2010 MATE International ROV Competition
www.marinetech.org/rov_competition/index.php

ROVs in Treacherous Terrain:
Science Erupts on Loihi, Hawaii's Undersea Volcano

June 24 – 26, 2010
University of Hawaii at Hilo
The Big Island of Hawaii

Competition Missions

COMPETITION OVERVIEW

The ROV competition is divided into two competition classes: **RANGER** and **EXPLORER**. Eligibility requirements for both classes are listed within the **2010 General Information** document. Please review these requirements carefully. (The SCOUT class is also available at the MATE Monterey Bay, Pacific Northwest, Big Island, and Southern California Regional ROV Contests. See the individual web sites of these contests for more information.)

The 2010 competition theme focuses on the Loihi seamount, an active undersea volcano that rises more than 3,000 meters above the seafloor. The mission tasks challenge teams to deploy instruments, take sensor readings, plot data, and collect samples of geologic features as well as organisms that inhabit the volcano's flanks.

The competition consists of underwater missions, technical reports, engineering presentations, and poster displays with the following scoring breakdown:

- Mission
  - **EXPLORER** – 300 points (max), plus a time bonus
  - **RANGER** – 300 points (max), plus a time bonus
- Engineering & communication – 200 points (max)
  - Technical reports – 80 points (max)
  - Engineering evaluations – 80 points (max)
  - Poster displays – 40 points (max)

Information about the **EXPLORER** and **RANGER** class competition missions, including how to build the mission props, is included in ***this*** document, **Competition Missions**; photos of the mission props are located in the document entitled **Mission Prop Photos;** and SolidWorks files of the mission props are located in the document entitled **SolidWorks Assemblies and Drawings.** The **Engineering & Communication** document contains information about the technical report, engineering evaluation, and poster display.

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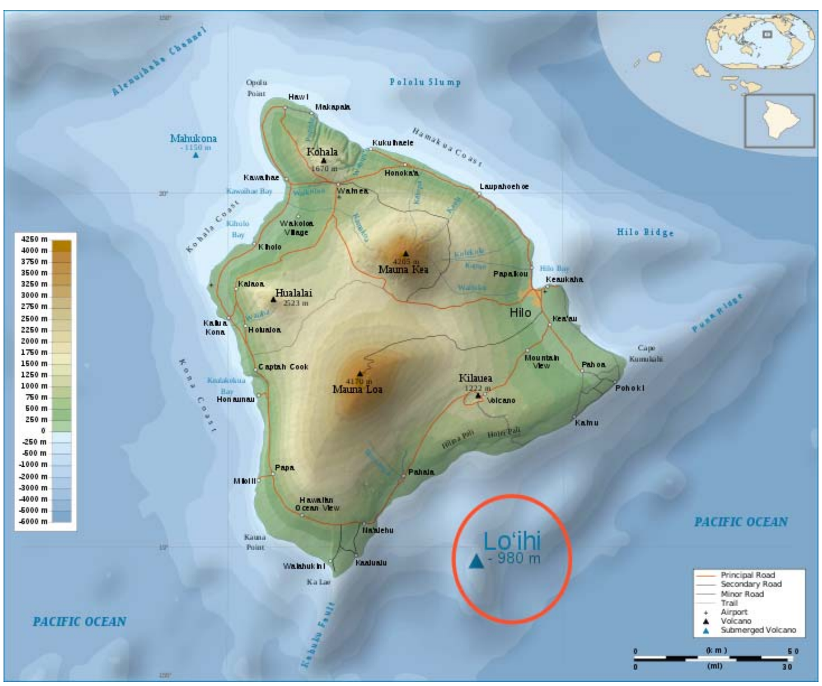
ROVs in Treacherous Terrain: Science Erupts on Loihi, Hawaii's Undersea Volcano

The Loihi seamount is an active undersea volcano located approximately 35km off the southeast coast of the Big Island of Hawaii. It is the newest volcano in the Hawaiian-Emperor seamount chain, a string of volcanoes that stretches more than 5,800km northwest of Loihi and the Big Island of Hawaii. This seamount chain consists of over 80 undersea volcanoes; the Hawaiian Islands are the "links" of this chain that rise above sea level. Loihi began forming around 400,000 years ago and, at its current rate, is expected to begin emerging above sea level about 10,000–100,000 years from now.

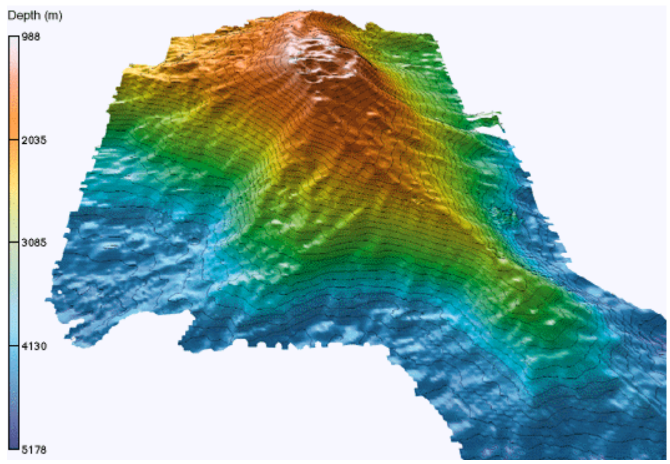
The Hawaiian-Emperor Seamount chain was created by the Pacific plate moving over the Hawaiian hotspot. While most volcanic activity occurs along the boundaries of tectonic plates, hotspots are areas where volcanic activity occurs over long periods of geologic time as a narrow stream of hot liquid mantle moves up towards the Earth's surface as the tectonic plate passes over. Loihi lies on the southeast flank of the Mauna Loa volcano that presently sits over the Hawaiian hotspot. Mauna Loa is the largest volcano on Earth in terms of area covered and still very active today.



