Technical Report
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CAMS ROV Team
California Academy of Mathematics and Science
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2008 MATE International Competition
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CAMS ROV
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I. Abstract

An ROV (Remotely Operated Vehicle) is a mechanical 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 three 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. The team was able to save money by using inexpensive parts for the system and was able to raise money by presenting their work to different organizations. They tried to keep the cost as low as possible and were able to stay within a reasonable budget of $2000. They are now prepared to compete in the international competition in San Diego, California.

II. 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.

III. Design Rationale

1. Structure

The frame of our ROV is composed of 1.27cm PVC (Polyvinyl Chloride) pipe and couplings. The ROV has a simple box frame in order to maintain symmetry and balance. This is a simplistic design that is designed for compatibility. The dimensions of the ROV are 54cm x 32cm x 20cm keeping the frame very small and compact. This allows for increased maneuverability due to the decreased surface area. The ROV is very compact, having all parts of the ROV to be very close to the frame. The ROV was designed for balance and maneuverability by keeping the weight to a minimum and having the motors in line with the center of gravity.

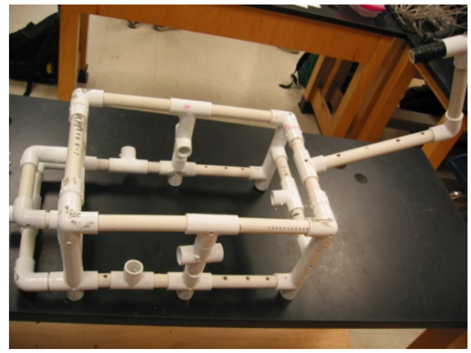


Fig. 3.1 The frame of the ROV

2. Motors

The ROV has four motors for maneuvering, two for forward/reverse and yaw (turning), and two for vertical movement. The motors are 5.678 m^3/hour 12V DC bilge pumps. They each supply 13.5 N of thrust. A 15.24 cm diameter three-bladed plastic airplane propeller is attached to a custom adaptor which attaches to the motor shaft.

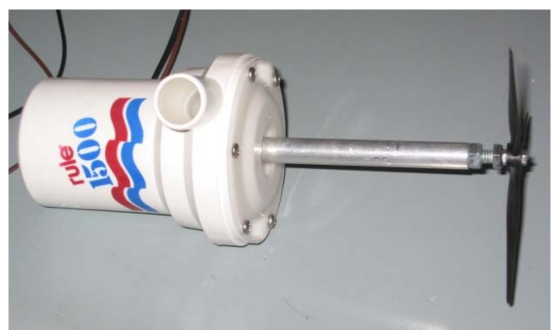


Fig. 3.2 A complete motor assembly with a custom adaptor and a propeller

3. Buoyancy

Our buoyancy system is comprised of foam floats securely attached to the top of our ROV and four empty 2-liter soda bottles, with a volume of approximately 2000 cm each, attached inside the frame of our ROV. The foam floats are mounted at the top of the ROV to provide stability by making the top weigh less than the bottom in the water, effectively lowering the center of gravity. Once the ROV has completed all that is necessary at the bottom of the pool, air will be pumped into the soda bottles to increase buoyancy and quickly bring the ROV to the surface.

4. Payload Tools

The ROV uses three major payload tools. For the OBS and lava retrieval, the ROV will use two hooks to secure the top of the OBS to the bottom of the ROV. The ROV will then use the pneumatic buoyancy system in order to raise the entire package to the surface. The personnel on deck will retrieve three lava pieces manually, and then let the OBS float on the surface without the ROV.

5. Sensors

Fig 3.3 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. The second most important sensor is the temperature sensor. To measure temperature, we used a 10K Ω thermistor. The specific thermistor that we used has a negative temperature coefficient, meaning that as temperature increases, decreases. To read the thermistor, we originally planned to use a Basic Stamp microcontroller, but after much testing, this proved too difficult. This is because the microcontroller does not directly measure resistance, but measures the amount of time it takes for a capacitor to discharge through the thermistor. We decided that it would be best to simply use an ohmmeter to measure resistance and an ohm to temperature conversion chart to ultimately measure temperature.

Fig 3.4 A camera after waterproofing

Fig. 3.5 The thermistor after waterproofing

6. 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.

