Technical Report

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CAMS ROV Team

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2009 MATE International Competition
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CAMS ROV
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Abstract

An ROV (Remotely Operated Vehicle) is a mechanical and electrical device that is used to accomplish tasks in environments where it is hazardous for humans to enter. The CAMS (California Academy of Math and Science) ROV team came together in late 2006 to compete in the Southern California MATE regional competition in San Diego. The team designed and built a working ROV system consisting of an ROV, control box, and tether. The ROV was built to accomplish the 4 missions in an efficient manner. The frame was made from PVC and had motors to move it through the water. It is connected to the tether which links the ROV to the control box. The control box acts as an interface between the operator and the vehicle.

Introduction

ROVs (Remotely Operated Vehicles) are mechanical devices that are used to aid people in difficult tasks, often in areas where it is hard for people to go. The first ROV, Poodle, was developed by Demitri Rebicoff in 1953 and have since been used in military operations, offshore oil missions, and law enforcement. The MATE institute along with the MTS formed a competition to increase ocean career opportunities. The CAMS ROV team runs both an Explorer and Ranger Class vehicle. The 2007-08 season is our second year as a team, and our first competing in the explorer class. In addition to competition, the team showcases their efforts at school functions, and this summer will be displaying our ROV at the Cabrillo Aquarium. This year's 6 person team highly anticipates the competition in June, and is looking forward to meeting teams from around the world.

Design Rationale

Structure

The frame of the ROV is made from PVC (Poly Vinyl Chloride). PVC was used because it is cheap, close to neutrally buoyant, easy to work with, and structurally sound. The frame is roughly 24 inches (61 cm) long by 14 inches (36 cm) wide by 14 inches (36 cm) tall. There is a cutout in the back to allow for the transfer skirt to mate with the escape hatch easier. The motors stick out on each side to allow the ROV to turn easier. The ROV is of moderate size to allow it to manipulate the payloads without being affected as much as it would if it was smaller.

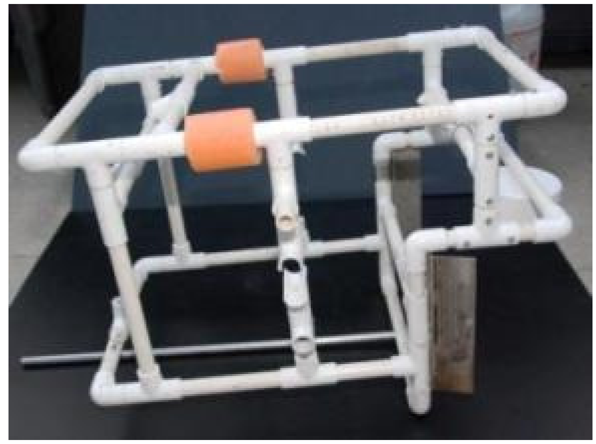


Fig. 1: Frame of the ROV

Buoyancy

The ROV is neutrally buoyant so that the user does not have to worry about the vehicle drifting vertically. The ROV uses foam floats to provide enough buoyant force to counteract the weight of the vehicle. The volume of the vehicle is 8000 cubic centimeters and the weight is 8 kilograms. There is a 1 kg weight at the base of the ROV to maintain stability, ensuring the vehicle will not roll.

Propulsion

The ROV uses eight Rule 1100 GPH bilge pump motors to propel it through the water. The bilge pumps have been modified and refitted with propellers instead of impellors. This was done with and adaptor that fits onto the bilge pumps output shaft and allows the pump to push water in both directions rather than just one. Large PVC couplers were placed around the propeller to act as prop guards.

Fig. 2: Motor assembly

Fig. 3: Comparison of the new and old motors

Payloads

To turn the hand wheel two pieces of ½" aluminum tubing about 6 inches (15cm) long are pointed straight down. The ROV will spin in place with the aluminum rods in the hand wheel. To pick up the ELSS transfer pods three more rods of aluminum tubing will be pointing straight forward. The ROV will move forward when the tubes are in line with the U-bolts on the transfer pods.