The location of Loihi relative to Hawaii's Big Island

(courtesy of http://en.wikipedia.org/wiki/File:Hawaii_Island_topographic_map-en-loihi.svg)

Loihi consists of a summit area with three pit craters; an 11km long rift zone, an area of long cracks and fissures from which lava can extrude that extends north from the summit; and a 19km long rift zone that extends south-southeast from the summit. At its summit, the seamount stands more than 3,000m above the seafloor, making it taller than Mount St. Helens, the volcano in Washington state that erupted catastrophically in 1980.

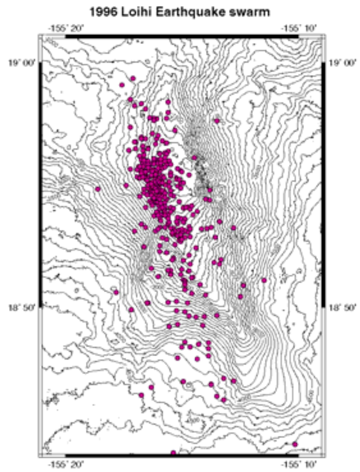


A bathymetric map of the Loihi seamount
(courtesy of http://oceanexplorer.noaa.gov/explorations/02hawaii/background/plan/plan.html)

Scientists initially thought that Loihi was an old, "dead" seamount that is common around the Hawaiian Islands. That understanding changed in 1970 after an "earthquake swarm" of intense, repeated seismic activity sent researchers racing to the summit. Their investigations revealed that Loihi was a young, active volcano, rather than an old dead seamount from a bygone eon, covered with lava flows and actively venting hydrothermal fluids.

1996 Earthquake Swarm

In August of 1996, Loihi rumbled to life again with a vengeance. Between July 16 and August 9, more than 4,000 earthquakes were recorded. This swarm of earthquakes was the largest ever recorded for any Hawaiian volcano in both amount and intensity. Most of the earthquakes had magnitudes of less than 3.0 on the Richter scale. Several hundred had magnitudes greater than 3.0, including more than 40 with magnitudes of over 4.0.



(courtesy of www.soest.hawaii.edu/GG/HCV/loihi_j_a_1996.html)

A rapid-response research cruise was launched almost immediately after the seismic activity was detected. Scientists viewing the scene found that visibility was greatly reduced by high concentrations of displaced minerals and large floating mats of bacteria in the water column.

Additional research cruises to the site took place in September and October. These more detailed studies showed that "Pele's Vents," the southern portion of Loihi's summit named after the Hawaiian goddess of the volcano, had collapsed – a result of the earthquakes and the rapid withdrawal of magma from the volcano. A crater 1km across had formed out of the rubble. Renamed "Pele's Pit," the crater has extremely steep walls and is nearly 300m deep.

The earthquakes also resulted in the creation of new areas of hydrothermal venting along the floor of the crater. In just a few short weeks, bacteria had already begun colonizing these sites.

Hydrothermal vents

The bottom of Pele's Pit and Loihi's north slope are sites of spectacular and extensive hydrothermal venting, with temperatures ranging from 30°C to nearly 200°C. Diverse microbial mats surround the vents and cover the nearly vertical walls of the pit.

Interactions between hot rock and seawater beneath the ocean floor result in high-temperature hydrothermal vents (less than 200°C to greater than 400°C). The fluids emerging from these vents form sulfide and sulfate precipitates when they mix with the cold, sulfate-rich seawater. These types of vents are predominantly found at mid-ocean ridges where the precipitates can form giant chimney-like structures called black smokers.

Prior to the seismic events in 1996, Loihi's hydrothermal vents had emitted only low temperature fluids (less than 30°C), which precipitated iron oxide and iron-rich clay minerals. The sulfide and sulfate minerals collected from Pele's Pit during the October 1996 expeditions were the first time high-temperature hydrothermal venting had been documented on an oceanic seamount.

While the metabolism of the sulfur-oxidizing bacteria can produce spectacular structures, it is the iron-oxidizing bacteria that dominate Loihi's landscape. The venting fluids of the seamount are especially high in both iron and carbon dioxide, which is the ideal environment for these bacteria to thrive. Mats of iron-oxidizing bacteria carpet Loihi and give the seamount a rust-colored glow. The seamount is also home to other microbes, including one species of high-temperature bacteria that was the first to have its entire genome sequenced.

