

*(**S**uper **A**gile **B**enthic **E**xploration **R**OV)*

Ian Jasper, Team Captain	Electrical—Spring 2009
Francisco Canul	Electrical—part time, maybe Spring 2018 ☺
Ricardo Casaine	Electrical—Spring 2009
William Hillhouse	Computer Engineering—Spring 2009
Yasin Khalil	Bio-Medical Engineering—Spring 2009
Adam Ramsey	Electrical—Spring 2009
Andy Walsh	Electrical—Spring 2009
Leonard Fellman	Sage Advice
Scott Fraser	Instructor



ROV 1 - Viking SABER at Long Beach Aquarium of the Pacific

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Judge's Access to Forum

In various parts of this technical report, judges are directed to the team Web site for additional information and to gain an insight into the engineering practices used by the team in developing this ROV. Twenty pages is only a summary of all the documentation compiled by the team over the year of development, building and testing. Judges are directed to visit http://www.vikingexplorer.org/forum, sign in as **Judge,** with a password of **MATE** (all upper case)

From there you will see a number of categories. Of specific interest to the judges may be the ROV Design Documents forum and the Scheduling forum. Judges are invited to browse other forums as well to get a feel for the teamwork that was involved in creating this ROV. The forums are provided instead of many pages of appendices.

Abstract

Long Beach City College (LBCC) returns to the 2008 MATE ROV Competition with the Viking SABER ready for work. The purpose of this ROV is to explore the depths of the mid-oceanic ridges while taking temperature readings of black smokers, recovering samples and safely returning them to the surface. The ROV was designed with a frame made from buoyant PVC. The design made in SolidWorks greatly increases water flow, allowing it to glide through the water to a depth of about 30 meters due to tether length. The length, width, and height of the ROV is 76cm, 50cm, and 28cm, respectively. With a surprising 16 kilograms of weight, an average person could lift it easily, using the handles that are part of the frame design. LBCC's ROV carries four cameras: a dual camera stereovision system, which creates a distance-measuring viewing system; a single high-resolution low-light color camera with multi-directional movement; and an unfixed camera which can be mounted anywhere for extra viewing. The five thrusters provide 2.9 kg of thrust each, enabling it to be quick and powerful. In order to complete the assigned tasks, a multifunction gripper was designed and built. This gripper has a built-in hook to grab the Ocean Bottom Seismometer (OBS) and help return it to the surface. The gripper has a channel cut into the middle of it to allow water flow so the temperature sensor can be deployed properly and it can also easily pick up the lava samples.

Team Introductions

Ricardo Casaine came into the robotics course in spring 2008 with the intentions of becoming an electrician, wiring commercial and residential buildings. Enrolling in the LBCC Robotics course was an eye-opening experience for him, which helped him change his career path and seek the unlimited opportunities in an ROV-related career.

William Hillhouse took the robotics course for the first time in the spring of 2008. His reason was that it looked like a lot of fun. He heard that LBCC had a good robotics course, and since it was not too distant from his major in Computer Engineering, he decided to jump aboard. With minimal skills, he has taken this semester as a major growing experience. In his spare time, he is always fiddling around on the piano improving his skills as a composer.

Ian Jasper is an electrical student returning for his second year as team captain. He currently works part time as an assistant design engineer at a lighting company, while maintaining an average of 15 units per semester. He plans to work in marine-related field upon completion of his degree.

Yasin Khalil is a fairly new addition to the team. He is a Bio-Medical Engineering major. He spends his free time playing guitar and writing music.

Adam Ramsey is a veteran team member from last year. He changed his major from International Business to Electrical Engineering after last year to pursue a career with ROVs.

Andy Walsh entered the robotics program in the summer of '07. He came into the class in order to get a head start on electrical classes at LBCC. He found something that he could really get behind and go with; he has put a lot of effort into learning this year and has helped out a lot on this year's ROV project.

Francisco Canul is a part-time electrical student and plans to graduate sometime in the future. How soon, he will not say. He has been on the previous ROV teams and is here this year because he cannot tear himself away from the fun

Instructor's Note: One requirement to be on the ROV team is a minimum GPA of 3.0 in all subjects. All these students exceed that requirement.

Using ROVs to Explore the Mid-Ocean Ridge

Figure 1 - Victor 6000 ROV

The Victor 6000 remotely operated vehicle (ROV) was first launched in September of 1997, its first scientific operation took place in 1999, and as of 2007 has performed at least 300 dives. Victor 6000 has achieved a maximum depth of 5917 meters with a maximum dive duration of 101 hours. It has a 70-liter buoyancy system, motion, depth, and altitude sensors, and runs on hydraulic and DC power. It is also equipped with a 600-kilogram sampling module, eight cameras, the main three having zooming capabilities, and eight lighting units.

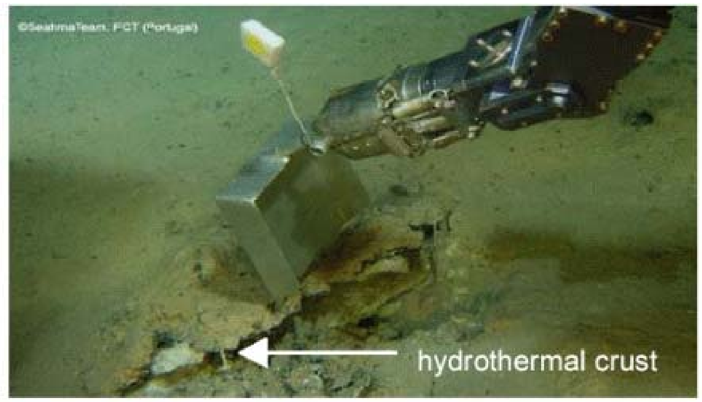


Figure 2 - Sampling Hydrothermal Crust

Victor 6000 played a huge part in two research cruises, Iris and Seahma-I, in 2001 and 2002, respectively. The missions at hand were to gather data on the hydrothermal activity located at the Rainbow, Menez Gwen, Lucky Strike, and Saldanha hydrothermal fields that are located on the mid-Atlantic ridge, south of the Azorean islands, located about 1500 km of west of Lisbon, Portugal. During the Iris cruise, Victor 6000 enabled scientists to study the Rainbow hydrothermal field, including its hydrogen-rich environment caused by hydration, a chemical reaction that occurs when water is added to various metals that are part of the mantle rocks located on the floor of the field. Also, during the Iris cruise, samples were taken, including fluids from hydrothermal vents, rocks, sediment, and chimneys, which are formed by minerals deposited and built up around the vents.

Fig. 7: Seahma-1 (2002) cruise: *Maestro* manipulator operator is performing precise temperature measurements in a black smoker (Rainbow hydrothermal field, venting temperature up to 364°C).

Figure 3 - Sampling Black Smoker Temperature

The Seahma-I cruise had many of the same focuses as the Iris cruise. In addition, it gathered observational data through video recordings, as well as creating geological and biological maps, and collecting a range of samples, including organisms such as fish, crustaceans, and single-celled microscopic organisms called microbes. Results from the Seahma-I cruise proved valuable as they provided evidence of the precipitation of metal-rich minerals occurring beneath the sea floor, as well as the discovery of new species.