To land on the escape hatch, the ROV takes advantage of the cutout in the back of its frame by backing onto the hatch. This gets the ROV roughly the correct placement to land on the hatch from one direction. To line up the other direction two pieces of a recycled aluminum ladder are attached to the sides of the cutout to guide the ROV onto the hatch from the other direction. The transfer skirt itself is a 4 inch (10 cm) PVC end cap.

The third mission task requires the ROV to deliver an airline to the side of a submarines conning tower. The ROV uses two aluminum hooks and a simple gripping claw to manipulate the hatch airline, and valve. The claw is composed of a car-door lock linear actuator motor, 1.27cm PVC tubing, a .5 cm aluminum rod, and two plastic gripping attachments. This is attached to the front of the ROV. The claw transports the airline down to the submarine and positions it into the conning tower. It then opens and closes the valve by gripping the handle. The two hooks allow the ROV to open and close the door by simply strafing to the right or left.

Sensors

Fig. 3: A camera prior to waterproofing

Our ROV has several different sensors on it. The most important sensor is what allows us to see, cameras. We used two different styles of cameras. One camera views in black and white, has optional infrared lights to allow us to see when it is dark and is already waterproofed. The other style is typically mounted on the back of a car to provide sight when in reverse. These cameras have infrared lights that turn on when there is not much light and automatically adjust themselves. Because these cameras are not meant to go underwater, we had to waterproof them ourselves.

Fig. 4: A camera after waterproofing

Tether

Our tether has 16 conductors of varying gauges. Six of the conductors are for the motors (two for the left motor, two for the right motor, and two for the up and down motors), six are for the camera video (two wires for each camera), two supply power to the cameras, and there are two extras for any changes that may occur. The conductors for the motors are of a much thicker gauge than the conductors for the cameras. In the tether there is also a tube that air will be pumped through into the ROV to provide extra buoyancy. All of the wires and the tube are taped together and enclosed in a synthetic netting material that makes sure that the tether stays neat and in one piece.

Control System

Fig. 5: Microcontroller

The 2009 ROV control system that we are to be designing is centered on the Arduino microcontroller platform. An Arduino is an Atmega168 with a bootloader allowing for ease of uploading programs without an external programmer. This controller will be connected to various sensors and motor controllers. One type of sensor that we will be using is the thermistor. Thermistors will be used to measure the temperature of all of our high current motor controllers. This will allow the control system to automatically shut down motor controllers if they are getting too hot, preventing against possible damage. Our control system will utilize motor controllers from Pololu. Each controller is capable of driving two individual motor channels, each capable of supply 20 amps at 12v. The controls also have current limiting capabilities, incase we need to decrease current draw to fit the 40 amp budget.

Besides sensors and motor controllers, a video multiplexer will be hooked up to our Arduino microcontroller. This chip will allow us to control which camera input goes to what quadrant on our monitors. This would allow for quick clustering of data for performing tasks. Say if the driving was about to open a latch, they few cameras feeds useful for that operation would be shown together at the same time. This would prevent the driver from searching between monitors to get the data that he or she wants.