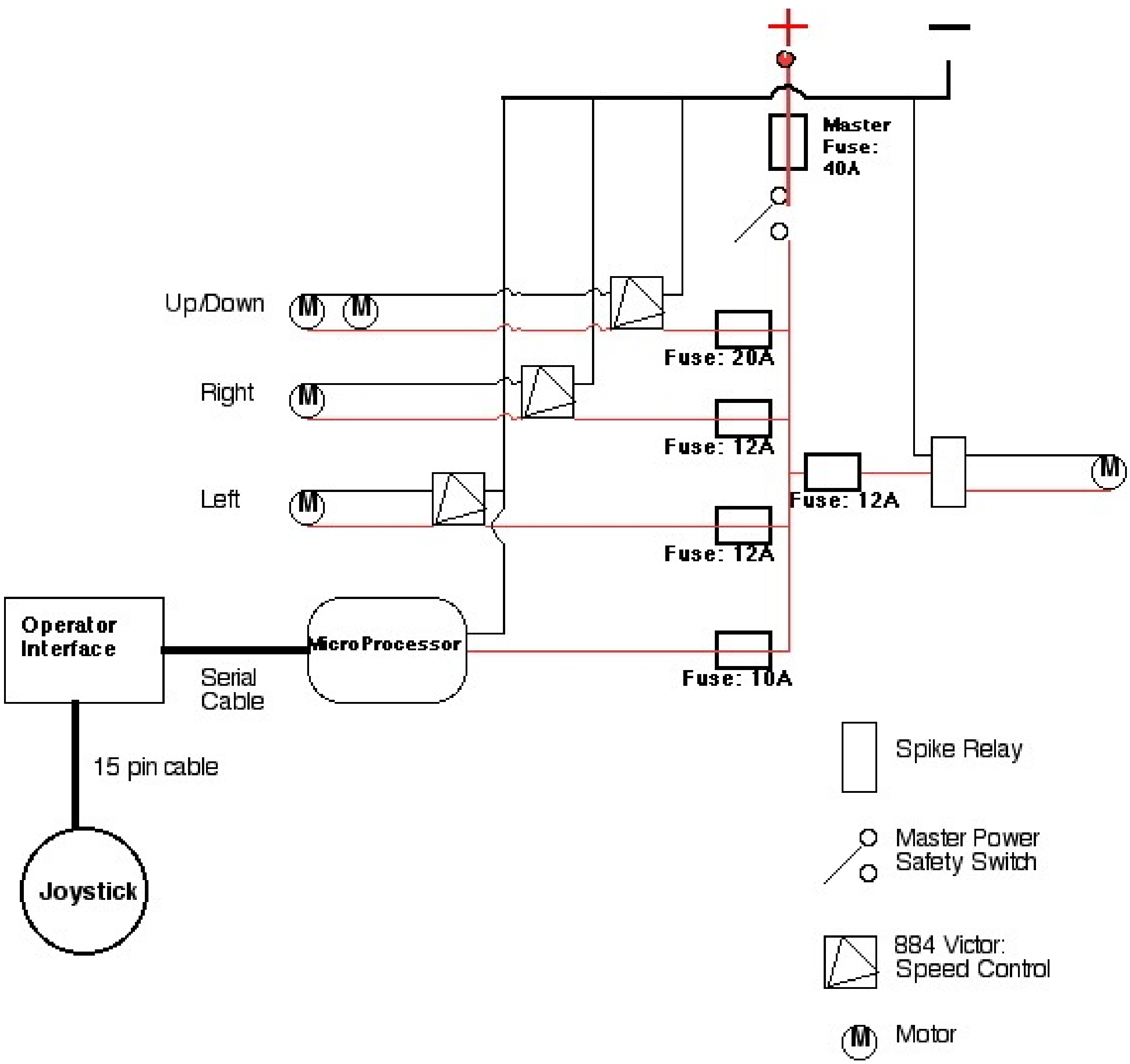
7. Control System

Our ROV control system is a very complex system. The heart of this system is the Innovation First FRC Robot Controller. This controller has digital and analog IO, which are used to control Victors (motor control modules) and Spikes (H-Bridges). We are using motor control modules this year so we can vary the speed of the robot. Last year, we just used a basic full forward, full reverse system which was hard to control. On the contrary, this year's system will allow the driver to maneuver the robot with ease.

