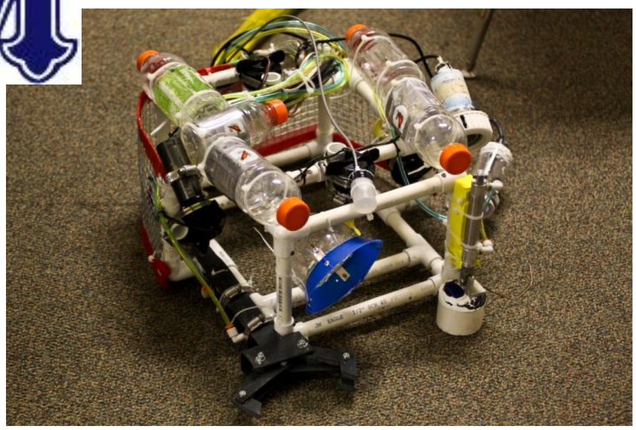
Mission Prep Robotics Tech Report



Back: Ruslana Cannell, David Lundberg
Middle: Ivy Arkfeld, Rita Preciado, Carl Ferber, Patrick Douglas
Front: Niels Smidth, Ray Hurwitz

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Abstract

The Mission Prep Royal ROV

The primary design goals for our ROV were excellent underwater maneuverability and multitasking tools to accomplish tasks efficiently. Our ROV is built to move with four converted bilge pump motors. The claw is operated from a pneumatically controlled air system. The sensors on board include four customized underwater cameras, a hydrophone, and a temperature probe. A pneumatically operated coring tool takes bacterial samples. Our ROV is designed to resurrect an undersea observatory, collect new species of crustaceans, sample a new underwater vent site, and sample a bacterial mat, all of which accurately reflect the tasks associated with an undersea exploration of the Loihi Seamount. Our team has overcome challenges besides the usual building and testing issues. An additional challenge was having our seniors leave the team after the regional competition. As a result, we have incorporated members from the Lady Royals team into the Royals team, and worked to build a cohesive team.

Design Rational

We had different ideas driving our design as we built our ROV and control systems. Our primary goal was to have the greatest possible ease when driving the robot and controlling the tools. We wanted our pilot to be able to concentrate on completing the tasks efficiently and not simply keeping control of the robot. Because our school sent two teams to the Ranger level regional competition this year, another goal was to make our ROV out of materials that cost less.

The biggest influences on how we designed the ROV itself were the mission props and tasks we had to accomplish. We designed the robot to accomplish all the tasks in the most efficient way possible while still being able to change the ROV's design on the fly if needed.

Structure

Our frame is made of PVC, an inexpensive material that provides a solid frame on which to build. The 42.5 x 30 x 21 cm open box shape best facilitates the mounting of tools and cameras. PVC is lightweight, yet sufficiently stable to support our tools and cameras. The ROV has been tested in water up to 4 m deep, which is the greatest depth we must operate in. We have reduced the size of this year's robot compared to past years, to increase mobility in small spaces.

PVC Frame

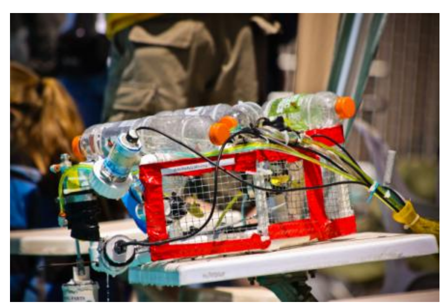
Propulsion

Four bilge pump motors propel our ROV: two of which are 1000 gph and draw 8 amps and the others are 750 gph and draw 7 amps. These motors were tested at Long Beach City College to see which propellers would be the most efficient (provide the fastest speed while drawing the least amount of amps). Two motors are laterally mounted on either side of the robot to provide movement in all horizontal directions. Our other motors are dedicated to vertical motion. These powerful 1000 gph motors allow for quick and easy descents and ascensions; and since our ROV is neutrally buoyant, we are able to control our exact depth in the water.