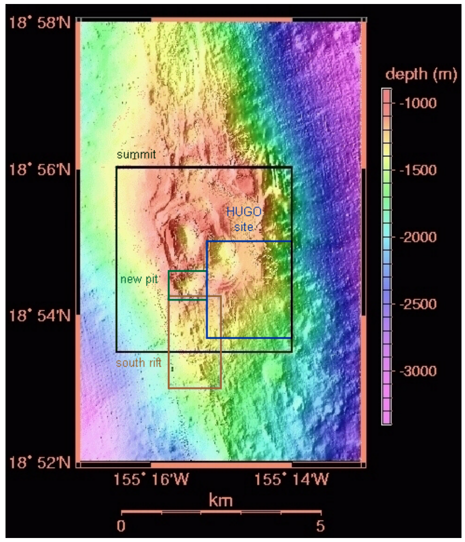
Sampling a bacterial mat on Loihi
(courtesy of www.soest.hawaii.edu/HURL/video2.html)

Marine life inhabiting the waters around Loihi is not as diverse as life at other, less active seamounts. Fish found living near Loihi include the Celebes monkfish and members of the cutthroat eel family. Invertebrates include a bresiliid shrimp and a tube or pogonophoran worm, two species that are endemic to the hydrothermal vents. Animals new to science, including a species of cephalopod, have also been discovered on the seamount.

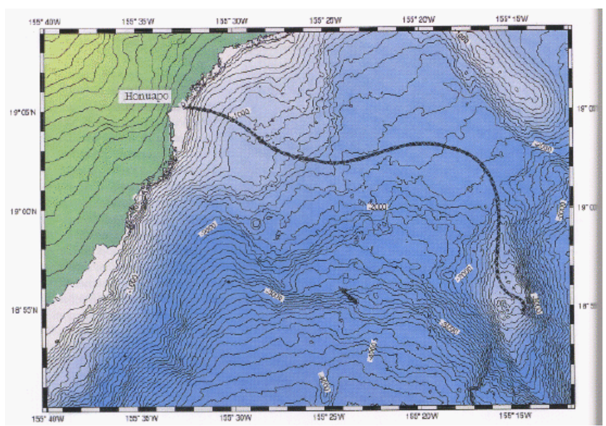
HUGO

The 1996 event made it clear that scientists needed a better way to monitor the seamount and collect information about its activity in a more timely fashion. In response to this need, the Hawaii Undersea Geological Observatory (HUGO) was installed on the summit of Loihi in October of 1997. It was the first undersea volcano observatory, giving scientists real-time seismic, chemical, and visual data about the state of the seamount.

HUGO communicated with and received power from a shore station in Honuapo Bay on the Big Island via a fiber optic more than 40 km long. The far end of the cable was connected to the HUGO junction box, the hub and lifeline of the observatory. From the junction box the cable was laid along the length of Loihi's north rift zone then continued across the relatively flat bathymetry to Honuapo Bay on the Big Island. There the cable terminated at the HUGO shore station. The initial instrument package deployed on the seafloor and connected to HUGO's junction box included a high-rate hydrophone and pressure and temperature sensors.

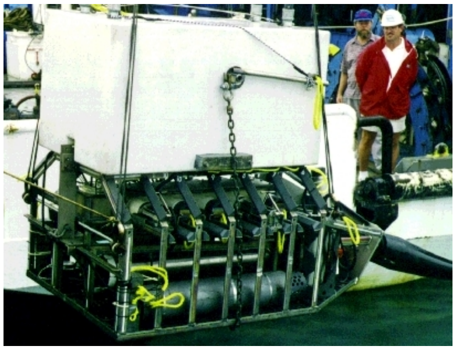


A bathymetric map of Loihi's summit with the location of HUGO (and the new, Pele's Pit) highlighted
(courtesy of www.soest.hawaii.edu/GG/HCV/loihi-tour.html)



More than 40km of fiber optic cable links HUGO to shore
(courtesy of www.soest.hawaii.edu/GG/HCV/LTOUR/hugo.site.gif)

The cable that provided HUGO with power and communications flooded in October of 1998, effectively shutting down the observatory and its data stream. The cable was repaired in January of 1999, allowing HUGO to function for another four years before the cable failed again in 2002. Thus far, the cable has not been repaired or replaced. HUGO is no longer operational.



HUGO's junction box being lowered to the seafloor
(courtesy of www.soest.hawaii.edu/GG/HCV/LTOUR/hugo1a.jpg)

HURL

The Hawaii Undersea Research Laboratory (HURL), NOAA's National Undersea Research Center for Hawaii and the Western Pacific, conducts regular monitoring and supports research projects that study Loihi as well as deep water marine processes in the Pacific Ocean. Located on the island of Oahu, HURL's facilities include two deep-diving (2000 m) submersibles, the *Pisces V* and *Pisces IV*. HURL also maintains and operates an ROV, the *RCV-150*, and the support ship R/V *Kaimikai-o-Kanaloa*.

The *Pisces V*, in particular, has played an important role in the exploration and study of Loihi. It has been the workhorse of scientists from HURL and around the world who investigate the seamount's geology, volcanism, hydrothermal systems, and microbial communities. During its lifetime, the submersible has made over 50 dives to Loihi, collecting data, sampling organisms, deploying instruments, and repairing HUGO.