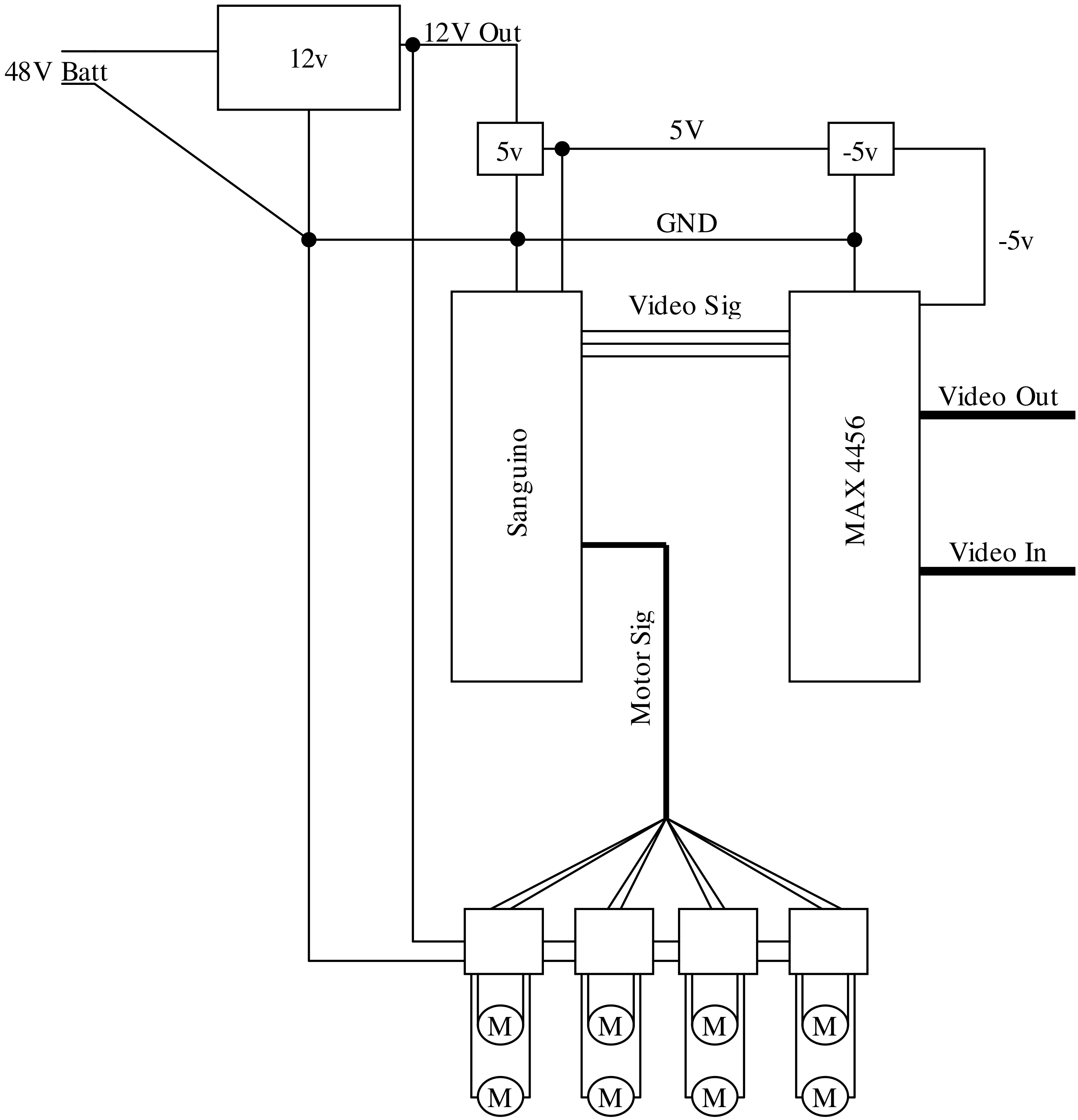
Fig. 6: XBOX controller

To collect user input from joysticks will be a program running on a laptop. The program will be written in Java, and will allow the user to easily view the status of the robot, as well as any and all data from sensors. The main user input will be provided via an XBOX 360 wired controller. This controller has enough joysticks and buttons to perform all the tasks needed by the driver.