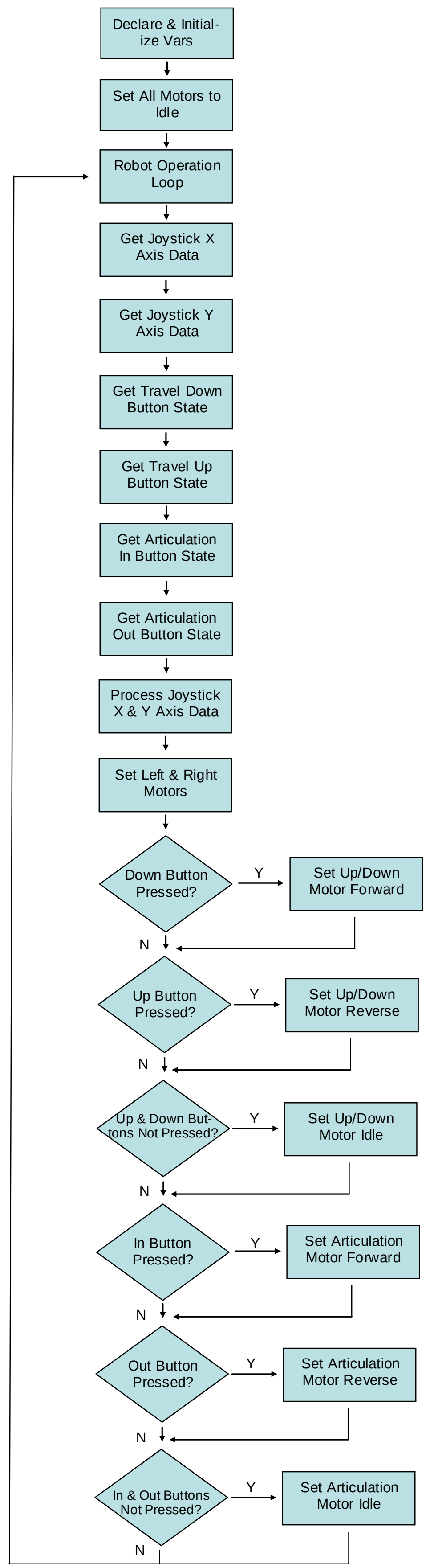
Fig 3.6 Innovation First Control System parts

To gather user input, we are using the Innovation First FRC Operator Interface. This module can gather data from up to four analog joysticks, and send it to the Robot Controller. Though we are only using one joystick this year, the three extra ports allow for expansion in upcoming years. On the controller that we are using, the x-axis controls turning, the y-axis controls moving forward/back, and the two buttons beside the directional pad control moving up/down.

IV. Electrical Schematic



V. Software Block Diagram



VI. Challenges

The greatest challenge during the ROV design and build process was determining how to cause the OBS to surface. The initial plan was to tilt the OBS with small PVC "legs" and let the lava pieces slide off while the OBS surfaced. The ROV would then use a sweeping device, utilizing a motor and small "fingers" in order to sweep the lava pieces into a basket. We then realized that the lava pieces may not slide off of the OBS easily and the sweeping device would cause the ROV to move unfavorably. The team then decided to lift the entire OBS with the additional weight of the lava pieces. The team calculated the buoyant force needed to surface would be approximately 8000 cm^3, approximately four 2 liter bottles. The ROV is now able to efficiently complete the task in a favorable amount of time.

VII. Expenses

	Item	Source	Quantity	Value
Structure				
	PVC Fittings - Tees	Home Depot	15	$4.95
	PVC Fitting - 90 Degree Elbows	Home Depot	8	$4.56
	PVC Fittings - Four way	Home Depot	6	$7.32
	PVC Fitting - 1/2 inch Threaded Sprinkler Elbows	Home Depot	4	$4.72
	1/2 inch PVC Pipe	Home Depot	4.6 m	$2.72
	Self-Tapping Screws	Home Depot	100	$57.50
			Subtotal	$81.77
Control System				
	40 AMP Glass Fuse Pack	Donated	1	$6.99
	5 AMP Automotive Blade 25 pack	Pepboys Auto	1	$6.49
	Inline Fuse Holder	Donated	1	$4.99
	Operator Interface Control Board	Innovation First Robotics (IFI)	1	$349.95
	Robot Controller Board	Innovation First Robotics (IFI)	1	$449.95
	6 ft DB9 Cable Female-Female	Innovation First Robotics (IFI)	1	$7.49
	H-Bridge Rely Module, 20A	Innovation First Robotics (IFI)	1	$34.95
	12 Volt Vicyor 884 w/ 12 Volt Fan	Innovation First Robotics (IFI)	3	$334.85