HURL's Pisces V submersible
(courtesy of www.soest.hawaii.edu/HURL/pisces_V_specs.html)

However, like HUGO, the *RCV-150*, and the other technologies and underwater vehicles that visit the volcano's summit, the *Pisces V* has experienced the challenge of working in this very treacherous terrain. Dives to the site can be quite precarious, and often tasks are aborted after being deemed too unsafe for the vehicle and its crew.

But the work on Loihi is far from over. As long as there is still so much more to discover and learn about this newest Hawaiian Island, scientists will continue to ask the designers and operators of underwater technologies to push the envelope of their engineering and skill.

And this is where your mission begins…

REFERENCES

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OVERVIEW

EXPLORER and **RANGER** class teams will compete in ONE mission that consists of the following four distinct tasks:

Task #1: Resurrect HUGO (100 points)
Task #2: Collect samples of a new species of crustacean (60 points)
Task #3: Sample a new vent site (80 points)
Task #4: Collect a sample of a bacterial mat (60 points)

Both **EXPLORER** and **RANGER** class teams will get **TWO** attempts to complete this single mission. The higher of the two scores will be added to the engineering and communication score to determine the total, overall score for the competition.

Teams have 5 minutes to set up their system, 15 minutes to complete the mission tasks, and 5 minutes to demobilize their equipment and exit the control shack. During the 5-minute set-up, teams may place their vehicle in the water for testing and/or trimming purposes, provided that a team member has the vehicle in their grasp at all times. In order to ensure that all teams have the opportunity to complete two mission attempts, the 15-minute mission period will begin after the full 5 minutes of set up time expires, regardless of whether teams are ready to start the mission.

During the mission, teams may pilot their ROVs to the surface and remove the vehicle from the water at any time for such things as buoyancy adjustments, payload changes, and trouble shooting, but the clock will only be stopped by a judge who deems it necessary for reasons beyond the teams' control. Otherwise, the clock will only stop after all four mission tasks are successfully completed, the ROV has returned to the surface under its own power so that it touches the side of the pool, and a team member at the launch station has physically touched the vehicle. The ROV is not required to return to the surface between mission tasks.

The 5-minute demobilization begins as soon as the 15-minute mission time ends, regardless of where the ROV is located (i.e., still at depth, on the surface, etc.). Teams that 1) successfully complete all four mission tasks; 2) return their ROV to the surface under its own power so that it touches the side of the pool; and 3) a team member at the launch station physically touches the vehicle before the mission time ends will receive a time bonus.

TIME BONUS

Teams will receive 1 point for every minute and 0.01 point for every second under 15 minutes remaining. Your mission performance period ends when your ROV has successfully completed ALL FOUR OF THE MISSION TASKS, returned to the surface under its own power so that it touches the side of the pool, and a team member at the launch station has physically touched the vehicle. Time bonus points will be awarded accordingly.

GOOD LUCK!

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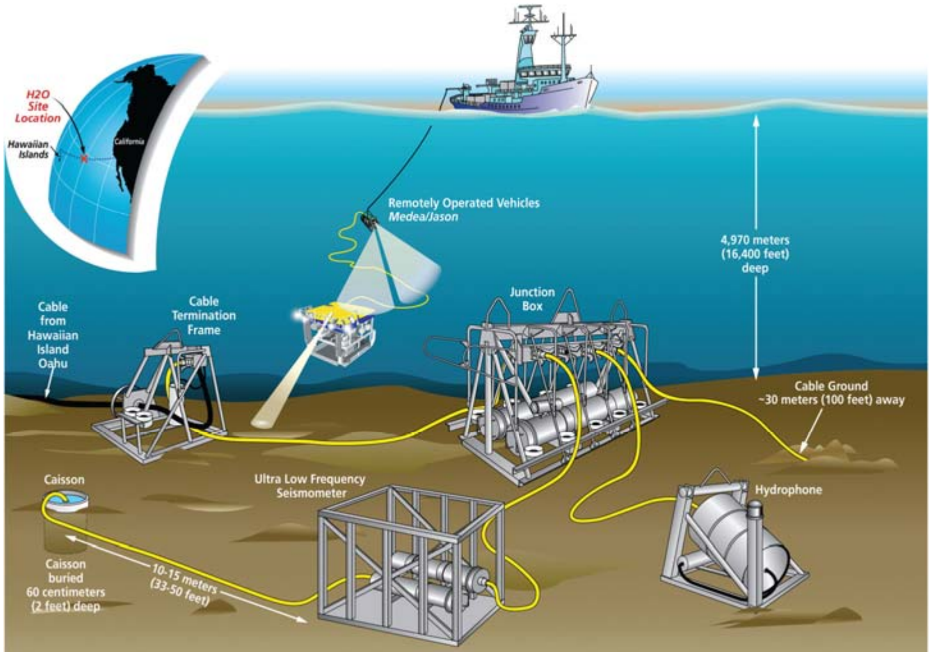
Task #1: Resurrect HUGO

Scientists, engineers, and technicians are working to resurrect HUGO and make it operational once again.

