MIT ROV Team

ROV Rocktopus

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Explorer Class

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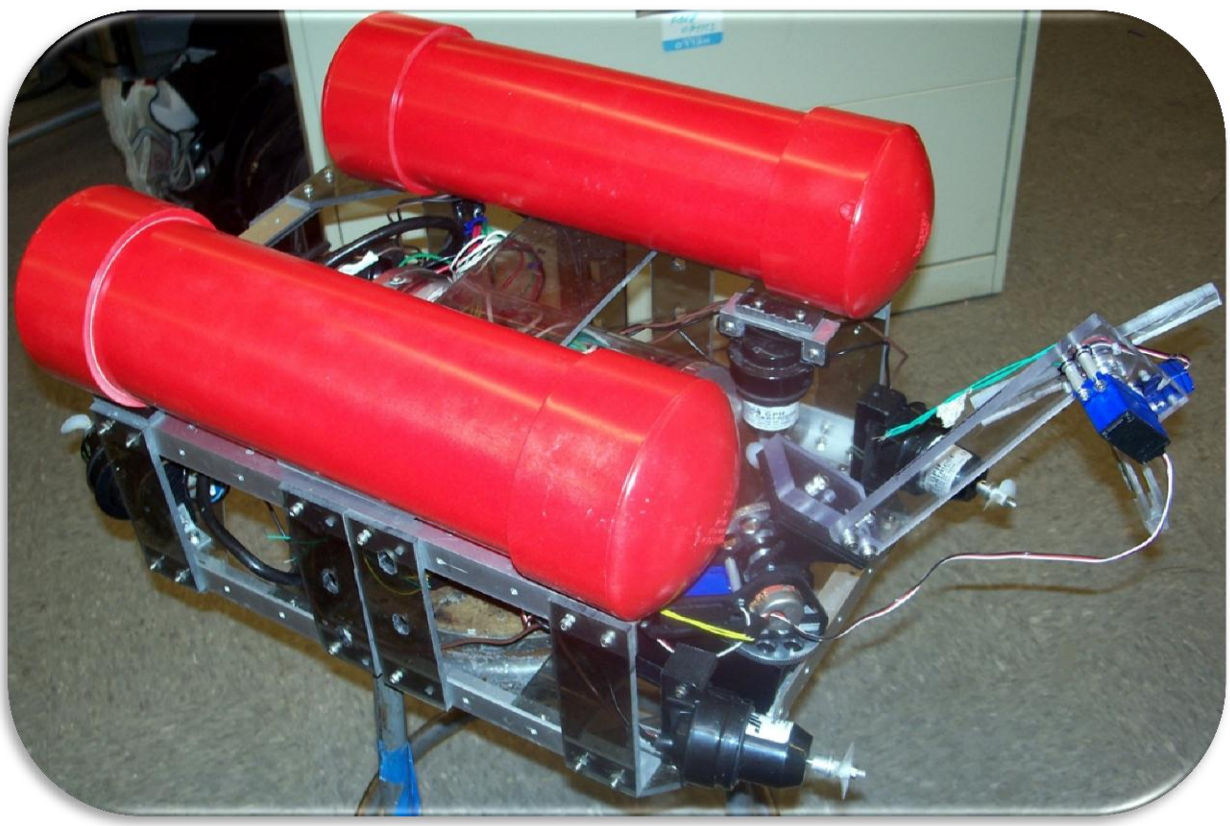
Abstract

The ROV Rocktopus was designed and built by the MIT ROV team for the 2010 MATE International ROV Competition. The ROV was designed to complete numerous tasks which simulate collecting data and samples and facilitating repairs at Hawaii's Loi'hi Seamount. Given the time constraints, the ROV was engineered for efficiency and speed in performing its tasks. Its other major design consideration was modularity, allowing the team to distribute the building process, to easily test systems as they were completed, and troubleshoot and replace systems as necessary. Through this process great improvements were made, both to the ROV and to the team.



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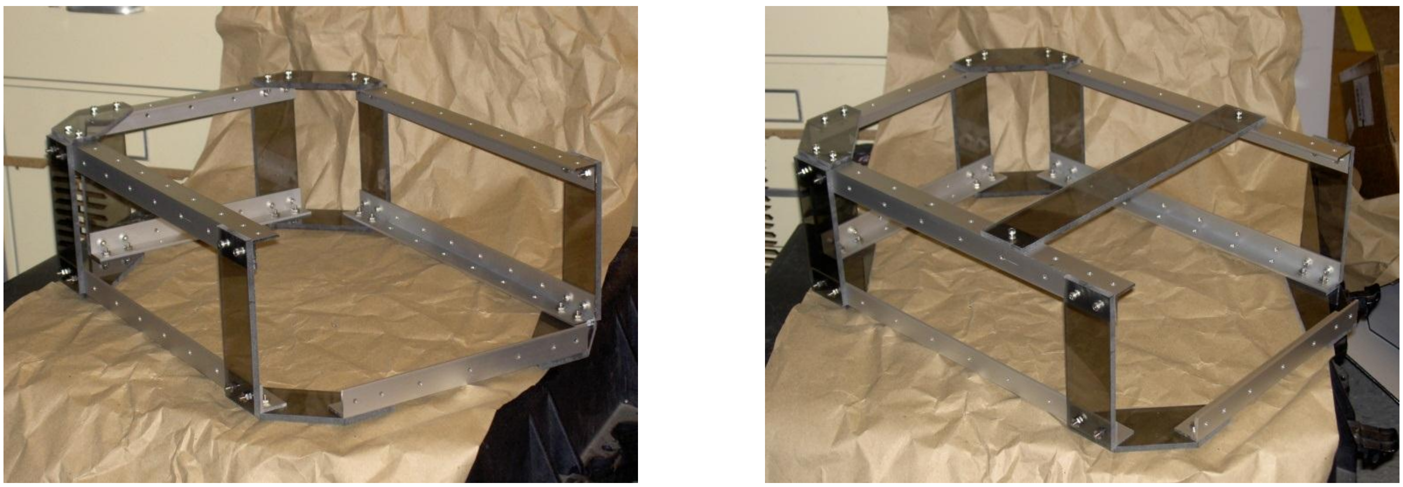
1.0 Design Rationale

This year the MIT ROV team sought to design a vehicle which was compact, fast and modular. A compact design allows the vehicle to maneuver easily within the cave. The competition this year included a large number of tasks, making speed an important factor in performance given the 15 minute time limit. A modular design allowed for a distributed and adapted design philosophy and simplified testing. The following sections describe how these goals were incorporated into the design of each subsystem.