Though our ROV is not able to dive anywhere near 6000 meters, it shares many basic similarities with the Victor 6000; for example, it utilizes fiber-optics in its tether, and it can take temperature readings from hydrothermal vents, specifically black smokers. Also, both vehicles allow researchers to spend long time periods at depths that humans can normally not dive to without the use of time-limited manned vehicles. Other similarities are the abilities of both ROVs to recover and return samples to the surface and provide a video recording of the area being explored.

Design Rationale

Gripper and Tasks

The gripper was designed to be a multi-task tool for this year's ROV. It is able to complete all of the tasks and has a built-in digital temperature sensor. The gripper is strong enough to pick up the lava samples and place them in the recovery package to be returned to the surface.

A problem arose in a discussion over how to get an accurate measurement of the black smoker. The original idea was to take the temperature by inserting a probe into the black smoker. The team decided that this would be a problem in a real-world situation because of the potential damage to the black smoker. The decision was made to put the temperature sensor into the gripper, then to use the gripper to carefully clamp around the top of the water stream to avoid damaging the structure of the black smoker.

When brainstorming on how to return the lava samples to the surface, the idea was formed to return the Ocean Bottom Seismometer (OBS) and the lava samples at the same time to increase efficiency by only needing one trip to the surface to retrieve everything. A real-life ROV trip to the seafloor may take in excess of eight hours for a one-way trip. A small box will be inserted into the center of the OBS by the gripper and will contain a scuba lift bag. The lava samples will be placed inside the box. Once all the remaining lava pieces have been cleared from the OBS, the ROV will return to the front of the sample box and OBS. The ROV will then grab the box that was inserted into the OBS and inflate the dive bag with air from the surface. The gripper will clamp onto the OBS and be able to maneuver it where it is needed at the surface. The lift bag will neutralize the total combined weight of the OBS and lava samples. This allows for a controlled ascent to the surface with all the lava samples and the OBS. If in real life the OBS were released from a depth to "float" to the surface, it could return many kilometers from the boat after being subjected to ocean currents on the way up. We felt it would be best to return the OBS and lava samples under ROV control.

Figure 4 - Gripper Shown Picking Up "Lava" Sample

Figure 5 - Gripper Shown Picking Up OBS

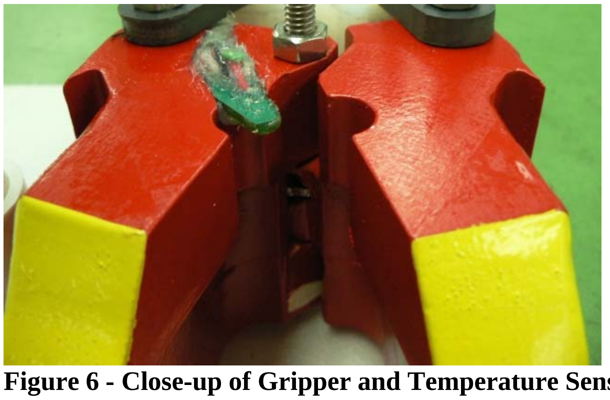


Figure 6 - Close-up of Gripper and Temperature Sensor

ROV Frame Configuration

The basic platform for Long Beach City College's ROV this year can be broken down into several systems. These systems were all designed in order to best approach this year's mission tasks. These systems include the frame, thrusters, electronics, cameras, and control system.

The frame is an extremely important part of this year's ROV design because all the other aspects of the robot are dependent upon the design of the frame. We opted to use a system of interlocking panels, bolted together with a series of three bulkheads that create a very strong yet lightweight skeleton. By using a CNC router, we were able to take a set of two-dimensional shapes, cut as precisely as possible, and create one three-dimensional shape. This design allowed for easy maintenance of the robot by simply removing one of the side panels. One of the other key features of the robot is the material that the frame is made from. By doing a lot of experimentation with various types of plastics for the frame, we finally ended up with a form of PVC that had the correct strength characteristics we needed, but was also very low density. This resulted in the frame being positively buoyant. This concept radically changed how we thought of the frame and any other parts that could be made from plastic. For the first time we did not need to minimize everything but, instead, wanted it to be bigger in order to displace more water and thus achieve more positive buoyancy to offset the weight of the other components on the robot.

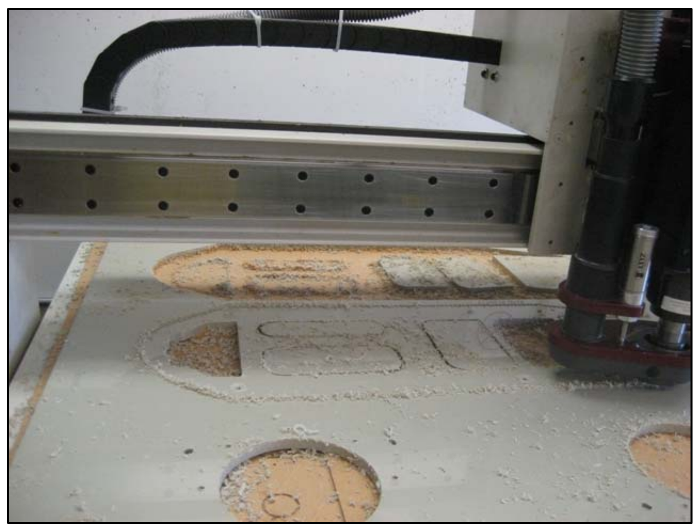


Figure 7 - CNC Router Used to Cut the ROV Frame

Another concept that we began to experiment with this year was the use of vectored thrusters. In total, the ROV has five thrusters: three vertical and two horizontal thrusters. We used a 30-degree angle on two of our vertical thrusters in order to gain a whole new range of maneuverability. The concept driving our use of this idea was that by running the thruster motors in opposite directions, the vertical thrust will essentially cancel itself, leaving the sideways thrust vectors to add and move the robot from side to side or “crabbing.” This proved to function perfectly, as long as we did not run the thrusters with so much power that there was enough thrust to overcome the buoyancy on top of the robot. When more than 50-percent of our total thrust was used on the two vectored thrusters, the robot was able to do a lazy barrel roll. This was also a type of maneuver we had hoped to be able to achieve and were astonished to see just how well it worked. We found the ability to barrel roll particularly useful in untwisting loops in our tether. By using the thruster motors running in the same direction, we achieve our up and down movement. All of this was used to gain the ability to crab left and right, barrel roll left and right, and to ascend and descend with only two thrusters. By using two thrusters to achieve all of these various movements, we still had the power budget for one additional thruster. We used this third thruster as a straight up and down thruster at the front-center of the ROV to compensate for the load being lifted by the ROV. In testing, we found that we could pick up 2kg of load without any problem using this configuration. A side benefit of this configuration is that we are now able to change the ROV angle of attack in the front. This allows us to make angled ascents and descents by moving the robot forward and then moving the front of the ROV either up or down. The net effect of our experimentation in the use of thrusters is the most maneuverable robot we have made to date.