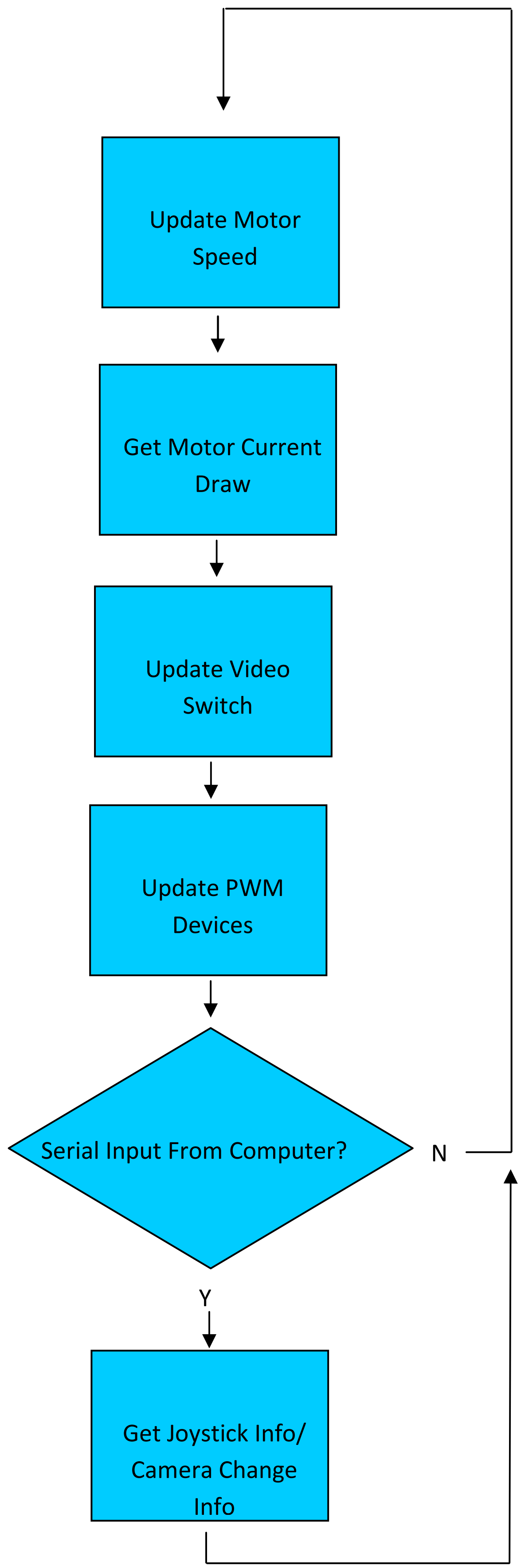
Fig. 7: Java

The entire system will be built upon 12volts. Since we are only supplied 48volts by the competition, we need to regulate this down into something that we can use. To do this, we need high current voltage regulators. The output voltage will be 12volts, and the max current 40amps. This is 480watts of electricity that the voltage regulator needs to output.

Electrical Schematic



Software Block Diagram



Expenses

This year's budget was significantly harder to manage due to decreases in funding from our school. However, as a team we were able to overcome the hardships of this recession by advertising our team across the school, community, and nation to gain whatever funding possible. As a team were able to raise about $2550 from various sources:

1. PTSO: $600
2. Northrop Grumman Partnership: $1200
3. Norris Foundation: $750

Our expenditures on the ROV were focused entirely around the electrical system. Using funding from precious years we were able to implement a very adaptive and reusable system that will be beneficial for years to come. This system is designed to maximize driver convenience. The actual ROV(including cameras) cost about 450 dollars to construct while the electrical system will cost about $1209.

Travel expenses, not included in this budget, will have to come almost entirely as out of pocket expenses for the team members.

CAMS ROV Expense Sheet 2009

Date: 5/26/09

Category	Item	Price	Quantity	Total Cost	Purchased From
Frame					
Connectors	1/2" x 10' Plain End PVC Pipe SCH-40	1.14	3	3.42	Home Depot
Connectors	1/2" Tee 10 Pack SCH-40	2.61	3	7.83	Home Depot
Connectors	1/2" Slip 90 Degree Elbow 10 Pack SCH-40	1.98	2	3.96	Home Depot
Hardware	Pro-Twist 10 x 3/4 Self Drilling 100pkg.	9.95	1	9.95	Home Depot
Mounting	4"-6" Diam. Stainless Steel Hose Clamp (In Stock)	0	8	0.00	Home Depot
Frame Total				25.16	
Payloads					
Claw					
Articulation	Omega DS-1 Door Lock Actuator	9.95	1	9.95	Amazon.com
Gripper	Robotic Claw Grip Toy	3.99	1	3.99	handhelditems.com
Transfer Skirt					
	4" White PVC Drain Cap	1.67	1	1.67	Home Depot
Supply Pods					