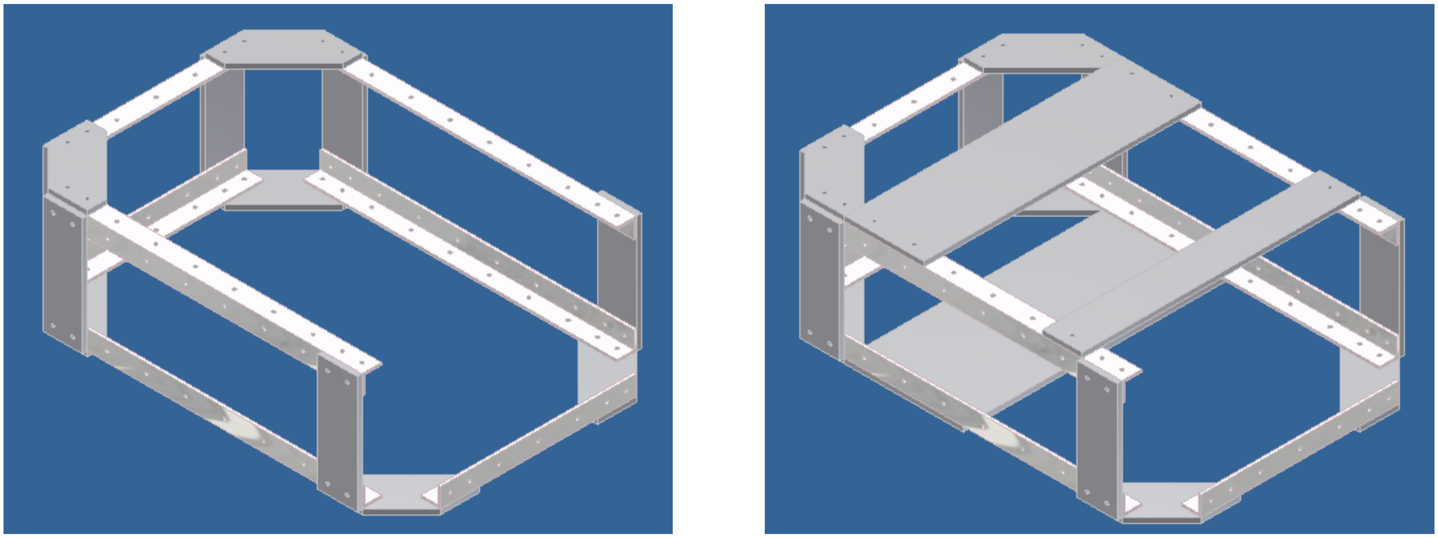
1.1 Frame

For our vehicle this year we had three major design criteria for a simple, sturdy frame: flexibility in mounting, a large containment capacity, and robustness. We worked through a few design iterations before arriving at the final design, shown below as is, and modeled in Inventor:



(a) (b)

Figure 1: (a) Bare frame hull and (b) frame with optional support and mounting plate.



(a) (b)

Figure 2: CAD drawings of (a) bare frame and (b) frame with additional mounting and support braces.

This design is simple and flexible; constructed of aluminum angle brackets and polycarbonate struts and connectors, the design also includes additional mounting and support braces that can be added as needed, and in any location that the standardized pre-drilled hole settings allow. The braces can also be drilled to allow for additional mounting, and can be added for support as well. In addition to the optional braces, the angle brackets allow for maximum mounting ability across any of the faces of the frame box. The pre-drilled holes themselves allow for flexibility in mounting mission modules, cameras, and any other equipment in a variety of locations and configurations.

We had originally thought to construct a standardized system of struts and connectors to allow for a multitude of modular boxes to be connected and disconnected from the main frame at will. For example, if one desired to attach the heat sensing module to the frame for a mission, one could simply attach the heat sensing module box to the main frame box via the standardized connections. However, we realized that perhaps the modular attachment boxes did not provide any more advantage over one frame box with many modular attachment points. In this way, many of our desired module platforms could be just as easily attached and detached, but avoiding the clutter and bulk of additional modular boxes.

We also chose to use struts and connectors to allow for an open spacious frame. The box frame itself is large and spacious, but it is the open frame design that truly allows us the freedom to add and mount as we like. The struts take minimal space, and do not restrict components to be strictly inside the box so that if we need more space or want a component in a certain configuration, we are not contained within the frame and can do so.

We also analyze our robustness. We desired to be lightweight, and originally had thought to have a completely polycarbonate frame. Again, we did not want to be inefficient in machining the angle brackets in polycarbonate, so we chose instead to use extruded aluminum angle brackets for the struts, with a minimal increase in weight. For the other 2D components, we chose polycarbonate. Indeed, our structure is lightweight, at .86 kg and robust: we placed the frame under a static stress analysis in Inventor, with a moment load of 0.32 Nm at the front bar to simulate the moment load from the hydrophone being picked up at the arm:

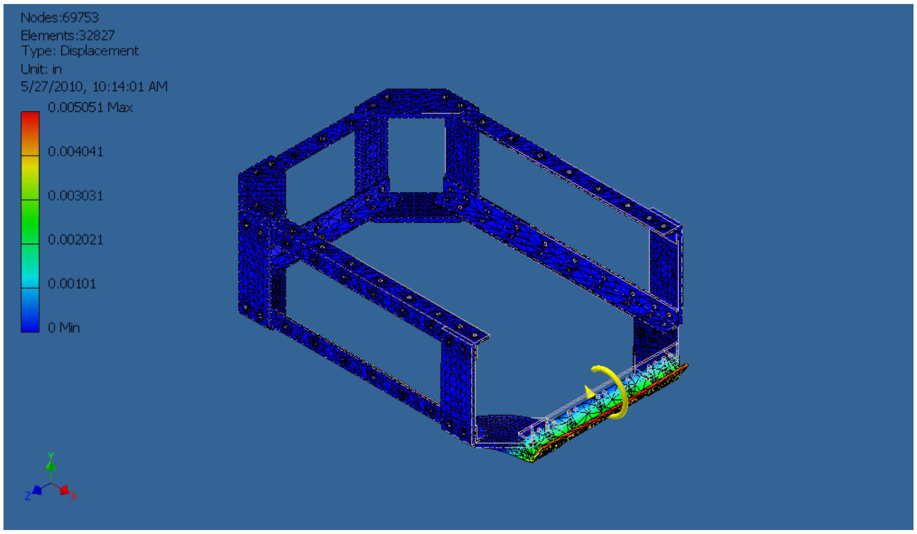


Figure 4: Static stress analysis of frame design.