The electronics on this year's ROV are contained within a central waterproof housing, with cables that branch off to the individual components on the robot such as thrusters and cameras. This housing contains the PIC18F4431 processors and H-Bridges that we use to control the thrusters and cameras. All of the data from the electronics housing is sent through a fiber-optic multiplexer that converts the electrical signals into light pulses which are then sent through a single fiber-optic cable to the surface. This series of light pulses are then converted back into electrical signals and sent to a PC. The PC interprets the data from the robot and the operator, then sends the signals back and forth, telling the robot what to do and the operator what the robot is doing.

The camera setup on the ROV consists of one main camera contained within an acrylic dome on the front of the robot that is used as the main navigation camera. There is then a set of stereo cameras focused on the main working point of the gripper used to get accurate depth perception when working with the gripper. The stereo cameras allow us to accurately place the gripper where we want it as quickly as possible. The signals from these cameras are then also sent through the fiber-optic cable to a video mixer and video switch that allow the operator to see all of the camera views at once and manipulate them as needed.

The end result of these systems is a highly agile and versatile robot that can be used for many different tasks in many different situations. The full functionality of the robot is best demonstrated when put in the context of the tasks it was designed to accomplish. Just how well it will line up against other designs remains to be seen.

Design and Design Analysis Documents

SolidWorks Analysis of Gripper Strength

Using SolidWorks COSMOS, the gripper was analyzed for strength and deflection. Maximum deflection was less than 5mm with a 10kg load applied. This is completely acceptable and with a load ten times what the gripper will be seeing while performing its tasks.

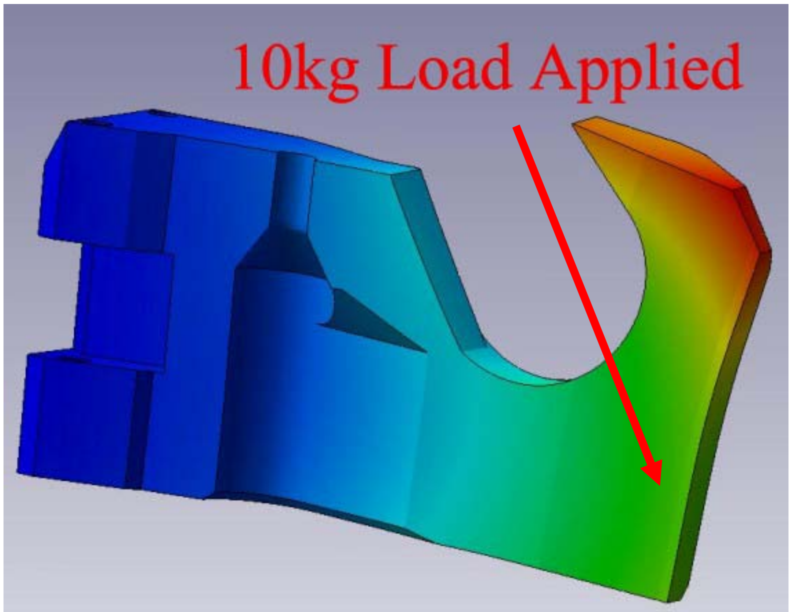
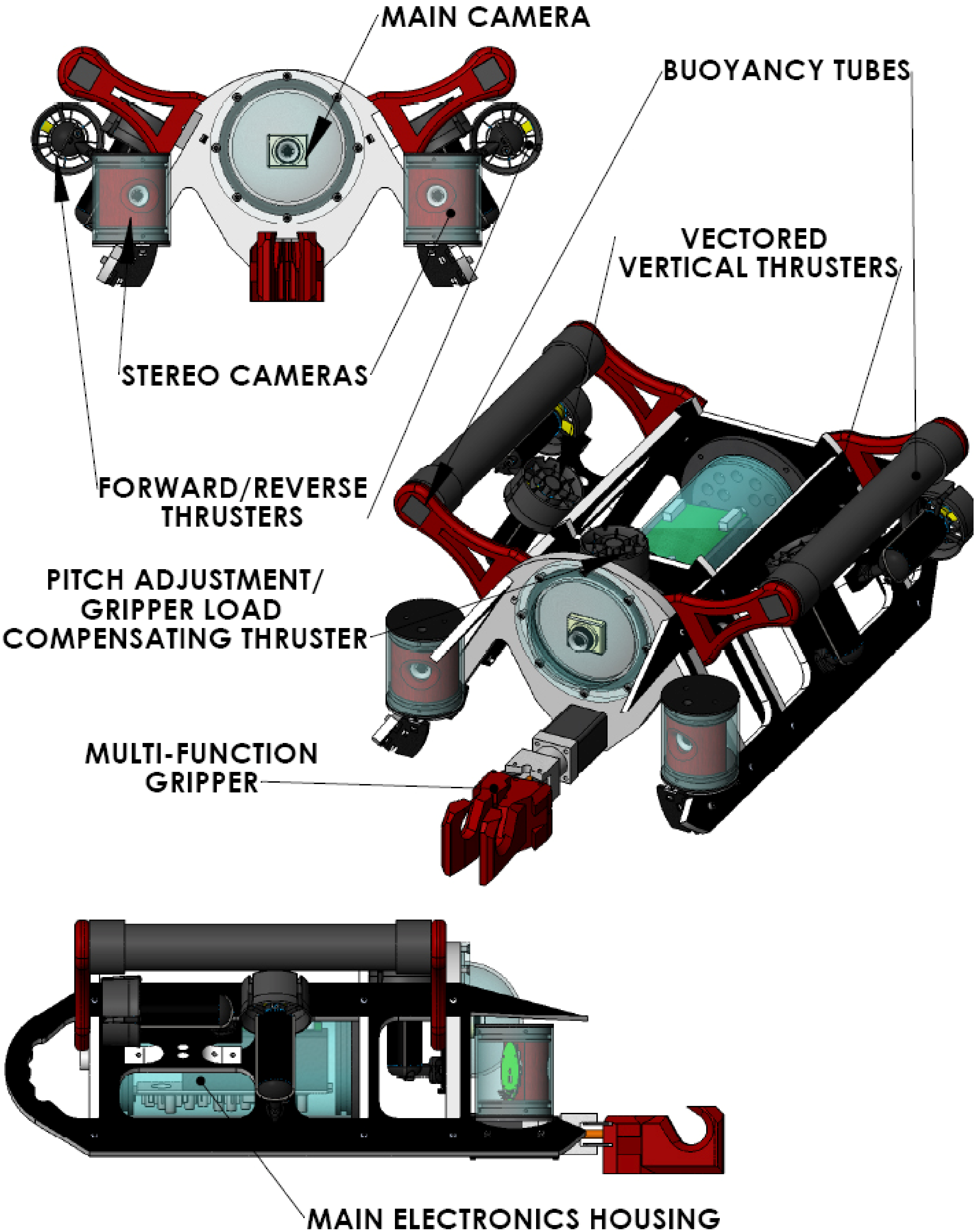


Figure 8 - COSMOS Analysis of Gripper Deflection

SolidWorks Drawings

The drawing on the following page is a mechanical drawing of the ROV. For additional drawings, go to the Web site at http://www.vikingexplorer.org/forum, and select the ROV Design Documents Forum