Structure	1/2" Aluminum Tubing	Donated	5'	0.00	N/A
Payloads Total				15.61	
Motors					
Forward	1100 GPH Bilge Pump	22	4	88.00	Great Lake Skipper
Strafing	1100 GPH Bilge Pump	22	2	44.00	Great Lake Skipper
Up/Down	1100 GPH Bilge Pump	22	2	44.00	Great Lake Skipper
Motors Total				176.00	
Sensors					
Cameras	Underwater Camera (3 In stock)	119.99	5	239.98	Harbor Frieght
Monitor	B&W Monitor (in Stock)		3	0.00	Harbor Frieght
Sensors Total				239.98	
Electrical System					
Connectors	Break Away Male Headers	$2.50	4	10.00	Sparkfun.com
Connectors	Break Away Female Headers	$1.50	2	3.00	Sparkfun.com
Connectors	Wire (Black)	$2.50	1	2.50	Sparkfun.com
Connectors	Wire (Brown)	$2.50	1	2.50	Sparkfun.com
Connectors	Wire (Gray)	$2.50	1	2.50	Sparkfun.com
Connectors	Wire (Red)	$2.50	1	2.50	Sparkfun.com
Connectors	Wire (White)	$2.50	1	2.50	Sparkfun.com
Connectors	Wire (Yellow)	$2.50	1	2.50	Sparkfun.com
Connectors	BNC to RCA	$0.95	8	7.60	discount-security-cameras.net
Electronic Control	Sanguino	$13.00	1	13.00	wulfden.org
Electronic Control	Dual Motor Controllers	$74.95	4	299.80	Pololu
Electronic Control	Various Resistors	$12.99	2	25.98	Radio Shack
Electronic Control	1000 microfarad Capacitor	$1.59	1	1.59	Radio Shack
Electronic Control	Voltage Regulator 5V	$1.59	2	3.18	Radio Shack
Electronic Control	.01 microfarad Capacitor	$0.15	24	3.60	Parallax
Electronic Control	USB to Serial	$4.50	1	4.50	Parallax
Electronic	32K EEPROM	$1.99	1	1.99	Parallax

Control					
Electronic Control	Pushbuttons	$0.35	5	1.75	Sparkfun.com
Electronic Control	Mini USB Cable	$3.95	1	3.95	Sparkfun.com
Electronic Control	USB Connector	$1.95	1	1.95	Sparkfun.com
Electronic Control	RCA Connectors	$4.95	10	49.50	Parallax
Electronic Control	Xbox 360 Wired Controller	$39.99	1	39.99	Microsoft
Electronic Control	470 Ohm Resistors	$0.99	10	9.90	Radio Shack
Electronic Control	LED Holders	$1.49	3	4.47	Radio Shack
Mounting	Standoffs	$2.99	4	11.96	Radio Shack
Power Management	Coaxial Barrel Plugs	$2.99	3	8.97	Radio Shack
Power Management	Coaxial Barrel Jacks	$2.99	5	14.95	Radio Shack
Video	Current Sensor	$64.99	1	64.99	robotshop.ca
Video	Video Multiplexer	$182.85	1	182.85	surveillance_video
Video	Video Cables	$3.00	10	30.00	graycables.com
Power	Module Power 48V/12V 600W	395.01	1	395.01	DigiKey
Power	18 Gauge Paired Speaker Wire 250'	99.95	2	199.90	Home Depot
Power	8 Gauge Power Wire 5'	10.32	1	10.32	Torrance Electronics
Electrical Total				1419.70	

ROV Total	**1876.45**

Challenges

Compared to many other competing groups, the CAMS ROV Explorer Team possesses a modest budget. In fact, we consider funding to a pressing challenge. As a result from our meek budget, CAMS ROV team has to be frugal. We do not have access to the best materials and are forced to reuse old motors and cameras year after year. Furthermore, our low budget increases the cost of traveling on our members. To go the Massachusetts championship, each member would have to spend nearly 600 dollars. This creates a new problem. Many crucial members of the team will not be going to the finals because they are unable to afford the expense.

This year, CAMS ROV looked to three sources for financial support: the CAMS PTSO, the CAMS Robotics Team and the Digi-Key Electronics Corporation. Our primary source of support is the CAMS PTSO. Every year, in order to secure funding, CAMS ROV gives a detailed presentation to the PTSO and is subject to hard questioning. As of 2008, CAMS ROV is a subsidiary team belonging to CAMS Robotics, a large and well-funded organization. In fact, the club consists of nearly 120 members and has a budget in the tens of thousands. Unfortunately, not a great deal of grant trickled down from CAMS Robotics to CAMS ROV. We invested a great deal of time into attaining sponsorship from the Digi-Key Corporation. Moreover, we were looking to receive a relatively expensive AC DC power converter from them. Much to our dismay, nothing came from the long process.