Stress analysis shows that the frame is strong enough to handle the moment from the loaded arm, with minimal stress being felt in locations away from the front bar, and the below displacement analysis shows that our structure will budge at maximum 0.005 in, and this is without any additional support:

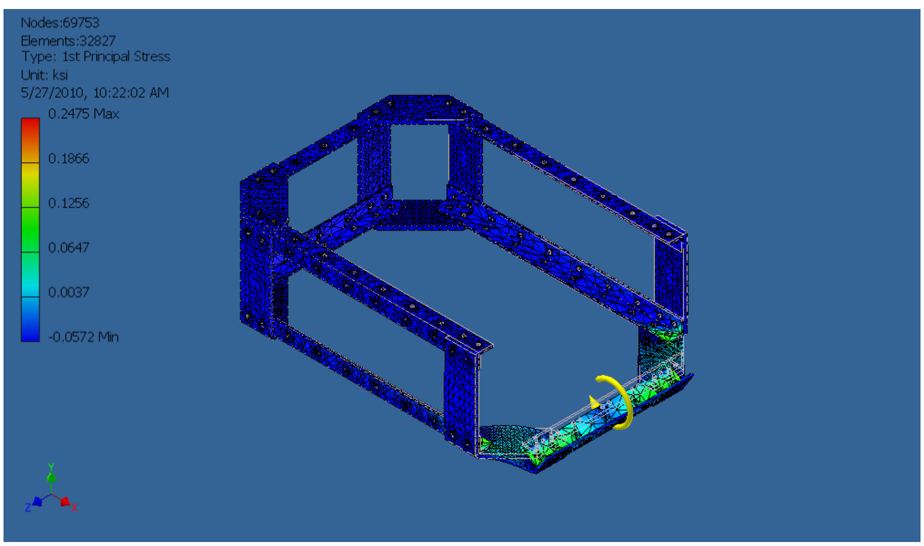


Figure 5: *Static displacement analysis of frame design.*

With this final design we achieve modularity, not dependent on other modules but rather on modular attachments within itself, with simple and efficiently made struts and connections. Optional support and mounting braces increase flexibility in mounting and robustness. Our open interior gives us maximum space and component configuration options, and stress analysis shows the sturdiness of this design. This frame design is highly flexible and adjustable, spacious, and robust.

1.2 Propulsion

For our propulsion system we investigated two competing designs, a vectored thrust system building off the previous year's work with water jets, and a more traditional system using bilge pump cartridges with propellers attached.

The vectored system was designed to support four nozzles, one in each corner, each capable of directing thrust in any direction in a horizontal plane. Our goal was to compensate for the low thrust of the water jets by orienting all nozzles in the desired direction, providing, at minimum, a 2X increase in thrust from past years. However, we did not want to risk the complexity or precision of a gearbox. Instead, we chose to use a four bar linkage, a rendering of which can be seen below in Fig. 6. This linkage translates 180 degrees of rotation of each arm into 360 degrees of motion of the nozzle, allowing us to rotate each nozzle through 360 degrees with just a single servo and no gears. Unfortunately, problems in the control system delayed testing until there was not enough time to properly test the vectoring system. However, our highly modular design allowed us to replace the vectoring system with our traditional design in a matter of hours.

Figure 6: Rendering of vector assemble

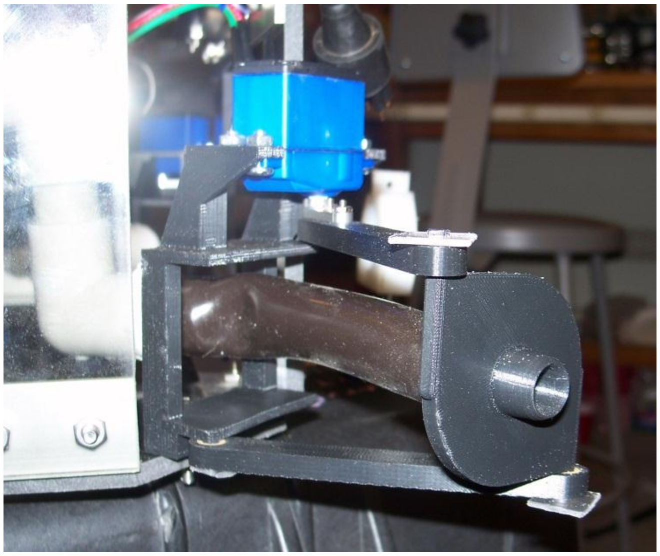


Figure 7: Completed 3D printed vector assemble.

Our final design used bilge pump motors, with propellers replacing the standard impeller. We selected the Johnson Pump Motor Cartridge, Model 2851, which pumps 0.06 m^3/s in combination with a Dumas plastic propeller, with a 44.8 mm diameter. The motors run on 12V voltage drop and draw a maximum of 5.1 A in water. From force testing, the motor and propeller combination produce 14.5 N in the forward direction, and 11 N in the reverse direction. Our vehicle has two forward thrusters and two reverse thrusters, each oriented at a 15° angle from the surge direction, each angled inward into the vehicle, to allow for surge, yaw, and sway motion. For ascending and descending we have two vertical thrusters located in to opposite corners of the vehicle. An example thruster appears in Fig. 8.