Bilge Pump Motors

Buoyancy / Ballast

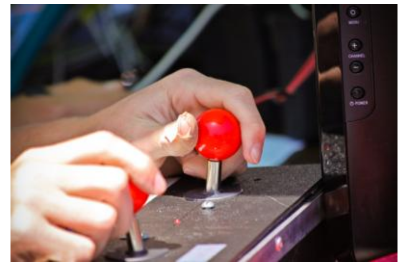
Gatorade bottles provide the buoyancy on our ROV because they allow for easy adjustment by adding or removing water to get the ROV neutrally buoyant at the bottom of the pool, which we have determined is the best for completing the tasks. We also have weights on our ROV as ballast in order to even out the weight distribution so that the robot stays stable while performing tasks.



Bottle buoyancy

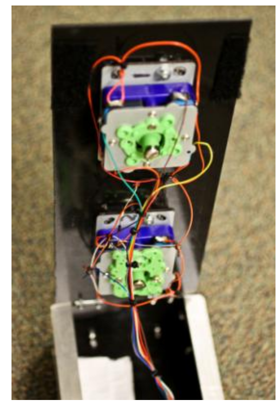
Control System

Instead of using manual switches as we always have in the past, one of our senior team members designed and built a new control system. Last year we used a very simple system of switches hooked directly to our motors and power supply to control the mobility of our robot. We found it to be cumbersome and make delicate movement difficult. We abandoned this system and used a set of relays attached to joysticks containing microswitches to actuate the motors. Relay switches activate using magnetic coils below the switch to open or close the flow of electricity. This system also allows for much more precision in movement, and makes control more intuitive.



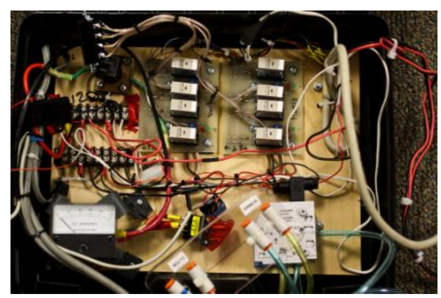
Joystick control box

The relays are rated at 10 amps, more than enough to handle the draw from a single motor. They are plugged into sockets which allow for quick changes in the event of a blown relay. The sockets are soldered into hand-etched printed circuit boards, which eliminates many wires from this circuit. The relays are arranged in an H-bridge configuration, which by default has both ends of the motor attached to ground. To activate the motor, one of the relays is actuated in order to move forward or backward. The relays are actuated by the microswitches in the joystick, one microswitch in each direction.