MAIN CAMERA
BUOYANCY TUBES
VECTORED
VERTICAL THRUSTERS
STEREO CAMERAS
FORWARD/REVERSE
THRUSTERS
PITCH ADJUSTMENT/
GRIPPER LOAD
COMPENSATING THRUSTER
MULTI-FUNCTION
GRIPPER
MAIN ELECTRONICS HOUSING

Wiring Diagrams

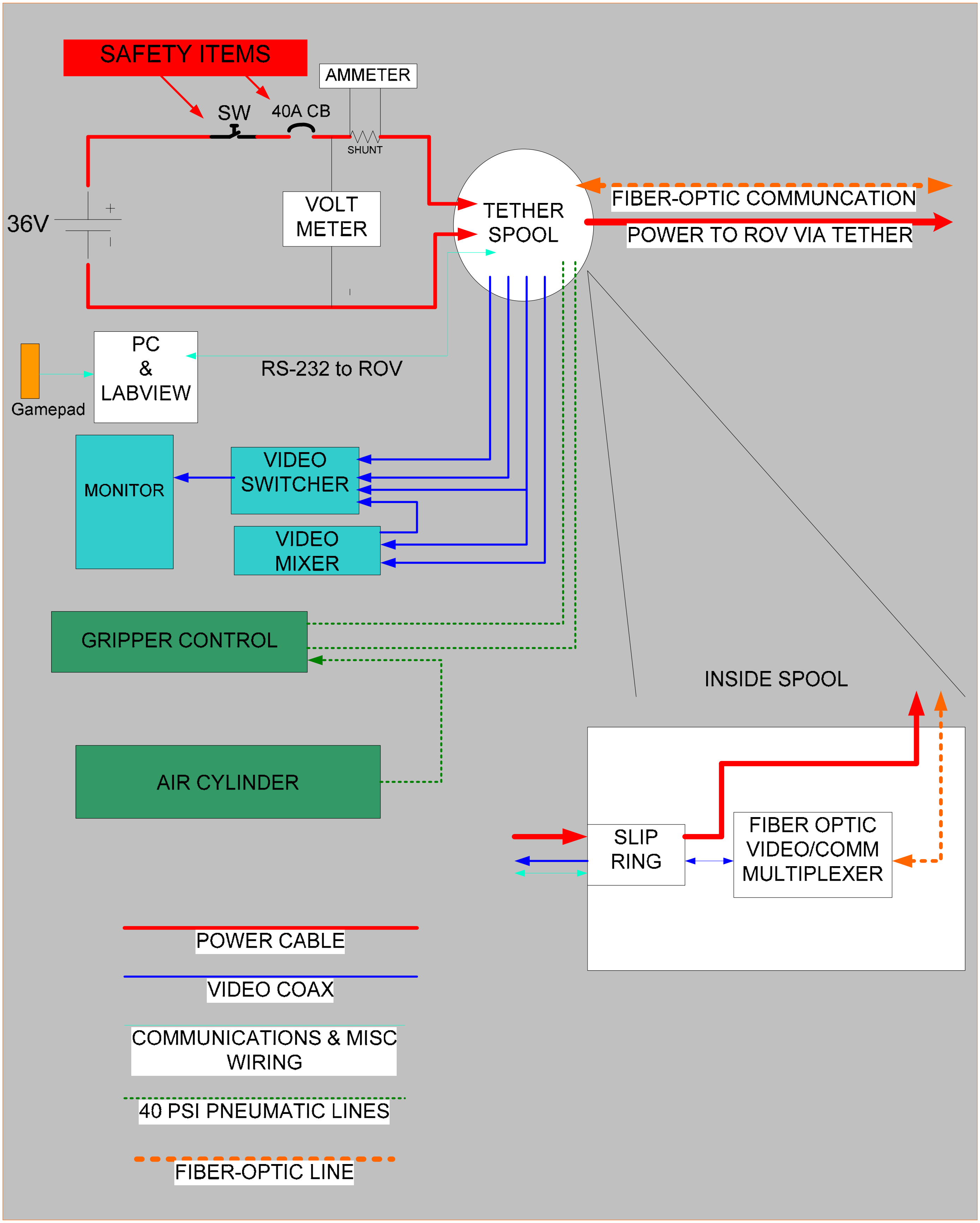
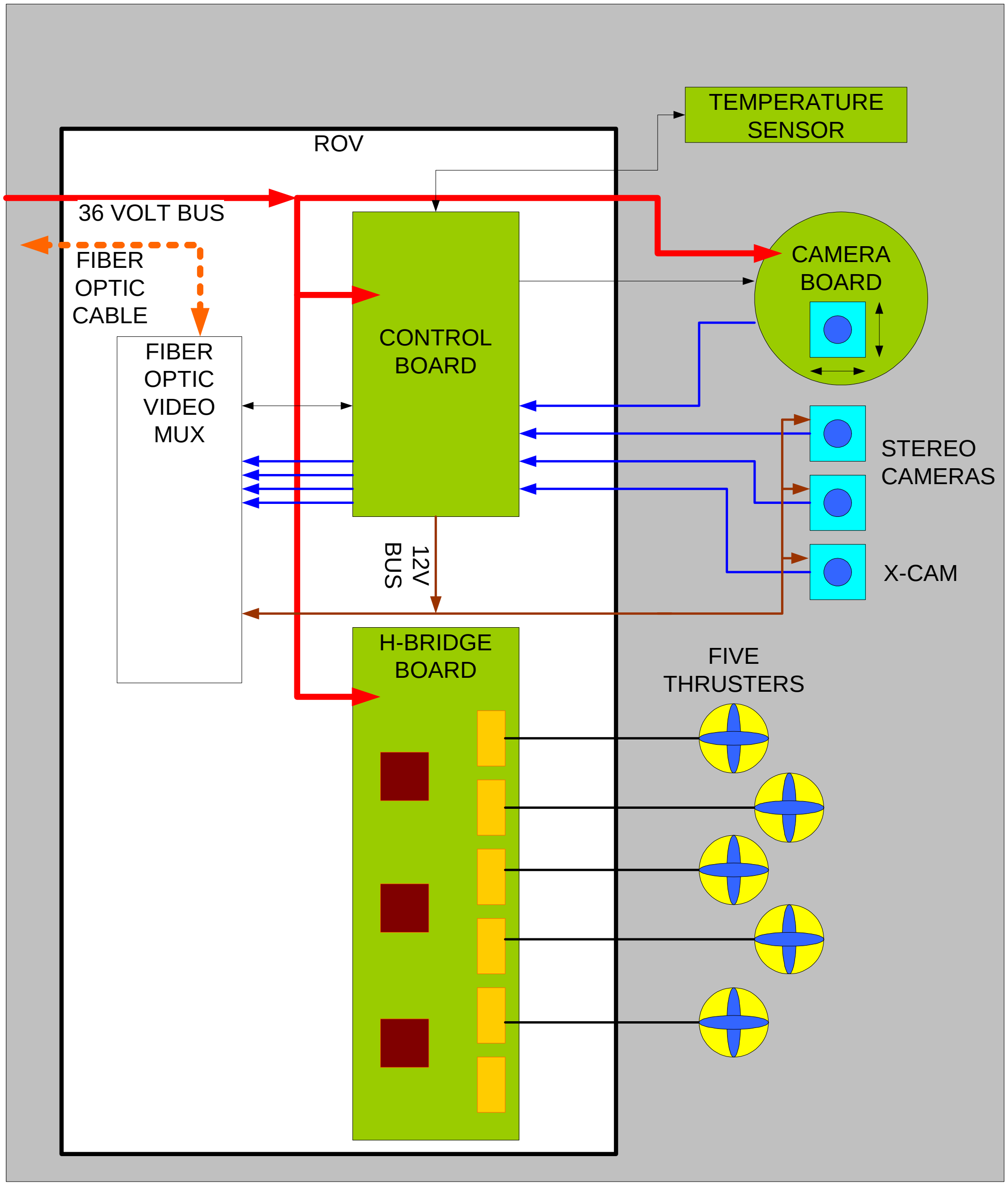