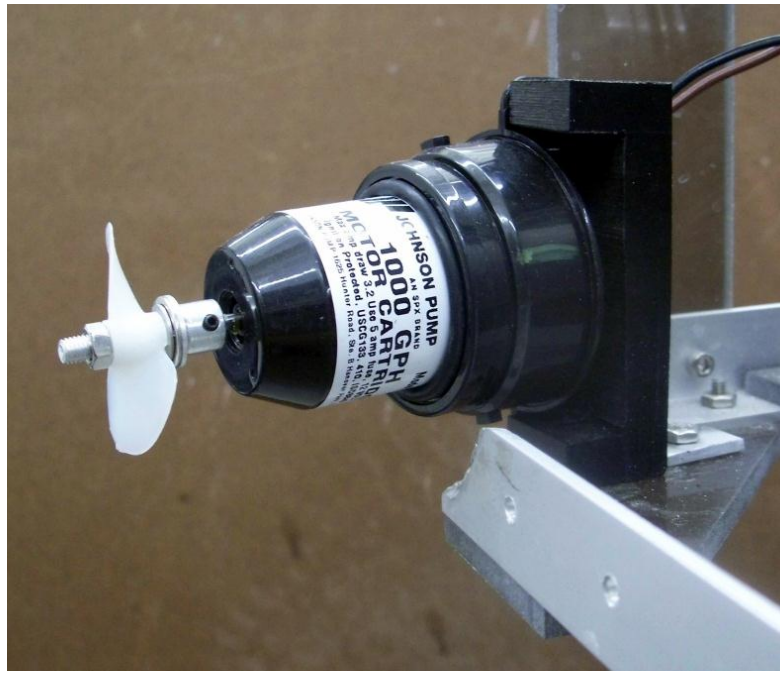


Figure 8: Bilge pump thruster

1.3 Control System

Our overarching design philosophy for this ROV was modularity. To accomplish this, we divided our control system into a bottom side Arduino microcontroller that managed the actual sensor and actuators, and a top side laptop which would collect user input, process sensor data, and decide desired actuator values to transmit to the Arduino.

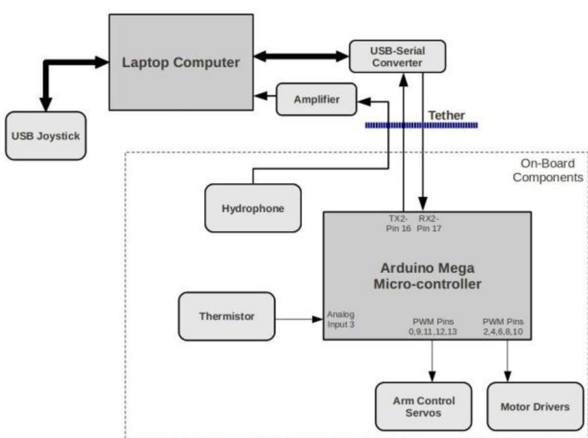


Figure 9: Control Schematic

Fig. 9, above, shows this division of our control system. To maximize modularity and reusability for future years, the bottom side does very little task-specific processing. An Arduino mega decodes incoming serial commands into a PWM value and a pin to apply the PWM signal to. In the event the mega does not have enough PWM pins to support all actuators, the mega can communicate with up to three additional Arduino minis over serial, providing them with a desired PWM value and pin. Upon a query over serial, the mega can return the voltage on a specified pin. With this system, our bottom side electronics and software can support any analog or digital sensor, and control any servo or motor, without any modification. All changes are made to the top side, where the use of a laptop allows for faster development and increased flexibility.

The top side is responsible for collecting user input and translating this into desired thruster and servo values, before encoding these values and sending them down to the Arduino. This year's tasks called for a combination of coarse, rapid maneuvering, fine manipulation, and the collection and interpretation of data from multiple sensors. To accomplish this, we designed an interface for two simultaneous users; a pilot, responsible for guiding the vessel, and an operator, who handles manipulators and sensors. To support this scheme, we designed a graphical user interface to provide necessary data for all users in as simple a format as possible, a prototype of which can be seen in Fig. 10.

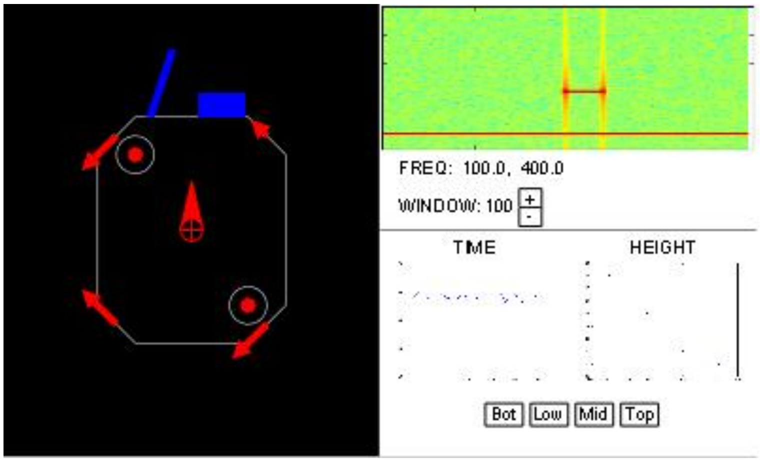


Figure 10: GUI Prototype

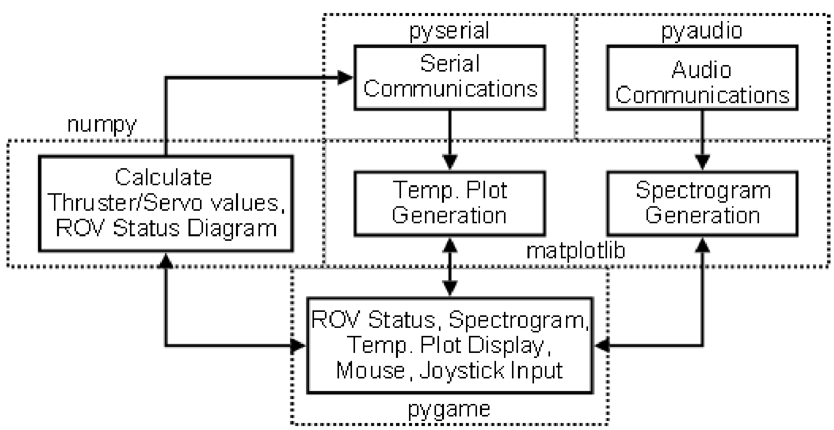
The GUI is divided into 3 panes, one for the pilot and two for the operator. The pilot's pane, the leftmost pane, is the sparsest and largest pane, designed to minimize the time required to locate information. The propulsion system, in red, shows the direction and power of all thrusters, while the manipulator system, in blue, shows the rotation and projected length of the arm, and the location of the storage tray.