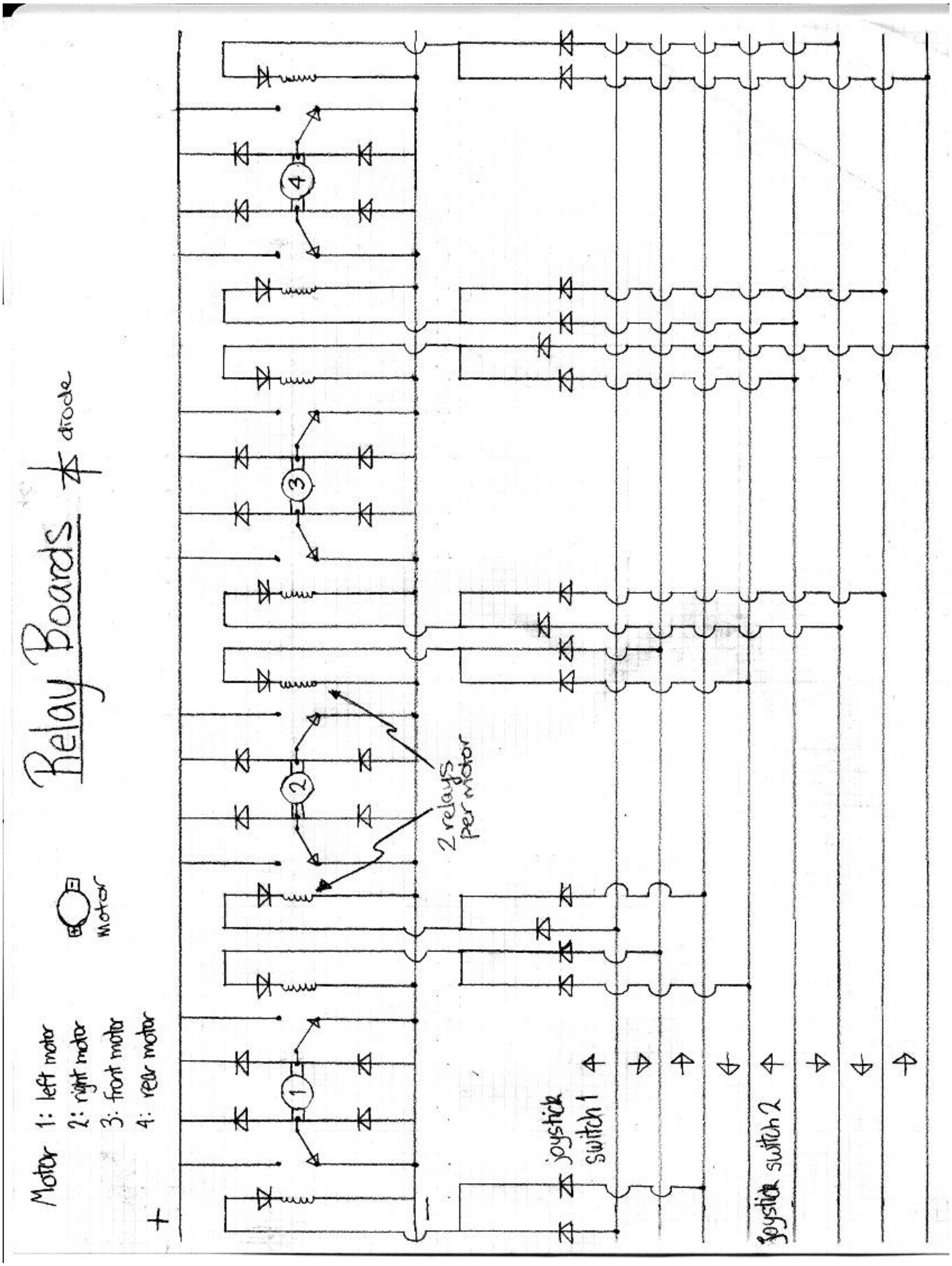
Inside of joystick box

By pushing the joystick in one of the corner directions, only one of the motors turns on to allow slow movement in that direction. By pushing the joystick diagonally to the right or left, the ROV gradually turns in the direction the joystick is pushed. For example: to turn left, the joystick is pushed left, which activates the right motor forward and the left motor backward. The relays for each motor have two wires going to them, so diodes were used to ensure that only the desired motors were activated; no programming was required.



Inside of main control box

Controlling the power over our entire system is a kill switch that we use as a safety measure while working on the box. This switch is connected to a 25 amp fuse, which connects to our ammeter allowing us to monitor the amps we are drawing. We have found this very useful in making sure our motors are working properly because a motor that has lost a propeller draws very few amps, and a tangled motor has to do more work, therefore requiring more amps. The power into our control box goes to two power distribution busses, one for ground and one for 12 volts. Power to the relay switches, cameras, and pneumatic control valves is provided from these busses.


Relay Boards
diode
Motor 1: left motor
2: right motor
3: front motor
4: rear motor
Motor
2 relays per motor
+
−
joystick switch 1
joystick switch 2

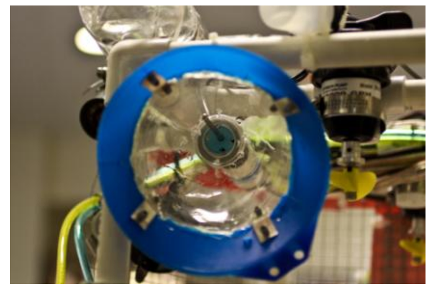
Sensors

There are six sensors present on our ROV: four cameras, a temperature probe, and a hydrophone. The cameras are used for underwater navigation. There are two LCA waterproof cameras with LED lights around the lens. The other two cameras are security cameras, placed in clear lexan tubing to ensure early detection of any leaks.