Figure 9 - Top Side Wiring Diagram

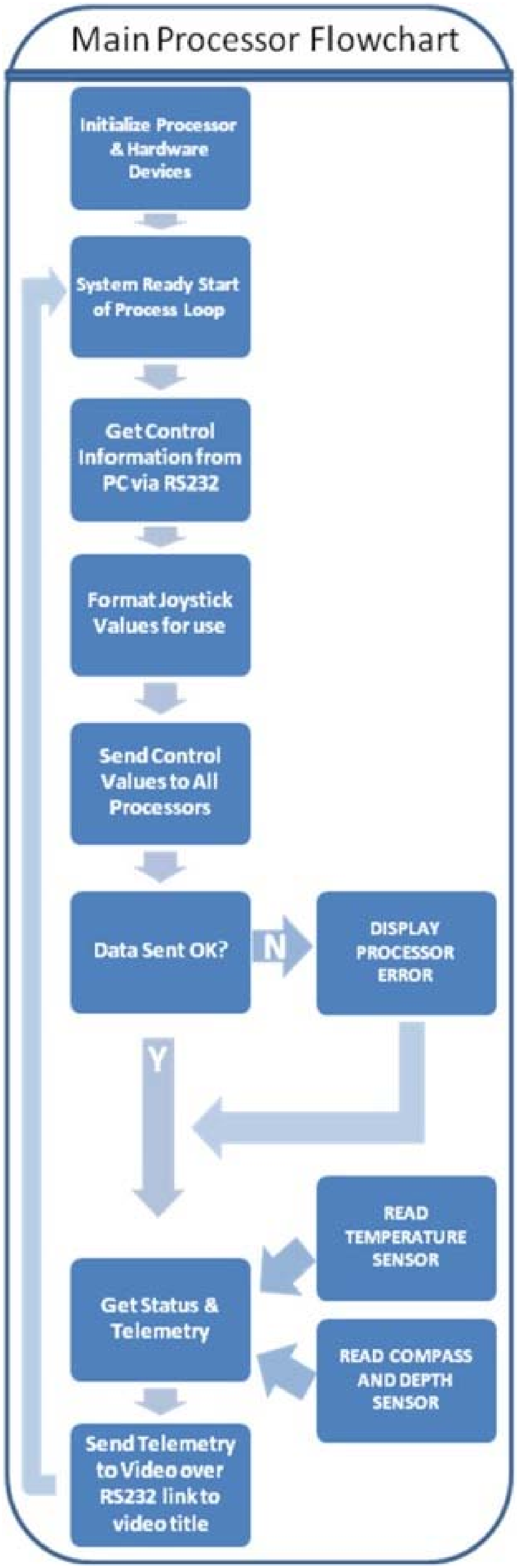


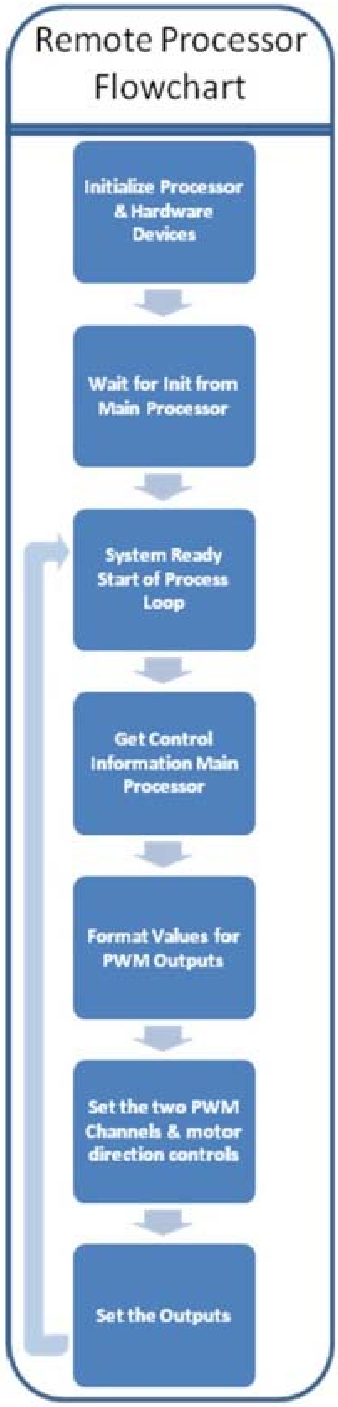
Board Schematics

The circuit boards for the ROV consist of four boards all serving different functions in the operation of the ROV. The boards were meticulously soldered according to the given schematics, highlighting each finished task, to keep track of our progression. The control board is designed to give power distribution between the motor and cameras. A second board with six H-Bridges (one spare) and three processors are used to control the five thrusters propelling the ROV. The temperature sensor board is the third that works in conjunction with the pneumatic gripper. It encases a sensor used for taking accurate underwater temperature readings for the black smoker task. The fourth and final camera circuit board controls the pan and tilt control for the main camera, as well as the camera power supply.

The cameras include a left/right stereo camera set, the main pan/tilt camera utilizing a motor from a car side-view mirror and a fourth camera (X-Cam), a back up for mounting wherever necessary if and when unexpected tasks may present themselves. The cameras are routed through a video mixer on the surface, where the ROV operators are able to use the stereo display to create depth perception when performing tasks with the gripper.

To view the schematics for each of these boards go to the Web site at http://www.vikingexplorer.org/forum, and select the ROV Design Documents Forum





Software Flow Chart and Electronics Description

The software development for this project was done with MicroEngineering's PIC Basic Pro compiler and assembler for the MicroChip PIC18F4431 Processors.

The ROV has four boards, the main control board, the H-Bridge board, the main camera board, and the sensor board. On the H-Bridge board, each of the three processors on board has two PWM controllers, which in turn control the individual H-Bridge chips for each thruster. The board has provisions for up to six thrusters, but only five thrusters are driven. The processor on the main camera board controls the pan and tilt movements of the main camera, as well as the brightness of the front LED lighting. The processor on the sensor board handles the temperature, compass, and depth sensors. The temperature sensor is a digital temperature sensor, factory calibrated to ±0.5C. It is connected to the processor by a five wire serial connection.