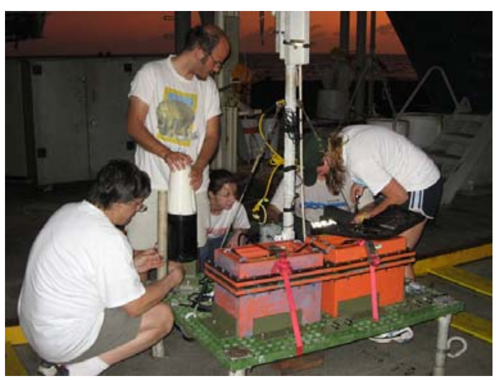
During a recent trip to the site, the main power/communications cable and junction box were installed on the seafloor. After connecting the junction box to one end of the main power/communications cable, the ship's crew lowered it to the summit of Loihi. The ship then sailed toward shore, laying 50km of the fiber optic cable as it went. When the ship reached port, the crew transferred the cable to technicians waiting on shore. From there, the cable was terminated then spliced into the shore-based research station.

In a subsequent expedition, HURL's *Pisces V* submersible visited the site to make sure that the box was positioned properly. The submersible then anchored the box firmly in place. The system is now powered up and ready to go!

Given a recent swarm of earthquake activity, seismologists on the scientific team are eager to begin collecting data. While the *Pisces V* was securing the junction box, the seismologists worked with the ship's crew to deliver a high-rate hydrophone (HRH) to the area. They accomplished this using an "elevator," which is a platform designed to carry bulky or heavy items and equipment to and from the seafloor independent of an ROV or submersible. It uses weight and flotation and/or a lift line from the ship. Currently the elevator, with the HRH securely attached, rests near the junction box.



A high-rate hydrophone and other oceanographic instrumentation from the Hawaii-2 Observatory (H2O)
(courtesy of Woods Hole Oceanographic Institution)



Scientists from Woods Hole Oceanographic Institute attach instruments to an elevator for deployment.
(courtesy of www.whoi.edu/page.do?pid=21075)

Your task is to locate an area of seismic activity ("rumblings"), release the HRH from the elevator, and install it at that spot. From there, your task is to open the port on HUGO's junction box and connect the HRH's cable to the port so that it receives power and, more importantly, begins to transmit data to the seismologists back on shore.

This mission task involves:

- **Removing pins to release the HRH from the elevator.**
- **Removing the HRH from the elevator.**
- **Identifying which of three potential sites is rumbling (generating sound).**
- **Installing the HRH within a 0.5m by 0.5m square at the site that is rumbling.**
- **Removing the cap from the port on the HUGO junction box.**
- **Retrieving the HRH power/communications connector from its holder on the elevator.**
- **Inserting the HRH power/communications connector into the port on the HUGO junction box.**

EXPLORER class scoring – up to 100 points:

- Removing TWO pins to release the HRH – 5 points for each pin (up to 10 points total)
- Removing the HRH so that it is no longer in contact with the elevator – 10 points
- Identifying which of three potential sites is rumbling (generating sound) – 20 points
- Determining the frequency of the sound within ±200Hz – 20 points
- Installing the HRH within a 0.5m by 0.5m square at the site that is rumbling – 10 points
- Removing the cap from the port on the HUGO junction box – 10 points
- Retrieving the HRH power/communications connector from its holder on the elevator – 10 points
- Inserting the HRH power/communications connector into the port on the HUGO junction box so that it remains in the port after your ROV releases it – 10 points

RANGER class scoring – up to 100 points:

- Removing ONE pin to release the HRH – 10 points
- Removing the HRH so that it is no longer in contact with the elevator – 10 points
- Identifying which of three potential sites is rumbling (generating sound) – 20 points
- Installing the HRH within a 0.5m by 0.5m square at the site that is rumbling – 20 points
    - Installing the HRH within a 0.5m by 0.5m square at a site that is NOT rumbling – 5 points
- Removing the cap from the port on the HUGO junction box – 10 points
- Retrieving the HRH power/communications connector from its holder on the elevator – 10 points
- Inserting the HRH power/communications connector into the port on the HUGO junction box so that it remains in the port after your ROV releases it – 20 points

Mission notes

The individual steps of this task can be completed in any order EXCEPT for the step of removing the cap from the port. The cap must be removed FIRST before inserting the HRH's power/communications connector. Teams do not need to place the HRH at the rumbling site in order to earn points for releasing and removing the HRH from the elevator; removing the cap of the junction box port; AND retrieving and installing the power/communications connector.

The HRH is attached to a small platform which is, in turn, attached to the elevator. The hydrophone is held in place by either ONE pin (RANGER class) or TWO pins (EXPLORER class). The HRH's power/communications cable is 5 meters long. One end of the cable is attached to the hydrophone, while the other end attaches to the power/communications connector. The connector rests in a holder that is secured to the elevator. The length of the cable is coiled and rests on the elevator.

There are three potential areas on the seafloor that are generating sound. These areas appear as "rocky outcroppings." Each rocky outcropping covers a PVC housing. Only one of the PVC housings contains a small "buzzer" – that is, only one outcropping is "rumbling."

Teams must identify which of the three outcroppings is generating sound and install the hydrophone at that location. "Identify" means that teams detect then demonstrate the sound to the mission station judges. This demonstration can take the form of sound generated through a speaker or headphones or as a graphical display, such as a read out on a video or computer screen. The mission station judges must be able to detect this sound either audibly or visually.