LCA and Security Cameras

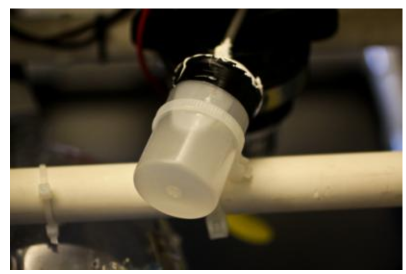
Cameras

We chose the LCA cameras because they have great quality, come waterproofed, and are color cameras. We chose the security cameras because they were small and cheap, but had to waterproof them ourselves. Our cameras are placed strategically, to provide the driver with a maximum viewing of the payload tools as well as an "overhead" view of where we are headed.


Temperature Probe

Temperature Probe

The temperature probe is composed of the top of a two-liter soda bottle to help direct the water into the top. The water hits the sensor and shows the temperature on a Venire Lab Quest that is hooked up through the tether to the ROV.


Hydrophone

Hydrophone

The hydrophone is a plastic film canister filled with mineral oil to help keep water out and away from the microphone in the canister. The microphone is wired with fifty feet of shielded audio wire that comes through the top of the film canister and out through the tether. The canister is taped with black electrical tape and then waterproofed with 5200 Marine Sealant.

Tether

Our tether contains four power wires for our motors, four video wires for our cameras, and the air tubes for the pneumatic actuators on our tools. It also holds a co-axial audio line from the hydrophone and a cat 5 cable from the temperature probe. Our tether is wrapped in a yellow nylon mesh cover that keeps all the wires and tubes together that run from the ROV to the controls on the surface.


Yellow mesh on tether

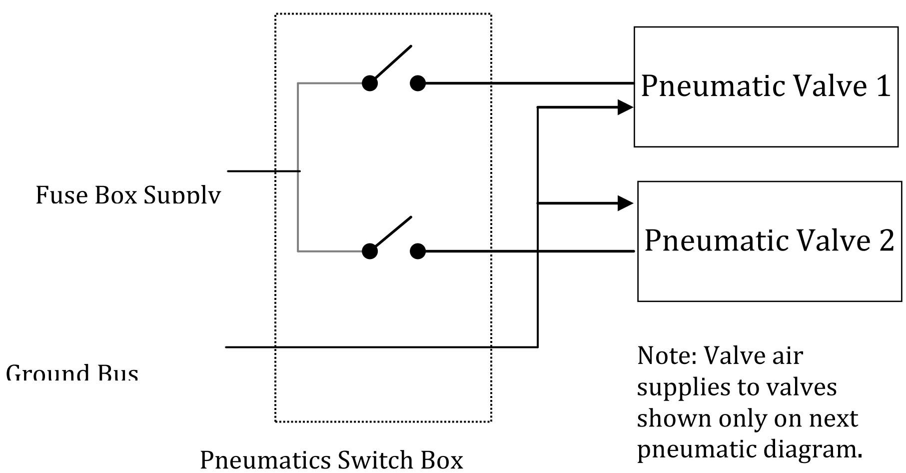
Flotation in the tether has been an issue and so far we have not solved the problem. We have not been able to adjust the flotation so that the tether doesn't get stuck in the cave but is able to get over obstacles. Further troubleshooting will be done to place floatation inside the tether in locations that eliminate this problem.

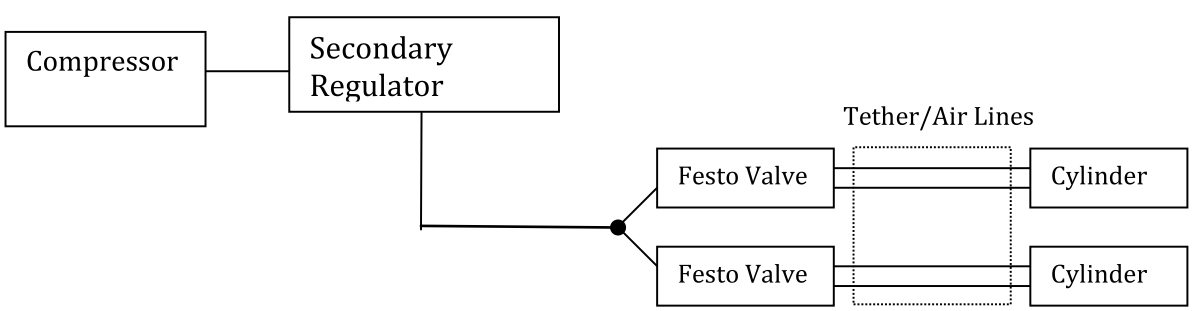
Pneumatics

We chose to use pneumatic cylinders for our tool operators instead of solenoids or a gearbox. To keep our design simple and easy to build, we used double-actuating pneumatic cylinders to provide reliably accurate and efficient action for the claws. Since the cylinders do not rely on springs, they do not open unexpectedly.