	ATC Fuse Block	Innovation First Robotics (IFI)	1	$17.03
	Auto-Reset Fuse 20A	Innovation First Robotics (IFI)	5	$24.75
	24 Inch PWM Cable	Innovation First Robotics (IFI)	4	$19.96
	Joystick	Innovation First Robotics (IFI)	1	$14.99
	5 ft Red 14 Gauge Wire	Innovation First Robotics (IFI)	1.52 m	$1.00
	5 ft Black 14 Gauge Wire	Innovation First Robotics (IFI)	1.52 m	$1.00
			Subtotal	$1,274.39
Tether				
	16 AWG Speaker Wire	Donated	50 m	$17.98
	20 AWG Speaker Wire	Donated	17 m	
	Cable Tie 100x Package	Harbor Freight	1	$7.95
	Foam Insulator	Donated	3.7 m	$5.95
			Subtotal	$31.88
Sensors				
	Diesel Audio NS-CAM-1 Cameras	Fry's Electronics	3	$150.00
	Underwater Black/White Camera and Moniter	Harbor Freight	3	$300.00
	Ohmmeter	Harbor Freight	1	$9.95
	Thermistor	Donated	13	$25.35
			Subtotal	$485.30
Payloads				
	eye hooks	Home Depot	2	3.58
	1/2 in PVC Pipes	Home Depot	1 m	$1.81
			Subtotal	$5.39
Propulsion				
	Rule 1500 GPH Bilge Pump	WaterPumpSupply.Com	5	$327.00
	Master Airscrew 3-Blade Propeller	Hobby People	5	$20.95
	Propeller Adaptors	Donated	5	$15.00
	Locktite	Donated	1	$4.00
	Hose Clamps	Harbor Freight	8	$3.52
			Subtotal	$370.47
Buoyancy System				
	Foam from motor packaging	WaterPumpSupply.Com	N/A	$0.00
	Bike pump	Donated	1	$11.99
	Empty 2 Liter Soda Bottle	Donated	1	$0.00
			Subtotal	$11.99
Construction of Task				

	3 inch ABS Pipe	Donated	80 cm	$4.16
	2 inch PVC Pipe	Donated	10 cm	$0.17
	1/2 inch PVC Pipes	Donated	3.5 m	$1.99
	PVC Fitting - 1/2 inch Threaded Sprinkler Elbows	Donated	4	$4.72
	3/4-inch MHT - 1/2 inch PVC Hose Fitting	Donated	1	$1.47
	3 inch ABS End Cap	Donated	3	$19.36
	3 inch PVC End Covers	Donated	4	$1.20
	PVC Fitting - 45 Degree Elbows	Donated	2	$1.14
	PVC Fitting - 90 Degree Elbows	Donated	2	$1.14
	PVC Fitting - Tees	Donated	4	$1.32
	PVC Fitting - 1/2 inch Couplings	Donated	1	$0.16
	2 inch to 3 inch ABC Pipe Increaser	Donated	1	$1.48
	1/8 inch ABC Sheet Base (50 cm x50 cm)	Donated	1	$9.99
	6 Quarts Drain Pan	Donated	1	$3.49
	Profinish Quikrete 50 lbs Concrete Mix	Donated	1	$5.97
	2 pound soft dive weights	Donated	3	$32.45
			Subtotal	$90.21
Travel Expenses				
	Housing and Food	MATE	8	$1,400
	Transportation	Donated	N/A	$0.00
			Subtotal	$1,400
			Total Cost of Travel :	$1,400
			Total Cost of ROV system :	$2,315
			Grand Total:	$3,715

VIII. Troubleshooting

At first, most of the troubleshooting involved tweaking the code to work perfectly. The ROV is not perfectly weighted, so one side needs a slight bit more power to move the ROV in a straight line. Many of the problems that we encountered were not real problems at all, the connectors were simply unplugged or the control system was not attached to the battery. These quickly became the first things we checked when a motor did not turn on.

IX. Lessons Learned

The ROV team has learned a lot while working on this project. In particular we learned to plan before building, if there was no structured plan, then much time and many ideas would be wasted because they could not work with each other. Another important skill that we learned was communicating ideas to each other. If we could not explain our ideas then we could not get suggestions on how to improve the idea or any other form of feedback.