The team understood that funding would be hard to find, especially in today's economy; therefore, we looked to more sources for sponsorship than we ever have before. Although not all of these sources made large contributions, the CAMS ROV team made nearly $3,000, enough to build and compete (if the team stays prudent).

Troubleshooting Techniques

Much of the initial troubleshooting had to do with the tether. The correct wire had to be connected with the correct wire at the surface and the correct wire on the ROV. This problem was solved with a continuity test from a multi-meter.

During the use of our ROV if any of the motors stopped working the fuses were checked and the motor was checked to see if anything tangled itself on the propeller.

The only other major technical difficulty was in the buoyancy. This was a simple matter of adding or removing floats, or moving their position on the ROV.

Lessons Learned

This year, the CAMS ROV Explorer Team learned a lesson in preparedness. We overlooked a particular rule concerning power distribution when we entered the championship qualifier. Once we got to the competition, we realized that we could not use our own power source, a 12-volt battery. Instead, we had to use the competition provided 48-volt power source. Unfortunately due to the price of 48 volt components, our 12v volt system was entirely incompatible. Nonetheless, despite this incredible disadvantage, the Explorer team prevailed, once again using ingenuity to accomplish what seemed impossible. Using an idea as simple as Ohm's law, we were able to track down a 14V Zener diode and six 3.5Ohm resistors to make a power regulator. Many of the mentors we talked to said would not work, but, as we had no other options, we continued on. Doing the math in our heads, we ran multiple resistors in series to reduce current, and use a vice grip as a heatsinc for the diode. Within 3 hours we rewired our motors in series rather than parallel and constructed a voltage regulator from scratch. Approaching the control tent, we knew that everything would work in theory, however nothing had been tested. Finally, to our good fortune, the regulator powered our single TV and the motors handled the over voltage for just enough time to complete the qualifying task. At the end of the day we were all exhausted, but very proud of our unrealistic feat. This issue showed the team how unrehearsed and ill-equipped it can be. The stressfulness of that day has motivated the team to check every detail of the competition in the future.

Reflections

By Neil Froschauer

I am a relatively new member on the team. For my contributions in 2008 I was awarded honorary member status. However, I am now a full pledged member.

Initially, I considered myself too busy to join the CAMS ROV Explorer Team; for instance, I am a team leader in CAMS Robotics, the CAMS Advanced Research Project Agency and CAMS Rocket Team. Before I joined, I offered my home and pool up to the team so they could test their ROV. Also, I did this to see what the team was all about. I found that CAMS ROV is far different than any other club or team I belonged to. Rockets operate in the sky and CAMS robots operate on the ground. Water adds such a different dynamic to engineering processes. After the testing, I knew I wanted join no matter how busy my schedule was.

CAMS ROV has reinforced my decision to enter the aerospace field. Although that sounds to be counter intuitive, aerospace, specifically aeronautical engineering is extremely similar to naval architecture. The main difference is the fluid involved. I loved designing the frames, chassis which had to be hydrodynamic. Furthermore, I learned more about electrical engineering in ROV than in any other club. In fact, last year I helped Max Friefeld wire the entire control system that we eventually placed in an old computer frame. CAMS ROV has introduced me to a variety of new subjects and has reaffirmed my career choice.

By Max Friefeld

This is my second year on the CAMS Explorer ROV team. When I joined last year, I was very unfamiliar with the concept of an underwater remotely operated vehicle. However, with the help of my teammates, I was able to take responsibility for the electrical and pneumatic systems that helped our team place third in the Explorer Class. Even so, I expanded my knowledge of ROV technology on all fronts, learning about structure, vision, control, and even examples of real life ROV’s.

This year, as a returning member, I am handling more responsibility by keeping track to the teams finances and official Bill of Materials. As one of the team’s financial officers I not only get to build the ROV, but I can also use my accumulative knowledge to make smart purchases for the team.