In addition, the pilot pane allows the pilot or operator to redefine the forward direction, and set an arbitrary centroid-the point about which the vehicle rotates. The circle and triangle at the center of the pane show the centroid location and forward direction, respectively. This feature is most useful when using the arm; by placing the centroid at the end of the arm, and the forward direction along the arm, maneuvering the vehicle is like operating the arm, with less precision but a greater range of motion.

The pilot pane is also used by the operator; it provides arm position relative to the ROV body and, as mentioned above, the operator may be responsible for centroid positioning. The two panes to the right, however, are used exclusively by the operator. The upper pane provides audio data; a spectrogram allows the strength of frequencies over time to be compared. Using this, a sound source can be located by rotating the vehicle and observing when frequencies peak. The “freq” line provides a list of peak frequencies at the current moment in time, while “window” is a user-adjustable parameter that determines how significant a peak must be for it to be explicitly listed in “freq.”

Below the audio pane is the temperature pane, with two plots, temperature versus time and temperature versus depth. The temperature versus time plot is updated continuously, to help the operator determine when the temperature probe has “settled” and is providing valid data. By clicking one of the buttons, the current temperature is assigned to the height associated with the button, and the temperature versus height graph is updated.

The entirety of the topside software was written in python. Fig. 11 is a block diagram representing how the software is structured; each block is a separate thread, while the dashed boxes show the libraries used in each thread. This threaded architecture was chosen to allow slow but very useful functions, such as spectrogram generation, to be used while keeping the GUI responsive and communications uninterrupted. While much of the sensor code is task-specific, the ROV status pane can be easily modified for different designs, as can the code for collecting and interpreting user input. This aspect of this software makes it possible to reuse it for future ROVs.



[Figure 11: Topside Software Block Diagram]

1.4 Control Housing

The ROV's bottom side control system in housed in a cylindrical waterproof container. This control housing was constructed out of polycarbonate tube with two aluminum lids. The tube is 0.3175 cm thick, 15.25 cm in diameter and 22.86 cm long. The aluminum lids seal against the tube's inner wall using two O-rings are held on the lid using 3setscrews each. Six Impulse plugs penetrate one lid to provide power and communications connections between the bottom side controls, topside and the ROV. These plugs can completely detach from the housing allowing the housing to be removed from the ROV. This provides easy access to the control hardware and eases trouble shooting. The housing is located centrally along the vehicle's long axis. It is attached to top and bottom cross bars with high strength Velcro. Inside the housing threaded rods act as mounting rails for several of the control system's components. A picture of this housing can be seen in Fig. 12.

Figure 12: Control Housing

1.5 Tether

The tether of the ROV is used to provide power and communications for the ROV. It consists of two 10-gage wires for power transmission, two insulated 18-gage wire for control communications, one speaker wire for hydrophone data and four camera lines. The maximum length of the tether is 18.29 m. Foam flotation is attached to the tether every ~0.4 m. This yields a slightly positively buoyant tether. The tether is able to completely disconnect from both the vehicle and the topside power box. This eases vehicle transportation and troubleshooting.

1.6 Manipulator and Mission Tools

One goal of ROV design this year was to incorporate a robust manipulation system that could be reconfigured in the future to be used with for a variety of missions. Additionally we wanted a manipulator which could be used to complete the majority of the mission tasks. This increases our mission speed and simplifies control. These goals were achieved through the design and fabrication of a multi degree-of-freedom polycarbonate manipulator arm with a multi-tool interface. This arm will be used to complete all manipulation mission tasks.

All aspects of the manipulator arm are controlled through PWM signals to each individual servo. These PWM controls are changed based on the position of the dedicated manipulator joystick. X and Y axis control main pan and tilt while buttons control tool actuation.

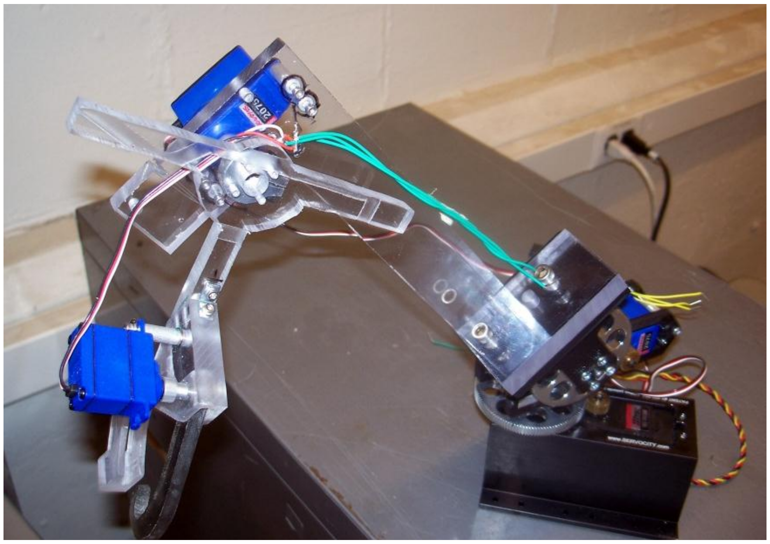


Figure 13: Manipulator Arm

The arm uses waterproof servos in conjunction with several pan and tilt systems to provide both a wide range of motion and large lifting strength.. The manipulator base uses a Hitec HS-785HB servo to provide 360° of pan. The Hitec has been waterproofed with o-rings and liquid electrical tape. Attached to the base is a tilt system actuated by a Traxxas 2075 waterproof servo. This servo provides 100° of rotation at 0.8827 Nm of torque. At the end of the arm is another tilt system using the Traxxas 2075. This tilt system is used to change the orientation of the tooling at the end of the arm. A photo of the arm partially assembled can be seen in Fig. 13.

This manipulator is innovative in that incorporates several tools to complete a variety of manipulation tasks. Attached to the rotating tool hub is located at the end of the arm a temperature probe, claw and agar collector. These tools are located at 90° from each other so that by rotating the hub all tools can be placed in the optimal position (see Fig. 14 and 15). The claw and agar collect are both actuated by their own Traxxas waterproof microservos.