A huge improvement is our purchase of a small air compressor. In the past we used a SCUBA tank. The new compressor is safer and more reliable, allowing us to maintain 40 to 125 psi in the air tank. A secondary regulator maintains our air system at 40 psi both in the control box and down to the ROV.

Regulated air travels into the control box and into two electric Festo valves. One valve controls the claw on the ROV, and the other controls our Agar tool. A unique feature we have is a claw that is actuated by a foot pedal, which is connected through our control box to one of the Festo valves. The agar tool is actuated by a toggle switch on the pneumatic control box. The air flows from the valve, down two pneumatic tubing lines (rated at 1200 kPa), through the tether and a pneumatic cylinder.



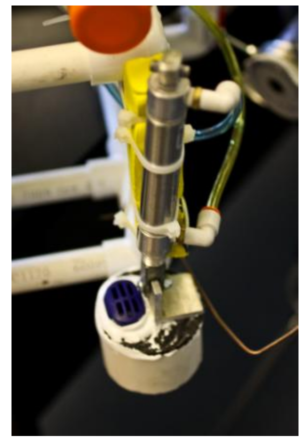


Payload Tools

The most important tool on our ROV is the pneumatic claw. The pneumatic actuator is connected to PVC sheet support structure that are attached to the frame of the robot. The claw's three fingers, that open or close horizontally, are attached to the end of the structure. The right finger interlocks between the two fingers on the left to increase the claw's ability to grab objects. The fingers are also PVC sheet layered to increase their strength. The piston of the pneumatic actuator is connected to the end of each of the fingers with PVC sheet, so that when the actuator pushes forward, the fingers move out; when the actuator moves in, the fingers close in. We use the claw to grab crustaceans, the HRH, the HRH power connector, and spires and to remove the cap from the HUGO.

Pneumatic Claw

To pick up the agar, we have a sharpened piece of 5.08 cm PVC piping attached to a vertically mounted pneumatic actuator. The tube is covered on the topside with plastic and is sealed so it is water tight. In the top is the one-way valve from a snorkel so that when the actuator pushes down, the water flows out but then creates a vacuum when the actuator pulls back up.



Agar Tool

The third tool on our ROV is a metal hook to pull the j-pin out of the HRH.

J-Pin Hook

Troubleshooting

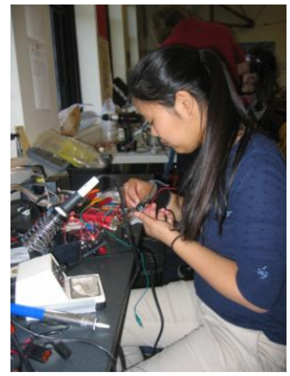
Our troubleshooting technique was based on the process "discover the problem, isolate the cause, fix, and test". Our team refined our ROV through trial and error. When doing this, we found problems that we had to fix. Among them, we had issues with the agar tool. As we started building our ROV, we realized that the agar tool would be hard to build, so we saved it for last. This was a mistake, for we discovered that we had to redesign the tool several times before being it functioned correctly on the ROV. Originally, we started out with a digging claw for removing the agar, but this version did not work. We thought the problem was in the strength of the tool and the sharpness of it. After making a succession of changes we tested the tool again and again, but it still did not work. Then, we decided to change the design itself. For this, we found a snorkeling valve and inserted it into a two-inch PVC pipe, thus creating our current version of the agar tool.

One of the greatest problems was when we faced a problem with our agar tool 15 minutes before the second mission attempt. The agar tool broke and we had to repair it by screwing, gluing, and taping the pieces together.