X. Reflections

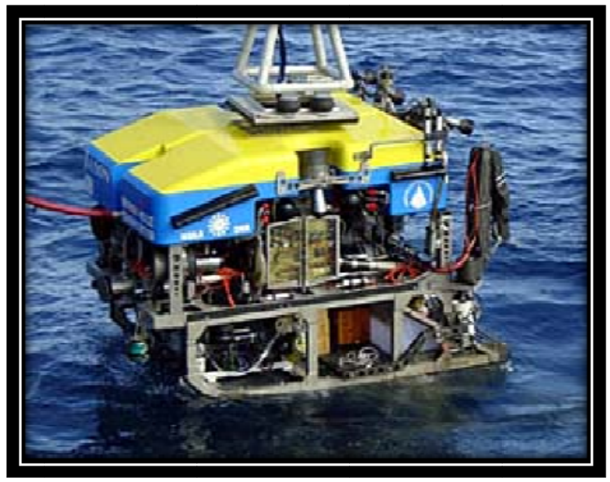
Designing and building the ROV was an excellent experience for the CAMS ROV team. We all learned much about how ROVs work and what they can do. The competition provides excellent hands on experience while still providing a fun atmosphere. We will definitely compete again next year and encourage others to join into the competition.

XI. Future Improvements

We hope to improve our ROV in the future by making it out of a stronger material to eliminate any chance of the frame being damaged. We would also like to use stronger motors to increase the speed at which our ROV can move through the water.

XII. ROV Research of Mid-ocean Ridges

Since the discovery of hydrothermal vents by oceanographers 25 years ago, scientists have been exploring the vents for signs of unknown animals and microbes. With newly developed technology, scientists can now explore the ocean bottom to search for hydrothermal vents and vent life using underwater submergible vehicles, such as remotely operated vehicles (ROVs). Dive and Discover is a research team of scientists, biologists, and chemists that conduct various research projects that explore the ocean.
In 2001, Dive and Discover's Expedition 4 was the first US research expedition launched to explore hydrothermal vents in the Indian Ocean. Scientists boarded the RV Knorr, a research vessel owned by Woods Hole Oceanographic Institution (WHOI), to search for new hydrothermal vent animals and ancient bacteria. While the scientists analyzed data samples, technicians from WHOI's Deep Submergence Operations Group operated the deep-sea vehicles, including the Argo II mapping system, the DSL-120 sonar and ROV Jason ("Dive and Discover: Expedition 4"). WHOI Engineers in the Deep Submergence Laboratory designed ROV Jason and its sidekick Medea. While ROV Jason roams and collects data from the ocean floor, Medea acts like a weight between Jason and the ship, allowing ROV Jason to explore without being affected by motion of the surface's ship ("Remotely Operated Vehicle Jason/Medea").
In Expedition 4, ROV Jason was able to collect a total of 350 pounds of sulfide, over 600 different types of water samples from the vents, bacteria samples, and bits of tissue from mussels, snails and shrimp. This allowed scientists to find missing links between the genetic makeup of the fauna in the Atlantic and Pacific Ocean ("Dive and Discover: Expedition 4").
Like the ROV Jason, the CAMS ROV will be collecting samples from the ocean floor—lava samples that will determine how the old the volcanic eruption is. The CAMS



ROV Jason is launched into the Indian Ocean.

Picture from:

An image of a diffuse vent located at the base of a discovered chimney take by ROV Jason.
Picture from:
http://www.divediscover.whoi.edu/expeditio n4/daily/ss010420/6.html

ROV Jason collecting shrimp samples.
Picture from:
http://www.divediscover.whoi.edu/expeditio n4/dailv/ss010424/11.html

ROV also has sensors, one of which will take the temperature of the hydrothermal vent.

Works Cited

"Dive and Discover: Central Indian Ridge." Dive and Discover. 2001. 31 May 2008 <http://divediscover.whoi.edu/expedition4/index.html>.

“Remotely Operated Vehicle Jason/Medea.” Woods Hole Oceanographic Institution. 27 May 2008. 31 May 2008 http://www.whoi.edu/page.do?pid=8423>.

XIII. 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:

Mr. Jett, our mentor, for advising the team.

The Marine Advanced Technology Education (MATE) Center

The team would like to thank the CAMS Parent Teacher Student Organization (PTSO) for giving the team funds to build and complete the ROV.

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.