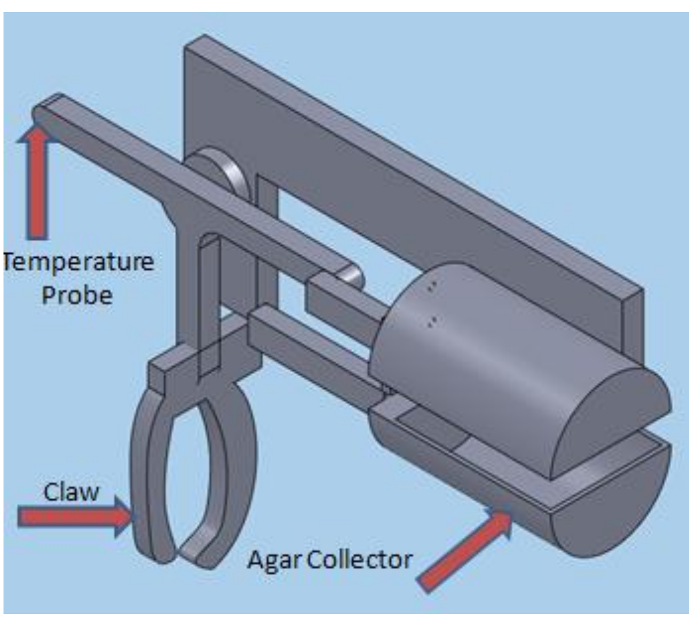


Figure 14: Vertical claw configuration

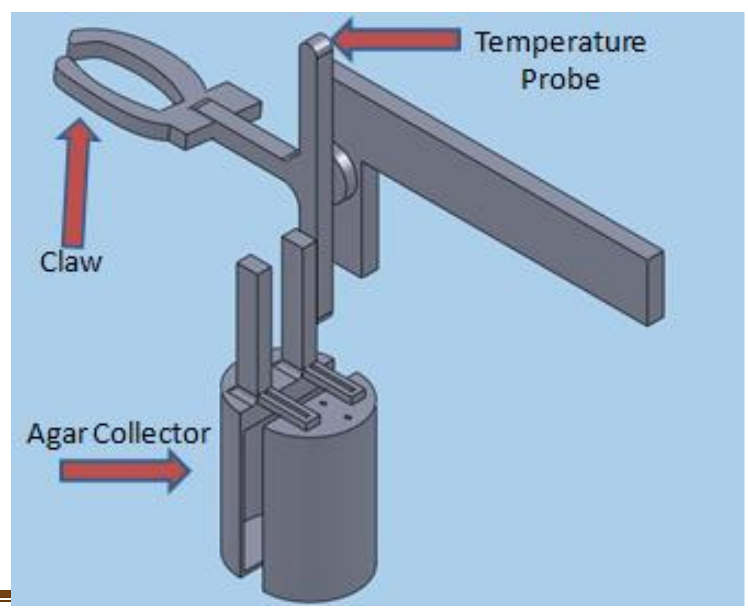


Figure 15: Horizontal Claw and Agar Collection configuration

The two main tools on the arm are a traditional claw and the agar collector. The claw is actuated using a small microservo. This servo rotates one side of the claw which fits into a slot on the opposite side. This claw will be used to pick up items for the mission tasks and to pull the HRH pins. The claw can be rotated into any position between completely horizontal and completely vertical. A collector basket will be placed to the right of the arm so items maybe dropped into it.

The agar collector is designed as a cylindrical scoop that split in half to open and close. The size is such that the collector can be fully submerged in the agar container and when closed, will hold about 165 ml of agar. The cylindrical shape helps avoid misalignment into the container.

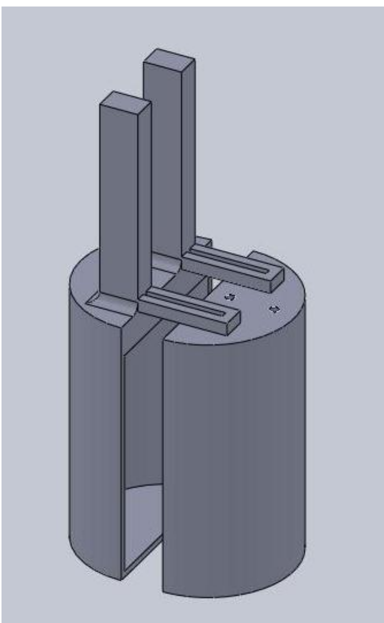


Figure 16: Agar Collector Rendering

The collector is on the end of an arm and is operated by a servo with a rack and pinion configuration attached to the top. The collector is opened, inserted into the agar container and is given enough time for the agar to flow in. We ran tests with the agar to ensure that the consistency would allow easy flow into the collector and minimal mixing with the water during the process. After the agar flows in, the collector is closed and any excess agar is squeezed out. Since the collector can be fully submerged we can be sure that the collector will be full. A rendering of the collecter can be seen in Fig. 16.

1.7 Temperature Probe and Hydrophone

The mission tasks require the ROV to take temperature readings of water exiting a undersea chimney. This is accomplished using a 5 kΩ thermistor connected to the bottom side Arduino. This mission also requires the ROV to take sound observations. This is accomplished using a passive hydrophone. The hydrophone is attached to the vehicle and the line is incorporated into the tether. The output is passed through an amplifier and into the control laptop.

1.8 Cameras

Attached to the vehicle are four waterproof underwater cameras. There cameras' are attached to adjustable mounts so that their position may be changed depending on the subsystems. One camera will face forward, one will monitor the manipulator arm, one will face backwards and one fill face down. These cameras will connect to a USB capture card, which will display the four video feeds on one screen.

1.9 Buoyancy

The assembled weight of the ROV in air came to approximately 120 N before attaching any flotation. Subtracting for approximately 48 N of buoyancy for the control housing and an estimated 5 N buoyancy for other components, we decided to add about 70 N of flotation, then adjust for specific pool setting with weights or foam. We used schedule 40 PVC pipe with an outer diameter of 11.5 cm, providing approximately 98 N/m buoyancy and weighing approximately 24 N/m with. Two sections, 47cm in length, were cut and mounted with hose clamps to the top of the ROV, providing the necessary flotation.

2. Mission Summary

2.1 Task 1

To complete task 1 the ROV will make primary use of its claw. The claw will remove the HRH pins and move the HRH to the rumbling site, which will be identified using the hydrophone. The claw will then be used to remove the junction box cap and place the HRH connector in the junction box.

2.2 Task 2

Task 2 will be completed by entering the cave and retrieving three crustaceans. These crustaceans will be picked up using the claw and placed in the collection basket. The ROV will then leave the cave and complete the other tasks.