Communication between the processors was implemented using a simple RS-232 serial transmission.

The ROV receives its commands from the PC which is running National Instruments LabView. The team wrote this program to read a gameboy-style joystick and then send those values to the ROV for control purposes.

Advanced Circuits built the bare boards for the team, and then all the components were installed, soldered and tested entirely by the team.

Thruster PWM/Power and Tether-Loss Calculations

In order to compensate for the voltage drop in the tether and ensure that we did not drive the thrusters beyond their design of 80 watts/3 amps per thruster, we put together the following analysis spreadsheet. The results show that in order to achieve an effective voltage of 28V to the thrusters, we should run the thruster PWM at a maximum value of 78%. (See the team forum for a description of PWM). By doing the analysis with one to five thrusters running at full power, we were able to approximate real-world usage of the tether by the ROV. We also verified these values in practice.

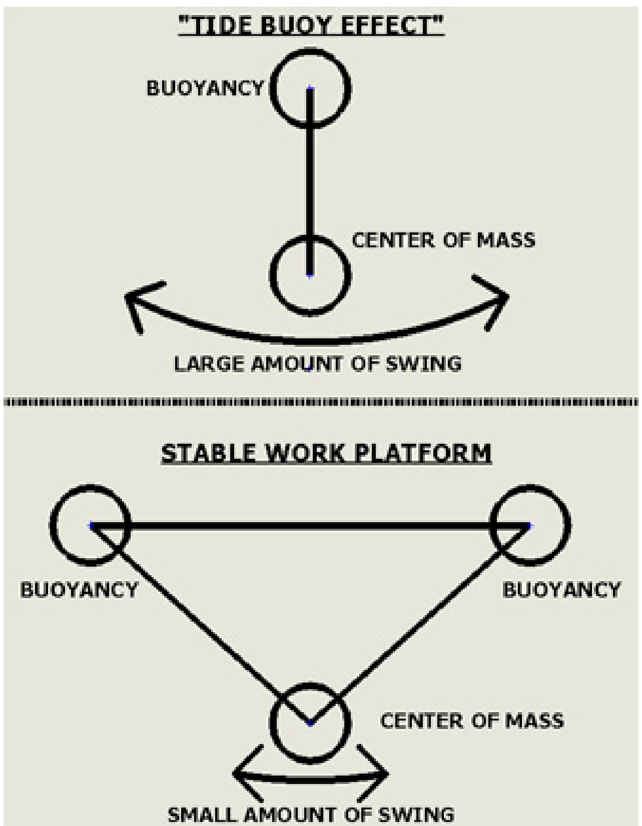
		PWM	78%				
O	Tether Resistance (Ohms)		0.121	0.121	0.121	0.121	0.121
H	Thruster Resistance (Ohms)		9.333	9.333	9.333	9.333	9.333
M	Number of Thrusters		5	4	3	2	1
S	Thruster ohms in parallel		1.867	2.333	3.111	4.667	9.333
	Total ohms, Tether & Thrusters		1.988	2.454	3.232	4.788	9.454
V		24	12.074	9.779	7.425	5.013	2.539
O		28	14.087	11.408	8.663	5.848	2.962
L		36	18.112	14.668	11.138	7.519	3.808
T		42	21.130	17.113	12.995	8.773	4.442
S		28.08	14.127	11.441	8.688	5.865	2.970
		32.76	16.482	13.348	10.136	6.843	3.465
	Amps Per Thruster @	24V	2.415	2.445	2.475	2.506	2.539
A		28	2.817	2.852	2.888	2.924	2.962
M		36	3.622	3.667	3.713	3.760	3.808
P		42	4.226	4.278	4.332	4.386	4.442
S		28.08	2.825	2.860	2.896	2.933	2.970
		32.76	3.296	3.337	3.379	3.421	3.465
	Thruster Power at 24V		54.4	55.8	57.2	58.6	60.1
W	Thruster Power at 28V		74.1	75.9	77.8	79.8	81.9
A	Thruster Power at 36 V		122.5	125.5	128.7	131.9	135.3
T	Thruster Power at 48 V		166.7	170.8	175.1	179.6	184.2
T	Thruster Power at Low PWM		74.5	76.4	78.3	80.3	82.3
S	Thruster Power at High PWM		101.4	103.9	106.5	109.2	112.1

YELLOW = Thruster current is below optimal
RED = Thruster current is above maximum continuous current
OPTIMAL RESULTS WITH 78% PWM MAXIMUM

Build and Test

Technical Challenge to Overcome

During one of our first test runs at the Aquarium of the Pacific we encountered a major technical challenge. What it came down to was that we had yet to properly trim out the ROV with the proper amount of buoyancy and ballast in the correct locations. Due to time restraints on testing our robot, we created a temporary float by using some low-density plastic mounted in the center of the robot. Previously we had measured the fully assembled robot in fresh water and found out that we were 0.91 kilograms negatively buoyant. As it turned out, we ran some calculations and just barely had enough of the plastic to achieve neutral buoyancy. The way we mounted it, however, was in the center of the ROV, which created the dreaded "tide-buoy effect." With this buoyancy configuration, currents, waves, and any other forces act on the ROV, causing the robot to rock back-and-forth in a very wide arc, which makes precise control extremely difficult. The diagram below makes the concept easier to understand.



The following week we addressed the stability issues we were having at the aquarium. First we decided to handle the "tide-buoy effect." We corrected the problem by maintaining a high center of buoyancy and a low center of gravity as before, but this time we created a very wide buoyancy profile. The wide profile made it much more difficult for the robot to rock back and forth. The design uses the fact that the wider the center of buoyancy is, the more force it takes to create a rocking motion. Once the center of buoyancy has been expanded, a stable platform is easily achieved. The design we came up with was to use two sealed tubes filled with air on a set of brackets to put the buoyancy where we needed it. We then calculated how much positive buoyancy each tube would give us, the way we calculated the buoyancy is as follows.

The tube's outside diameter = 5.97cm
Tube length = 44.45cm
Volume of tube = 1.372 Liters
Mass of tube = 0.54 kg

Because the mass of 1 liter of fresh water = 1 kg (1.372L = 1.372kg)
Therefore 1.372kg – 0.54kg = 0.832 kg of positive buoyancy per float.
(0.83kg positive buoyancy) X (2 Floats) = 1.66kg of total positive buoyancy
1.66kg of Positive buoyancy – 0.91kg ROV negative buoyancy = 0.75kg of positive buoyancy remaining.

This extra buoyancy allowed us to use lead ballast in precise locations to make sure the ROV sits exactly as we want it to in the water.