Reflections

MCP Royals at regional competition

At the beginning of the 2009-2010 school year, our team gathered to construct an ROV for the Monterey competition. Some of us were skilled in building our ROV, for we had participated in last year's competition, while others were new to this experience. Throughout the year, we learned much more about building, robotics, operating tools, and physics. Besides gaining knowledge about the ROV, we also learned more about each other, and we feel this competition has helped us become more united as a team.



Lady Royal wiring (Rita)

Some of our club members chose to devote more time to robotics-related activities, while both of our seniors, Ray Hurwitz and Niels Smidth decided to go into engineering majors in college this fall. Even those members who are planning to work at fields unrelated to electronics in the future feel that this robotics competition influenced them in positive ways.
Our future plans:

- David Lundberg - mechanical engineering
- Carl Ferber - biochemistry
- Patrick Douglass - electrical engineer
- Rita Preciado - electrical engineering
- Ivy Arkfeld - mechanical engineering
- Ruslana Cannell - medical field
- Madison Fetyko- law, journalism

Our ROV and this competition had a major impact on our lives by teaching us to use tools and think outside the box to make undreamed-of projects. We will never forget this experience, and we are thankful we had the opportunity to see the various ROVs of the best teams, share our thoughts with colleagues, and participate in this competition.

Challenges and Lessons Learned

Ray Herwitz, senior; retired captain

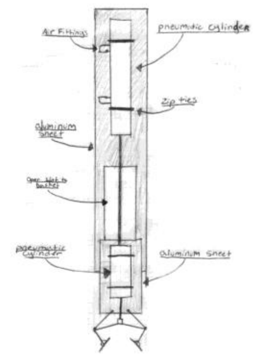
Niels Smidth, senior; retired electrical specialist

One technical lesson we learned throughout the competition was that we had to have a plan and consider camera angles before putting tools and motors onto the ROV. Often, we could not see our tools. When we wished to change our ROV's design, we needed to go through the trouble of taking it apart and reconfiguring the cameras. Before the regional competition, we had difficulties with our agar tool. Because of this we had to change the shape of our ROV many times. With each change came the problem of readjusting camera angles so that we could see the props and tools in the pool.

We learned a valuable lesson when our two seniors, the leaders of our crew, retired from the team after the regional competition. Because they left, we did not have enough members to compete, and therefore had to include some members of our Lady Royals robotics team into our previously all-male team. We taught our new members about the ROV, its payload tools, how it operates, and how to control it. The lesson we learned was how important it is to identify the strengths of the new members and match them with existing members' strengths.

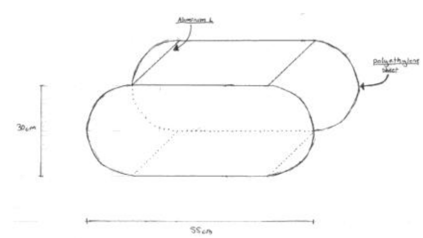
Future Improvements

We are planning to complete several improvements before the international competition. First, we are redesigning the frame out of a polyethylene plastic-aluminum combination that will be wider than the current frame. The future improvements we would like to make on our robot would be to make the frame out of a plastic aluminum combination. This would allow for sturdy mounting of all components in the inside of our robot. This frame will have rounded corners, reducing the chances of getting caught on obstacles.



Sketch of future claw

Another improvement that will be useful on our robot would be to add another motor for lift. During our trials we experienced trouble in lifting items from the bottom, with proper lift our robot would function better.



Sketch of future frame

Changes to the tools are crucial for improvement on mission tasks. One of the changes to the tools would be an integral basket for gathering of small items instead of the large separate basket our team carried down before. To use this interior basket, we will add an additional pneumatic cylinder that would extend the claw out of the robot, grab items and retract the claw back inside of the ROV, so that the item could be placed into the holding basket.

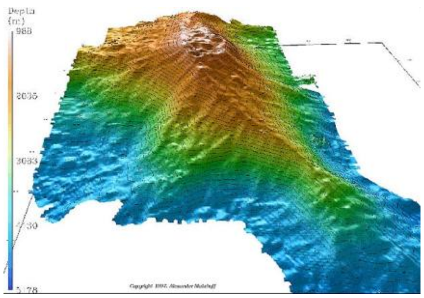
Safety

Our ROV and operating systems have multiple features that keep our crew and others around safe during operation. Our ROV is surrounded by hardware cloth to prevent anyone from accidently getting hit with a spinning prop, as well our tether from hitting the motors. All of our tools and motors with moving parts are clearly labeled to warn those near the robot of the danger when the ROV is powered up, and all sharp edges on the robot are labeled as well. We have also labeled the electrical parts of the control system warning of shock hazards.