2.3 Task 3

Task 3 will utilize the temperature probe located on the end of the manipulator arm. The manipulator tool changer will rotate so the probe is oriented slightly below horizontal. The ROV will maneuver towards the tower and take readings of the venting fluid at three locations. The tool changer will return to the horizontal position so that the claw and retrieve a sample of the spire and place it in the collector basket.

2.4 Task 4

Task 4 will utilize the agar collector. The tool changer will rotate to the agar collector position and maneuver above the agar tube. The arm will then slowly lower the collector in the tube. Once the collector is completely submerged it will close. The ROV will then return to the surface to complete the mission.

3. The Lo'ihi Seamount

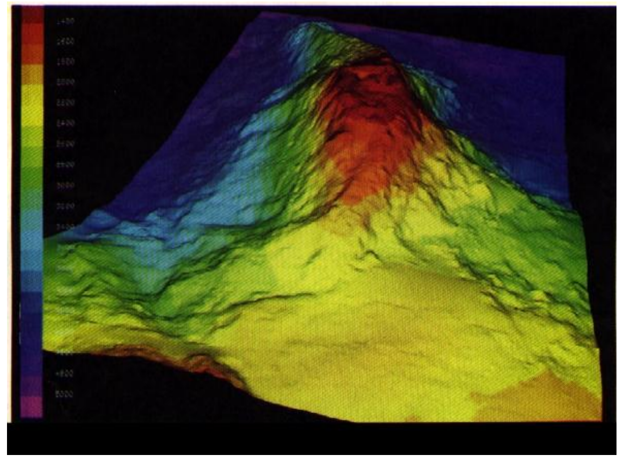


Figure 17: Lo'ihi Seamount (http://www.uhh.hawaii.edu/~kenhon/GEOL205/loihi/loihi7.jpg)

The Lo'ihi Seamount is an active underwater volcano, which lies right next to the Mauna Loa underwater volcano off the southern coast of the Big Island of Hawaii. The Lo'ihi volcano is a part of the Hawaiian-Emperor Seamount Chain. What is different about this chain than most other volcanoes in the Pacific Ocean is that it is not near any tectonic plate boundaries, but rather stems from a hot spot on the earth's crust. The Lo'ihi Seamount is the youngest volcano in the Hawaiian chain, at 400,000 years old. It rises 3,000 meters above the sea floor, and is expected to break the surface of the ocean in another 100,000 years[1]. A topographical map of the seamount can be seen in Fig. 17.

The Lo'ihi Seamount was first included in a map of the sea floor in 1940, on the US Coast Guard Survey Chart 4115. The marine geologist Kenneth O. Emery officially gave the volcano its name in 1955, calling it *lo'ihi,* the Hawaiian word for "long". The first major exploration of the summit took place in 1978 on a US geological research ship. The ship took pictures and samples of the solidified lava and from these scientists were able to determine that the volcano was still active.

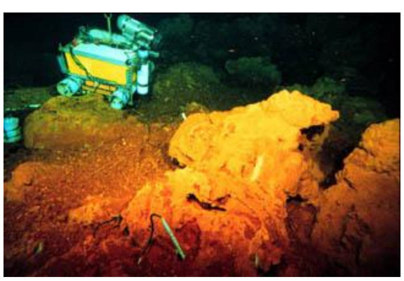


Figure 18: HUGO (http://www.oar.noaa.gov/spotlite/archive/images/robot.jpg)

Immediately after Lo'ihi's eruption in 1996, scientists began collecting data to learn more about the active volcano. The research vessel, Ka'imikai-o-Konoloa, used multibeam bathymetric mapping to create topographic maps of the volcano's new features after its eruption. The Hawaii Underwater Research Lab sent the ROV Pisces V to the site to take samples of minerals from the geothermic vents and the microorganisms that were living off of them. The

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bacteria found feeding off the nutrients expelled by these vents may indicate that new forms of inorganic material are being spewed into the ocean. While the activity and heat surrounding the volcano do make Lo'ihi's wildlife less abundant, some species of monkfish, eel, and shrimp are seen in the area, and a new species of cephalopod was discovered on the site. HURL also installed the Hawaii Undersea Geological observatory (HUGO) on the summit, connected by a 21 mile-long fiber-optic cable to shore. This was the first underwater volcanic observatory. HUGO gave scientists seismic readings, chemical data, and real-time images of the Lo'ihi Seamount until 1998, when the connection was broken. HUGO allowed for the seismic activity at a volcanic hot spot to be measured and also helped scientists predict when the volcano would next erupt. HURL dispatched Pisces V to repair HUGO, which functioned for another 4 years before becoming completely inoperable[2] [3].

Our competition missions simulate repairs to HUGO, as well as collection of data and samples from around the seamount. These data could lead to a deeper understanding of the seamount ecosystem, as well as the geological occurrences surrounding the volcano. They also help to predict eruptions and subsequent happenings in the area, allowing scientists and civilians more time to prepare.

4. Reflections

4.1 Challenges

The team faced a number of technical challenges during the design and construction of the ROV, which were overcome as swiftly and efficiently as possible. One such challenge was transmission of data to the ROV; the Arduino microcontroller and laptop were meant to communicate over USB, but were unable to. We had planned to wire the USB transmit and receive ports directly to 18-gauge wire in the tether for both the topside computer and the on-board micro-controller. However, further research revealed that USB transmission is only designed to work for cords 5 meters or less, so there was no way to communicate between the control computer and the ROV. The team's solution to this was a small USB-to-Serial converter, borrowed from a neighboring lab. The chip plugs into the USB port of the topside computer and can be wired directly to the communication wires already in place, which are then connected to the Serial transmit/receive ports on the microcontroller. This allows us to easily send commands to and receive feedback from the ROV using the computer's USB output.

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[2] NOAA Research- Collapsed undersea volcano gives view of island's birth http://www.oar.noaa.gov/spotlite/archive/spot_nurp.html

[3] School of Ocean and Earth Science and Technology- Loihi after the July-August event http://www.soest.hawaii.edu/HURL/hurl_loihi.html

Perhaps the greatest challenge the team faced, as in most engineering situations, was time. Team members all had jobs and other responsibilities, on top of academics, and it was impossible to find times where everyone could work. Most team members could only contribute a few hours a week, and never at the same time. While there is still no way to gain extra time or to ignore other responsibilities, we were able to find a solution to our unmatched schedules. By setting a brief weekly meeting where team members could come and go, we were able to work mostly autonomously while maintaining integration between systems and efficiently coordinating tasks.