One of the most important lessons I learned this year was how to work on a project as expansive and long term as the MATE ROV competition, while keeping expenditures to a minimum. I feel that the efforts our team makes to maintain as small of a budget as we do (under $2000), make CAMS ROV an incredibly unique team. The level of ingenuity that goes into our ROV allows our team to compete against college teams who have about ten times the funding and win. As a graduating senior, I will always be proud of the things I have done learned on this team. Whether I have learned integrate a control system into an old computer case, or give back to the community at the newly annual "Bots by the Bay" showcase our team participates in, I will always remember the two summers I spent on the CAMS ROV team.

By John Arakaki

My name is John Arakaki and I am a junior attending the California Academy of Mathematics and Science. This will be my fifth year competing in the MATE ROV competition and I started in 7th grade with my middle school. I have been competing in the Explorer division for two years and I continue to learn and gain experience. This year, I have worked on designing the RORV to be as simple and cost effective as possible. One of the things that set our team apart is that we operate on a very conservative budget. We try to make our vehicles out of simple materials that are easy and cheap to buy. The most important skill I have developed over the years is being able to work well with others. Our team is always relatively small and I make sure everyone works efficiently.

Future Improvements

The 2008-2009 CAMS RORV is able to accomplish every task in an efficient manner. Over the past two years of competition the team has used 12V motors because of financial constraints. In the future, the team would like to try using 24V motors so that the RORV would be able to move through the water faster. The team is also interested in using a different platform than PVC for the structure of our vehicle. The school has recently purchased two mills and two lathes, and the team hopes to be able to design and machined parts for the vehicles.

Submarine Rescue System

The NATO Submarine Rescue System (NSRS) is being developed and built to replace the United Kingdom's LR5 Submersible Submarine Rescue Vessel (SRV) and Scorpio 45 (an ROV). In 2004, the United Kingdom, France, and Norway placed a contract with Rolls-Royce to build the NRRS, which is expected to be completed by the mid 2009. In the case of a submarine distress call, the NSRS Submarine Rescue Unit will be deployed by road or air to the nearest port for embarkation on a mother ship. A free swimming vehicle will launched, mating with the escape hatches of the submarine on the seabed. Then, the crew would be transferred in batches to the surface. Currently, NSRS has been tested several times on the coasts of Norway and other countries along the Atlantic Ocean.

Fig. 8: United Kingdom's current LR5 submersible in the water

©Navy Technology

Fig. 9: NATO Submarine Rescue System
©Crown 2009

The NATO Submarine Rescue System consists of four sub-systems: Intervention Remotely Operated Vehicle (IROV), Submarine Rescue Vehicle (SRV), Portable Launch and Recovery System (PLARS), and Transfer Under Pressure (TUP) System. The IROV is compact mobile that can operate in depths up to 1000 meters and comprises of the vehicle, the launch and recovery system and the control module. The SRV, finished in 2007 and currently undergoing testing, is a manned submersible that was developed from older vehicles such as LR5. It can operate at depths between 20 – 610 meters and has battery life of 96 hours. The SRV is operated by three men, including a pilot, an observer, and a rescue chamber operator. The PLARS is for launching and retrieving the SRV and comprises of an SRV catcher and stabilization system. Lastly, the TUP system is a fully autonomous system that provides decompression and medical support. It is comprised of a reception chamber, two decompression chambers and a central control position.

The missions and goals of the CAMS ROV team are similar to the goals of the developers and creators of the NRRS. We want to complete a successful mission within a reasonable time frame.

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Acknowledgements

The ROV team has accomplished a lot over the past three months. The team could not have come so far without the support of friends and family. With this in mind, the CAMS ROV team would like to thank the following:

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- The Marine Advanced Technology Education (MATE) Center
- The CAMS Parent Teacher Student Organization (PTSO) for giving the team funds to build and complete the ROV
- Northrop Grumman for giving us a Partner in Education grant
- The Norris Foundation for giving us monetary funds
- Mr. Yocum for providing knowledge on building materials
- Thank you to Mrs. Cathy Arakaki for donating items necessary to complete the construction of the tasks.
- And lastly, all of the parents of the ROV team members for their support and investment.