EXPLORER class teams have the additional challenge of determining the frequency of the sound then demonstrating this to the mission station judges. Teams must show the judges the detected frequency using an instrument or computer display. The display can be numerical or graphical. Teams must show the judges the detected frequency and provide a way to show that the audio level at the rumbling site is higher than at the other two locations. A frequency within ±200Hz of the "benchmark" receives full points (20).

To be eligible for a time bonus, teams must correctly identify the rocky outcropping that is rumbling and install the HRH at that site.

The HRH is released from the elevator by removing ONE (RANGER class) or TWO (EXPLORER class) pins. Once removed, the pins can be placed on the seafloor; teams are **NOT** required to return the pins to the surface. From there, teams must physically separate the HRH from the elevator; teams **CANNOT** lift the entire elevator from the seafloor and install it, with the HRH still attached, at the rumbling site.

Teams must deploy the hydrophone within a 0.5m by 0.5m PVC square. One PVC square is located adjacent to each rocky outcropping. Teams must install the entire structure of the hydrophone on the seafloor within this square at the rumbling site to receive full (10 or 20) points. If the hydrophone is subsequently moved or dragged out of this site, teams will lose the points they received. To regain those points, teams must reinstall the hydrophone within the 0.5 meter square at the rumbling site before the mission time ends. Only RANGER class teams can receive partial (5) points for installing the HRH at a site that it NOT rumbling.

The cap is secured to the junction box port via a length of chain. Once removed, teams can place this cap on the seafloor or release this cap so that it hangs freely.

Mission prop specifications

See the **Mission Prop Photos** and **SolidWorks Assemblies and Drawings** documents for visuals.

Elevator:

The elevator is constructed out of ½-inch PVC. The horizontal face of the elevator is approximately 44cm by 48cm. The base (platform) of the elevator sits 15cm above the bottom of the pool and is covered with ¾-inch plastic mesh. A central spire of PVC rises 65cm above the elevator platform, 80cm above the bottom of the pool. A 1 ½-inch PVC end cap is secured to the base of the elevator. It serves as the holder for the HRH's power/communication cable connector.

Construct the elevator using ½-inch PVC. Start by inserting one end of a 15.5cm length of pipe into a short arm of a sideout (corner piece). Insert the other end of the pipe into one side of a PVC tee. Insert one end of a 3cm length of PVC pipe into the other side of the tee. Insert the other end of the 3cm length into another PVC tee. Insert a second 15.5cm length of PVC pipe into the other side of this PVC tee then attach a short arm of another sideout to this pipe. You have just completed one side of the elevator. Repeat this process to construct the other side of the elevator.

Construct the third side of the elevator by inserting a 14cm length of PVC pipe into the short arm of one of the sideouts from a previously constructed side. Insert the other end of the pipe into one side of a PVC tee. Insert a 4cm length of PVC pipe into the other side of this tee. Attach a PVC connector to the other end of this 4cm pipe. Insert another 14cm length of pipe into the other end of the connector. Insert the other end of this 14cm length of pipe into the sideout opening of the other completed side of the elevator. By doing this you have just completed three of the four sides of a 48cm by 44cm rectangle.

Complete the fourth side of this rectangle by inserting one end of a 14cm length of pipe into a short arm of either corner sideout. Insert the other end of this pipe into a PVC tee. Insert a 3cm length of pipe into the other side of this tee. Attach another PVC tee to this 3cm length of pipe. Finish this side by connecting another 14cm length of PVC pipe from this PVC tee to the sideout from the far side, completing the rectangle base.

Cut three more lengths of 15.5cm PVC pipe and four more lengths of 14cm PVC pipe. Insert the three lengths of 15.5cm PVC pipe into the tee openings so that they correspond with the 15.5cm pipes in the rectangle. Similarly, insert the four lengths of 14cm PVC pipe into the tee openings so that they correspond with the 14cm pipes in the rectangle. Use two PVC crosses, one PVC tee, and one sideout (the long arm with adapter should be facing up) to complete this center portion of the elevator. Use 3cm pipe to connect this center portion together.

Each corner of the elevator has a sideout with the long arm (male adapter arm) pointing down. Insert a 6cm length of PVC pipe into each long arm of these sideouts. Attach a 90^{o} elbow to each 6cm length of pipe. Cut two lengths of 36cm pipe. Connect two of the elbows with one length of 36cm pipe and the other two elbows with the second length of 36cm pipe. This forms the base of the elevator.

In the center, the sideout should be positioned so that the open, long adapter arm is facing up. Insert a 62cm long length of PVC pipe into the long arm of this sideout. This length is the elevator's central spire.

Fit the top of the elevator platform with a plastic mesh. Note: Chicken wire or other mesh may be substituted for the ¾-inch gray, hexagonal mesh shown in the photos. You may need to cut a small hole in the mesh to allow it to properly fit over the spire. Use cable ties or other fasteners to secure the mesh to the platform.

Use two screws to connect a 1 ½-inch PVC end cap onto the PVC cross that is adjacent to the spire of the elevator. The open end of the end cap should be facing up. Insert an 8cm length of 1 ½-inch PVC into this end cap.

The elevator is secured to the bottom of the pool with weights.

Platform and pins:

The platform of the elevator is a rectangle (23cm by 19cm) constructed out of ½-inch PVC.