4.2 Troubleshooting Techniques

Troubleshooting is a frequent challenge in engineering, and becomes exponentially more difficult as the hardware and software become more technically complex. On the other hand, the modularity of the individual components greatly improved our troubleshooting ability. Our troubleshooting process is a top-down approach through each component, starting with the topside controls. The first step is always to make sure that everything is connected, from power to controls to the ROV itself. The most common answer to a technical problem is just that someone unplugged a component for testing or safety, and reconnecting easily solves these. For more complex issues, a more thorough approach is required. We work down step by step at the connections between each component, testing the output with an oscilloscope or multimeter. This generally yields an answer, either a broken connection to be fixed or a broken component to be replaced. On the rare occasions that this does not solve our technical problem, we will continue to refine our search until we find the break. Once the break has been fixed, even in the case of a simple unplugged connection, we recheck the whole system to ensure that the problem has been solved.

4.3 Lessons Learned

An overall lesson our team learned this competition season is that constant communication and cooperation among every team member is crucial for a successful design strategy. We saw the benefits of this strategy manifested in our early design phase, when we designed not as individuals or small groups, but as an entire team on many fronts. When we designed as a team, we saw the design process go faster, more creatively, and more efficiently than if we had designed on our own. Not only do we get valuable ideas and perspectives from our fellow team members, but we also learn what systems depend on what other systems and where our bottlenecks are. This realization of dependence on other subsystems helps us to spot what needs to happen next, and when. This developing skill of designing as a team has allowed us to sharpen our abilities to design with each other spontaneously, designing together and incorporating ideas and feedback in real time

4.4 Future Improvements

As a team, we are constantly considering technical improvements that we can make, many of which we have had to delay until the next build. One such improvement is the inclusion of a full on-board computer to replace the current micro-controller board. The AUV team at MIT already uses a full linux-booting computer on their machine, and with netbooks and mobile PCs constantly going down in cost and size, this is becoming an increasingly viable option for ROVs. The change would require a completely new system of communication and far more complicated onboard software, but would allow far greater control and adaptability to other changes. Another technical improvement we'd like is to have camera power and data come through the same tether lines as the rest of the systems, as opposed to individual cables for each camera. This requires a more complex communication system and some way of converting the camera signals on-board the ROV, but would greatly decrease the size of the tether and increase its flexibility. Yet another improvement that we are considering is the inclusion of a hybrid thrust system, combining both the propeller-based thrusters we adopted and the vectored thrust systems that we tested. A hybridized system could give us both the stability and power of propeller thrust systems and the elegance and control of a vectored system.

A major non-technical improvement that the team needs, and that we intend to make, is in communication and sharing of information. Our distribution of systems and weekly check-ins helped with the incompatibility of our schedules and allowed us complete tasks individually, but the team still suffered from lack of time. One basic level improvement is to increase team size, simply allowing us more man hours to contribute and allowing us to assign more than one person to a task. We'll also create a team wiki to increase sharing of data, and make frequent progress reports more mandatory to keep all team members more up-to-date.

4.5 Reflections on a Four Year Experience – Stephanie Chin

Over the past four years, as I've learned things and built stuff and made valuable friends, I can say as I leave this undergraduate institution that I am proud to have been a member of the MIT ROV Team. Year after year we try something bold, and sometimes, we try something so bold we're not even sure it'll work.

This year we tried a new team strategy: work together and work together often. In previous years separate design groups worked on their own subsystems, occasionally conferring with other team members on their thoughts and efforts. This year, we spent much of our January term designing subsystems as a team, with input from every perspective. Designs evolved with many team members' input. There were many design iterations for many of the systems, but with each iteration we saw improvement and judged with a perspective on how they would fit with the rest of the vehicle. On the frame, we worked and reworked the frame design because I kept getting feedback from the other systems: how the thrust vectoring would fit and be mounted within it, keeping spaces open for where the arm would go, what materials and what connections would and would not work.

This year we also took risks - we took risks on our propulsion system, and while not everyone was convinced the thrust vectoring would work out we still took the risk, and gave ourselves a backup plan; if this system did not work by this date, we would go with traditional sturdy ‘ole bilge pump propulsion. This compromise, too, was a new team strategy, taking risks but actively preparing a backup plan we'd all be happy with.

As I leave the team in my final undergraduate year, I feel confident that our experiences from this year and previous years have built a solid foundation for how to build and rebuild a team, year after year, and I feel confident that the team will continue to learn each other's strengths and weaknesses, how to work with each other's strengths and weaknesses, and to continue to use this amazing group of friends to bounce the craziest of ideas off each other. Sometimes, we are bold, and we succeed, and other times we fail, but throughout the past four years I have learned that what I treasure most are the teammates I've learned to work with, learn with, and laugh with.

5. Acknowledgements

All the members of the MIT ROV Team would like to thank our sponsors and advisors for their support, without which we would not be able to continue our hands-on education in marine robotics.

Sponsors
Chevron
MIT Center for Ocean Engineering
MIT Department of Mechanical Engineering
The Edgerton Center
The MATE Center
MIT Sea Grant

Mentors
Prof. Franz Hover

Appendix A
Budget

2009 - 2010 Budget						
Category	Expenses- Components		Expenses -Total		Sponsors	Projected Funds
MATE Robot			$	4,400.00	Beginning of the Year Funds	$ 14,500.00
materials	$	1,500.00			Chevron	$5,000.00
pumps/motors	$	500.00			Edgeton Center	$6,000.00
nozzles	$	300.00			MIT Sea Grant	$500.00
servos	$	1,000.00				
electronics	$	1,100.00				
Tools, hardware	$	800.00	$	800.00		
Food	$	500.00	$	500.00		
Media (poster, t-shirts)			$	350.00		
presentation poster	$	150.00				
t-shirts	$	200.00				
Lodging			$	1,200.00		
double/night	$	100.00				
no. doubles		3				
no. nights		4				
Travel						
Flights	6 People		$	7,200.00		
Car Rental rates plus gas	$	75.00				
no. cars		2				
no. days		4				
Total			$	15,050.00		$ 25,500.00

Appendix B
Power Schematic