Build and Test Photos

Figure 13 - Inside Tether Spool Showing the Video Mux

Figure 14 - Adam Works on Soldering the Control Board

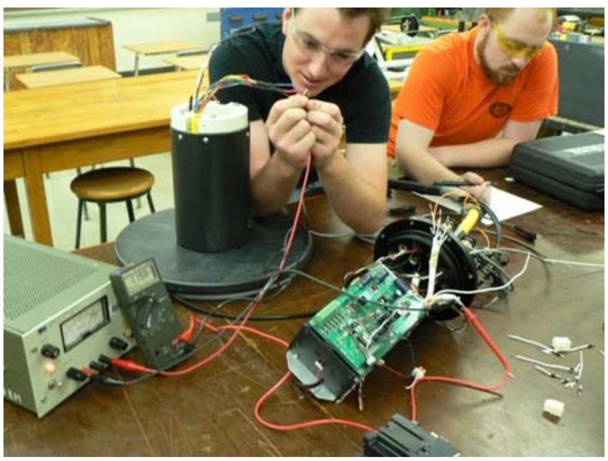


Figure 15 - Andy & Adam Perform Voltage Drop Tests on Tether

Figure 16 - ROV in Position for Programming Updates

Figure 17 - H-Bridge Board

Troubleshooting Techniques

Probably one of the greatest troubleshooting challenges the team encountered this semester was during our first off-campus test drive with the ROV. Sadly, the first run ended when the driver lost all control of the thrusters. First, we thought there was damage done to the ROV. Second, it seemed that the surface power supply control was accidentally adjusted too high. Further investigation, however, revealed what looked like broken leads to a voltage regulator.

Once that problem was found, it was easily fixed with a little bit of soldering. To our dismay, the ROV would still not function properly. It turned out those leads were not used by the ROV in any way. We proceeded to troubleshoot by checking voltages going in and out of the ROV. Next, we checked all connections on the ROV, as well as ones coming from the laptop. Any suspicious-looking connection found on the ROV was soldered. We also checked the continuity in the tether. Feeling like there was nothing left that could be checked, we stopped looking, but left the ROV powered up in order to demo the cameras with the gripper on the display table.

Oddly enough, after several hours went by, the ROV began to work as it did before the accident without the intervention of anyone. Because of time restrictions, we could not run the ROV in water anymore on that day. All throughout the week following this breakdown, students made special efforts to go to school and troubleshoot the problem. Since the ROV “magically” started working, we turned our attention to the laptop.

We later realized that the laptop was constantly running on 100 percent CPU usage. We started by shutting down all unnecessary programs. We then discovered that the problem only occurred when the laptop wireless card was active and searching for an Internet signal. When the wireless Internet card was disabled, the laptop and ROV worked without delay. We went back to the aquarium for additional testing two weeks later only, to encounter the problem again. When the wireless card was disabled, the ROV immediately operated normally. We were then able to do five 30-minute “shows” for the public, while testing our system and getting piloting experience.

Lesson Learned—One Person’s Perspective

This year when I entered into the robotics program I had very limited knowledge of robots and how they worked. For me to write on all of the valuable skills that I have learned in the past year and to touch on them, it would make for a very long paper, but due to limits on this report I have chosen one important lesson learned: patience. Some might describe it as a trait or a value, but patience for me has been a very important skill that I am fortunate to have learned this year.

I was never a patient person; I wanted stuff my way, and quickly. But when you are on a team with people ranging from really smart A-type personalities, to over-zealous lemmings, you learn to calm down and find your “Zen.” In this class you are often helping someone who is not entirely up to speed and you must be calm and show them what to do and how to do it because I was there not too long ago. With those that know more you, must be patient so you can find the right time to pick their brains. This skill/lesson/value has carried over into other parts of my life; I find traffic is not as bad, and I can stand the bank line a little better now. When everything is said and done, I think that all of Southern California could use some more patience; you know, maybe the world.

Please see the *Reflections on the Experience* section for various team members technical lessons learned.

Future Improvements

The improvements we have planned for our ROV after the competition lie mostly in the realm of programming. We hope to further refine our control system for smooth operation in all situations. This involves automating several of the features in the current control system that the pilot must oversee manually at the moment.

One of the more interesting capabilities we ran out of time to program was the use of an inclinometer on our control circuit board. An inclinometer is a device that indicates angles measured from a level surface. We plan on using this function to automatically control the pitch of our ROV as it is being used. We would be able to tell the controller to hold the front of the robot either up or down at a given angle. This capability would add a whole new dimension of maneuverability that would enable the ROV to work in extremely close-quartered environments.

The other ability we plan on adding to our ROV that we also simply ran out of time to program is the use of a depth sensor to automatically maintain a given depth. This sensor would be linked to the control system and automatically adjust the vertical thruster when the ROV moves out of the set range. This function would take a lot of strain off of the pilot, which would allow him to put that much more focus on the task at hand.

These improvements would be highly desirable to have on the ROV for the competition, but were deemed too large an investment of our team’s mental resources for functionality that is not essential to completing our mission goals. Due to the loss of one of our programmers, we simply did not have enough time to add these features before the competition, but we fully plan on incorporating them when time allows.

Reflections on the Experience

These are reflections of several team members and what they thought about this year’s experience of designing and building the ROV. They are not named but are reflective of the team as a whole.

- Being that this is my first year on the team I am really excited to be in the competition. After all of the extra hours that I have put into this machine built of plastic, metal, and circuit boards, I am eagerly waiting to go to San Diego. I cannot wait to see the reaction of the other teams when we unveil our ROV. Seeing what the other teams have come up with will be a very interesting part of this experience. I am really excited about the competition and the possibility of entering this field after graduation. I have learned a lot from this experience, and I am not done playing in this sandbox (pool).

- In looking back on the class, I met a group of bright minds all capable of coming together as one unit and achieving the tasks and assignments asked of us in order to build the ROV that is now a force to be reckoned with. From what I see, the sky’s the limit when it comes to design improvements on the ROV. As long as LBCC students continue to push the envelope and contribute fresh new ideas to stay ahead of the curve and the competition, this class will set the bar for robotics technology.

- This year on the ROV team has been quite an experience. There has yet to be a boring day. From the first day of the fall semester I was busy designing concepts and components for the robot. I really enjoyed the collaborative effort of coming up with ideas and continually revising them, never knowing exactly what we are going to end up with. This year was also a challenging one in which I spent quite a few late nights designing and running parts on the router so we would have work for everyone to do on class days. I learned a lot about what is involved when placed in a leadership position and I am continually learning more and more as captain of the ROV team. I also got to do a few things I would never have otherwise done, such as scuba dive at the Aquarium of the Pacific and speak at SolidWorks World. The skills I have learned throughout this year also directly turned into a job for me at a lighting company doing design work. All in all, it has been an incredible year for me on the ROV team.

Figure 18 - Ian Searches for the ROV While It Sneaks Up Behind Him

- I am a veteran on this year's team. Being in a leadership position (Schedule Overlord), I had to know what was going on with all parts of this year's project. I sat in on many brainstorming sessions on most of the different systems of the ROV. This put me in a position to help many of the new team members, since this time last year I was in their shoes, being new to the team. With this year's team, we were able to get everything designed and built months ahead of time, unlike last year when we worked right up to the competition, which has been awesome because the stress has been nowhere near the same level. I enjoyed designing the gripper and being able to call part of the ROV my own, despite all the headaches I had building it. Designing the gripper more or less forced me to greatly improve my SolidWorks skills, which has given me a short-term employment opportunity.