Construct the platform by cutting two 16cm lengths of PVC pipe and two 12cm lengths of PVC pipe. Use four 90^{o} elbows to form a rectangle that is approximately 23cm by 19cm.

Cut a section of flat 1/8-inch ABS plastic sheeting to the dimensions of 22cm by 18cm. Secure the four corners of the sheet into the corners of the platform using screws. (Check sign-making/printing stores for black plastic ABS sheeting. Alternatively, Plexiglass or Lexan sheeting may be substituted.)

The mechanism to secure the hydrophone to the platform is made out of ¾-inch angle aluminum, 1/16-inch thick (Home Depot Part # 796-942. Many other hardware stores have angle aluminum as well). RANGER class teams need to cut two 7.5cm lengths of this angle aluminum. EXPLORER class teams need to cut four 7.5cm lengths.

Drill a 5/16-inch hole through each length of the angle aluminum at the midpoint, approximately 3.75cm from the end. The hole should be drilled as close to the outer edge (away from the 90^{o} bend) of the angle aluminum as possible. A rat tail file can be used to remove any barbs or edges around the hole.

Next, you will need to secure the angle aluminum sections to the ABS sheeting of the platform. With the undrilled side of the angle aluminum face down, use small screws (6-20 ½-inch sheet metal screws) at each end to fasten the sections of angle aluminum to the black plastic sheet. One 7.5cm length of angle aluminum should be located flush along the short, 19cm-edge of the plastic sheet. The other length of angle aluminum should mirror the first length, with the sections that are flushed with the black plastic sheet touching. Align these two sections of angle aluminum so that the two 5/16-inch holes line up as closely as possible. The pin that holds the hydrophone to the platform must pass through both of these holes. EXPLORER class teams should repeat this process on the opposite edge of the ABS sheet with their second set of angle aluminum sections.

Use cable ties, hose clamps, or rope to secure the platform to the elevator. The platform should be secured to the corner farthest from the vertical arm of the elevator.

To attach the hydrophone to the platform, insert a pin through the hole of the outer section of angle aluminum, through the hole drilled into the PVC of the high rate hydrophone (see the high rate hydrophone mission prop specifications below), and through the hole of the inner section of angle aluminum. This will secure the hydrophone to the platform until the pin is removed. The pin is a 6-inch J-bolt with ¼-inch threads (ACE Hardware part #57933).

It will take less than 1 Newton of force to pull the pin and release the hydrophone.

<u>High rate hydrophone</u>:
The HRH is constructed out of a 20cm length of 3-inch ABS pipe. The bottom of the hydrophone is a 3-inch PVC end cap; the top of the hydrophone is a flat, 3-inch knockout end. Five meters of 1/8-inch polypropylene rope serves as its power/data communications cable.

To construct the HRH, drill a 3/16-inch hole into the center of the PVC end cap. Insert one end of the polypropylene rope into this hole and tie a knot so that the rope is secured inside the cap. Attach this end cap to one end of the 20cm length of 3-inch ABS pipe (3-inch PVC may be substituted for the ABS pipe). Cover the other end with a 3-inch knockout end (ACE Hardware part #45963). Alternatively, use a 3-inch round piece of flat plastic to cover the upper end of the hydrophone instead of a 3-inch knockout end. Drill several holes in the length of 3-inch pipe so that it is free-flooding.

Design note: The inner section of the HRH is the ELSS pod from the 2009 MATE competition mission. Remove the U-bolt and insert the 5 meter length of 1/8-inch polypropylene rope.

A protective framework of ½-inch PVC is fitted around the inner section of the high rate hydrophone.

To construct this framework, cut two 13.5cm lengths of PVC pipe and two 11cm lengths of PVC pipe. Insert these into the short arms of three sideout (corner) pieces and one 90^{o} elbow to make a rectangle that is approximately 19cm by 16cm. The long male adapter arms of each sideout should be left open and face the same direction (up).

With the base of the framework laid flat and the long male adapter arms facing up, move clockwise from the 90^{o} elbow to the first sideout. Insert a 3cm length of pipe into the open, long adapter arm of the sideout. Insert the other end of this pipe into the side of a PVC tee. Insert a 15cm length of PVC pipe into the other side of this PVC tee and cap the pipe with a ½-inch end cap. Moving clockwise to the next sideout (opposite the 90^{o} elbow), insert a 9cm length of PVC pipe into the open, long adapter arm of this sideout. Insert the other end of this pipe into the side of a PVC tee. Insert a 3cm length of PVC pipe into the other side of this PVC tee. Move clockwise to the final sideout and insert a 15cm length of PVC pipe. Next, take an 11cm length of PVC pipe and attach a 90^{o} elbow to each end. This should top off the hydrophone frame, reaching from the top of one open pipe to the top of the other. Finish off the hydrophone frame by adding a diagonal crossbeam. Turn the two middle openings of the PVC tees towards each other. Insert a 3cm length of PVC pipe into each opening. Attach a 45^{o} elbow to each length of PVC pipe so that the open ends of these elbows face each other. Use a 5cm length of pipe to connect the two 45^{o} elbows together. Note that slight adjustments may need to be made to counter small variations in PVC and cut lengths. Adjust PVC lengths accordingly.