Wearing safety glasses while cutting metal

Before switching the master power on, we always check the connections in the control box to make sure that everything is wired correctly to prevent problems. Another check we make is ensuring that no one has their hand near a motor or moving tool. Our team is often using dangerous power tools such as saws and dremel tools.

These can throw shards and sparks, so we always wear safety glasses and make sure no one else is near who could be harmed. We always make sure that the safety is on, and the tools are unplugged whenever we are not using them.



3D map of Loihi seamount

Mission Theme

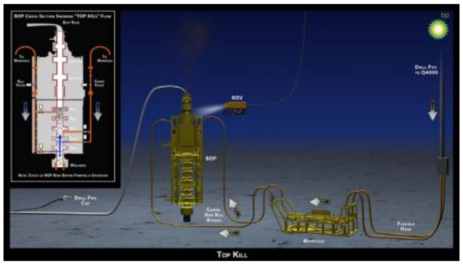
The Loihi seamount is located approximately thirty five kilometers off the southeast coast of the Hawaiian Big Island on the Mauna Loa Flank. This volcano is also part of the earth's largest shield volcano. Loihi was originally explored in 1940, when a survey of the United States coast was completed. However, the first real attention brought to the seamount was in 1952, following a series of earthquakes. That same year, a scientist by the name of Gordon A. Macdonald formed the idea that the seamount was an active submarine shield volcano. Nevertheless, with no proof of eruption the earthquakes were simply attributed to faulting in the earth. This caused the volcano to be somewhat ignored until 1970 when a group of scientist went to study another set of earthquakes. After this exploration it was confirmed that the seamount was, in fact, active.

In August 1996, Loihi came to life for the first time recorded in history. After this eruption, there was the first direct evidence of a volcanic eruption found by scientist from the University of Hawaii. This exploration also was able to conclude that due to the several earthquakes that had happened the southern part of the seamount had collapsed. Towards the Northern end of the volcano there was a newly formed crater pit. This was due to the fact that water was flowing so rapidly into the pit. In the end a dangerous bottom current was established which made late submarine diving dangerous. The most active area of the volcano is the southern tip. This area still contains high lava columns that have not dissipated. Exploration in this area is very difficult. The water is cloudy due to the high levels of minerals.

Organisms that live on Loihi seamount

A program called FeMO, or the Fe-Oxidizing Microbial Observatory Project, has recently been using ROVs to explore the microbiology on the volcano, specifically the bacteria, which have taken life on the seamount. Through the use of ROVs FeMo has been to discover that these organisms have formed coats of rust on the surface of much of the seamount.

The Hawaiian Undersea Research Laboratory is another organization that has taken to using ROV robots to explore the activity on Loihi. Since the volcano is so far down in the ocean, ROVs tend to have a better success rate with exploration. ROVs are capable of collecting samples and taking pictures just like man, except they are not affected as much by the shift in pressure. If man were to try and dive down to the seamount the pressure would cause them to have trouble breathing.



BP use of ROVs in oil spill

Aside from exploration of the Loihi seamount being more practical for ROVs, there have also been other recent cases where ROVs have been used. One specific example of this is in the BP oil spill in the gulf of Mexico . The oil spill was spilling about 200,000 gallons of oil a day. Due to the oil concentration in the water it was not neither safe nor efficient for humans to go down and explore the leak; so the company was not only using ROVs to monitor the spill but also devised a plan to try and put an end to it by sending out an ROV to go down and insert a smaller pipe into the one that was broken. This would hopefully stop the leak or somewhat slow it down. In the end the ROV was somewhat successful in the attempt. However, the leak was not slowed down, and efforts continue.