Budget

LBCC ROV TEAM EXPENSE REPORT	**AS OF 6/1/08**		
Item Description	**Source**	**Donated**	**Expense**
Printed Circuit Boards	Advanced Circuits	$ 396.00	$ -
LED Lamps	Bivar	$ 60.00	$ -
Underwater Connectors	Burton Connectors	$ 908.00	$ -
Electronic Components	DigiKey	$ -	$ 425.56
25 Student Versions of SolidWorks	GoEngineer.com/SolidWorks	$ 2,500.00	$ -
Fiber-Optic Cable	LBCC CISCO Program	$ 48.00	$ -
Aluminum Hard Anodizing	Lubeco, Long Beach	$ 300.00	$ -
IP68 Rated Cabling & Connectors	Lumberg	$ 75.00	$ -
Acrylic Tubing	McMaster-Carr	$ -	$ 95.00
Plastic & PVC sheets	MesaWest	$ 225.00	$ -
Fiber-Optic Video Link	Optelecom-nkf	$ 5,050.00	$ -
Tether	PIER Institute	$ 550.00	$ -
Foam Float Material (some donated, some purchased)	Plastic Depot	$ 75.00	$ 135.00
Video Cameras	Remote Ocean Systems	$ 375.00	$ -
Thrusters (5) 50% donated by Seabotix	Seabotix	$ 1,937.50	$ 1,937.50
Misc Supplies	Home Depot	$ -	$ 325.00
Salvage Parts - Hydraulics & Pneumatics	LBCC	$ -	$ 100.00
Salvage Parts - Video Mixer	LBCC	$ -	$ 300.00
Salvage Parts - Video Selector Box	LBCC	$ -	$ 75.00
Salvage Video Cameras	LBCC	$ -	$ 75.68
Solenoid	LBCC	$ -	$ 35.00
O-Rings, shaft seals & sealant	McMaster-Carr	$ -	$ 35.75
Stainless Fasteners	McMaster-Carr	$ -	$ 135.00
	Total Donations	$ 12,499.50	
	Total Costs		$ 3,674.49
	Salvaged Items already Paid for.		$ 2,523.18
	Actual Cost for 2008		$ 1,151.31
	Student Fundraising on Ebay		$ 3,872.80
	Balance available		$ 2,721.49

Scheduling

All of the week-to-week task scheduling took place on the Team Forum. Tasks were identified; in many cases people were also assigned ahead of time. At the end of each work session, the progress was reviewed and plans were made for the following week. This process is reflected on the forum in the ***Scheduling*** section. Visit http://www.vikingexplorer.org/forum and click on Scheduling.

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Rigaud, Vincent. "Innovation and Operation with Robotized Underwater Systems." Journal of Field Robotics. 24.6 (2007) : 449-459. < http://www.ifremer.fr/docelec/doc/2007/publication-2806.pdf>.

Soltwedel, Thomas, Michael Klages, and Mare Nokin. "French ROV Victor 6000 First Deployment from Polarstern." *Sea Technology* Apr. 2000. <http://findarticles.com/p/articles/mi_qa5367/is_200004/ai_n21454803/pg_1>.

Additional Photos—Stereo Camera Design View

The photos below show camera views in SolidWorks to determine the best location for the stereo cameras. When the cameras were first placed in the ROV design, this exercise in SolidWorks showed that the cameras were mounted too high. They were lowered in the design documents until the desired view was achieved. In water testing, the views shown here are what the operator sees after video mixing. In the center photo, this is the mixed view of both cameras. When the object in the center becomes one object, it has reached the proper location to be picked up by the gripper.

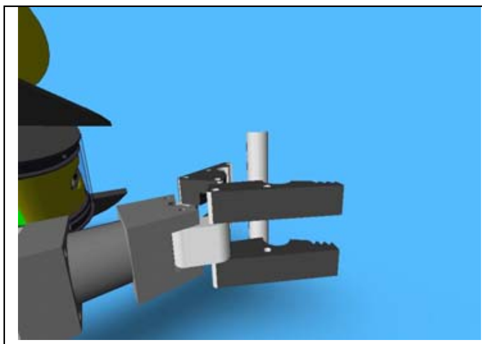

Figure 19 - View from Right Camera

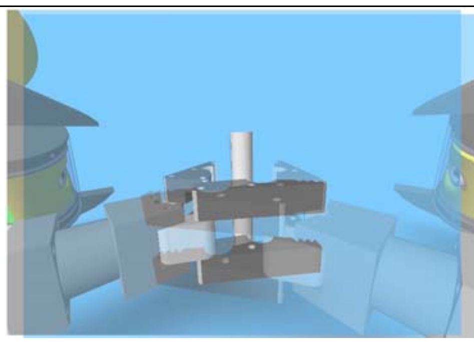

Figure 20 - View of Both Cameras After Video Mixing

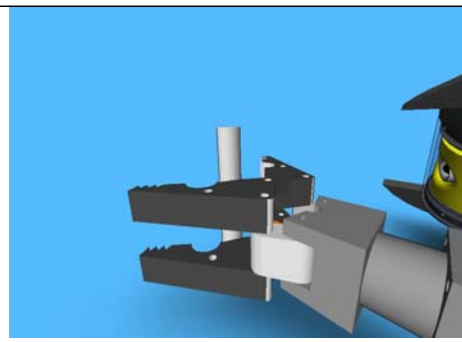

Figure 21 - View from Left Camera

Acknowledgements

The team would like to extend its thanks and appreciation to the following companies and organizations. With their continued help, we were able to create this great ROV and have tons of fun at the same time. It is through their generosity that all this became a reality.

Advanced Circuits
Bivar
Burton Connectors/Crouse Hines
GoEngineer.com/SolidWorks
Long Beach Aquarium of the Pacific
Long Beach City College Foundation
Lubeco
MesaWest
Optelecom-nkf
PIER Institute
Plastic Depot
Remote Ocean Systems
Seabotix
Standard Metal Products

Marine Advanced Technical Education Center!

Figure 22 - ROV in Action at Long Beach Aquarium of the Pacific

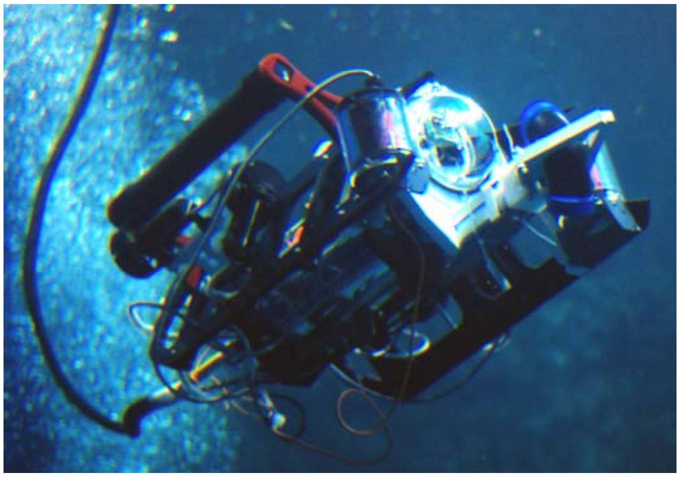

Figure 23 - ROV Demonstrating Ability to Vary Angle of Attack