<u>Acknowledgments</u>

This year's Mission Prep Robotics team would not have been possible without the generous assistance of a number of individuals. Each and every person contributed something positive to the team. Two especially heartfelt thank-you's go out to Vickie Backman and Noah Doughty, our team mentors, and the MATE Center. Without the MATE Center, this competition and its inherently valuable experience would not exist; without our team mentors, we could never have gotten so far. Thank you.

A complete list of donors, sponsors, and other important individuals is found below, and our gratitude goes out to all of them:

- Mission College Prep High School (MCP) (Primary financial supporter and undying loyal support from students and staff)
- The MATE Center
- Vickie Backman (MCP)
- Noah Doughty (MCP)
- Eagle Robotics (Pneumatic Parts)
- Greyhound Revolutionary Robotics (Pneumatic Parts)
- SolidWorks (Design Software)
- Absoulte AutoTech (Battery)
- Peter Smidth (Electronic mentor)
- Dan Atwell (discount on motors)
- LCA (discount on cameras)
- Softec ($500 grant)
- Anonymous Donors ($2000)

BUDGET

Category	Item	Quantity	Price Each	Total Price
Propulsion	4 bilge pump motors with propellers and adapters	2 at 3785 Liters per minute (L/min) 2 at 2839 L/min	40.00 each	160.00
	speaker wire	70 m	20.00	20.00
	Marine Heat Shrink	1 m	5.00	5.00
Frame	PVC and PVC joints	5 m	50.00	50.00
	Hardware	.3 cubic m	10.00	10.00
Cameras	Security Cameras with Lexan housings	2	60.00	120.00
	Lexan cement		13.00	13.00
	Quad Splitter		66.00	66.00
	LCA cameras	2	325.00 each	650.00
	Liquid Tight cord connectors	2	7.00	14.00
Pneumatics	Pneumatic actuators	2	25.00 each	50.00
	Pneumatic tubing	70 m	80.00	80.00
	Pneumatic Fittings	9	3.00	27.00
	Amp Meter		30.00	30.00
	Festo Valves	2	90.00	180.00
	Foot Controller		50.00	50.00
Controls	Reverse Polarity Protector circuitry		12.00	12.00
	Circuit Boards	2	10.00	20.00
	Buses	2	5.00	10.00
	Electric Switch Box		15.00	15.00
	Aluminum-L bar	2 m	20.00	20.00
	Zipties		50.00	50.00
	Joy Sticks	2	37.00	74.00
	Various size Fuses	2	5.00	5.00
	Main Power Cables	2	11.00	11.00
	Tether Cover	15 m	40.00	40.00
	5 volt Regulating Circuit for hydrophone		10.00	10.00
	Relays	9	11.00	99.00
	Miscellaneous wire and hardware		24.48	24.48

Category	Item	Quantity	Price Each	Total Price
Payload Tools	Temperature sensor		29.00	29.00
	Vernier Lab Quest		325.00	325.00
	Sheet of ABS for claw		13.29	13.29
	Hydrophone		30.00	30.00
	Liquid Tight connectors	2	14.00	28.00
Mission Props for Training	Miscellaneous Pipe and fitting		53.00	53.00
	Lead Weights		46.30	46.30
	Shrimp lures		12.00	12.00
	Agar		18.00	18.00
Hardware	Nuts, washers, bolts, etc.		79.08	79.08
Poster	Poster Printing for International		120.00	120.00
	Photo Printing		15.00	15.00
	T-Shirts		270.00	270.00
		Total Robot Expense:		**2926.15**

Travel	Item	Quantity	Price	Total Price
	Airfare	9 tickets	520.00	4680.00
	Food		792.00	792.00
	Transportation (vans and fuel)		1200.00	1200.00
	Lodging		2940.00	2940.00
			Total Travel Experiences	**9612.00**
TOTAL EXPENSES				**$ 12538.20**

Income	
Softec	500.00
Mission College Prep Regional	1200.00
Mission College Prep International	7000.00
Mission College Prep International Improvements	500.00
Mission College Prep International Competition Travel	6500.00
Student Contribution for air fare	4680.00
Parts Reused From Prior Years (cameras, motors, pneumatic parts)	770.15
Vernier instrumentation borrowed from school (Lab Quest, Temperature Probe)	354.00
TOTAL INCOME	**$ 13354.20**

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