Use multiple long screws (2-inch or longer screws) to secure the high rate hydrophone (3-inch pipe and end cap) to the framework. Position the high rate hydrophone along the side with the cross brace.

RANGER class teams need to drill a hole through one of the pipes that makes up the base rectangle of the hydrophone framework. Use a 5/16-inch drill bit to create a hole through the center of one of the 11cm lengths of PVC pipe. The position of this hole needs to be calculated carefully, as it needs to line up precisely with the two 5/16-inch holes drilled through the angle aluminum. The pin will fit through all three of these holes to secure the high rate hydrophone to the platform. EXPLORER class teams need to drill a hole though both sections of 11cm pipe.

Design note: Measure and drill holes carefully. They must be precisely aligned with the holes drilled into the angle aluminum or the pin will be difficult to remove.

There are no handles or lift mechanisms on the hydrophone. Teams may pick it up by the frame, by the hydrophone, or by other means.

The EXPLORER class HRH weighs less than 2.5 Newtons in water.
The RANGER class HRH weighs less than 1.5 Newtons in water.

Flotation or weights can be inserted into the 3-inch PVC pipe to achieve the desired weight and to provide stability.

The polypropylene rope that represents the HRH's power/data communications cable is 5 meters long and extends from the base of the hydrophone and terminates in the power/communications connector. It is this connector that teams must insert into the port on the HUGO junction box.

The connector is constructed out of ½-inch PVC and, all total, is 20cm long.

Cut a length of 15cm PVC pipe. Insert one end of the pipe into the center opening of a ½-inch PVC tee and insert the other end into a ½-inch end cap. Insert a length of 4cm PVC pipe into each side opening of the PVC tee. Cut a 3cm square of Velcro loops and attach it to the outside of the ½-inch end cap. The corner edges of the Velcro will fold over the side of the PVC end cap. Use a pair of small screws (6-20, ½-inch sheet metal screws) to hold two of the corner edges of Velcro securely onto the end cap so that the connector can solidly attach to the HUGO junction box. Drill a 3/16-inch hole into the top, center of the PVC tee. Insert the remaining, unattached end of the polypropylene rope into this hole and tie a knot to secure the rope inside the connector.

The HUGO connector will weigh less than 0.5 Newtons in water. Flotation or weights can be inserted into the 3-inch PVC pipe to achieve the desired weight and to provide stability.

HUGO:

The HUGO junction box serves as the power and communications "hub" for scientific instruments. HUGO is constructed out of a ½-inch PVC frame with a solid sheet of 1/8-inch black ABS plastic as its working face. This working face is 31cm by 31cm and sits at a 45^{o} angle. The port for the hydrophone's power/communications connector is constructed out of a 2-inch PVC connector. A 2-inch PVC connector has a 6cm diameter opening. This connecter is located approximately in the center of the 31cm by 31cm ABS sheet, but may be offset by up to 3cm in any direction. The connection port is 12.5cm deep. The back end of the port is covered with Velcro hooks to hold fast when the connector's Velcro loops are inserted. A protective cap covers the port on HUGO.

To construct the HUGO framework, start with a ½-inch PVC sideout with adapter. Insert a 21cm length of PVC pipe into the long, male adapter arm of the sideout. Insert the other end of this pipe to the long, male adapter arm of another sideout. Line up the two short arms of each sideout so that they are mirror images of each other. Insert one end of an 11.5cm pipe into one of the short arm openings; insert the other end of this pipe into a 45^{o} elbow. Insert a 5cm length of PVC pipe into the other side of this elbow; insert the other end of this pipe into a side opening of a PVC tee. Insert a 10cm length of PVC pipe into the other side of the PVC tee; insert the other end of this pipe into the side opening of another PVC tee. Insert a 5cm length of PVC pipe into the other side of this PVC tee; insert the other end of this pipe into a 45^{o} elbow. Insert a 3cm length of PVC pipe into the other side of this 45^{o} elbow; insert the other end of this pipe into the long end of a sideout with adapter. Use a 33cm length of PVC pipe to connect this sideout to the very first sideout to complete a loop. This creates one side of the PVC framework of HUGO. Repeat this procedure in mirror image to create the other side of HUGO.

Cut five lengths of 24cm PVC pipe. Use these lengths to create five cross beams that connect the tees and the remaining open ends of the three sideouts. This should complete the framework of the HUGO junction box.

The working face of HUGO is a 31cm by 31cm section of 1/8-inch black ABS sheet. Cut a 6cm hole directly in the center of the sheet. Use an appropriately sized hole saw or Dremel cutting tool to create this hole. Alternatively, the 6cm hole can be created by drilling a series of very small holes in a 6cm circle and punching the section out. When complete, the plastic sheet should have a hole approximately 6cm in diameter.

Design note: The size of the hole is very important. A length of 2-inch PVC pipe should be able to fit through this hole, but a slightly larger 2-inch connector and 2-inch end cap should not be able to fit through the hole. Measure or trace carefully to create the proper size hole.

Take a 2-inch PVC end cap and secure a 5cm by 5cm piece of Velcro hooks to the inside bottom face. Insert a 6cm length of 2-inch PVC pipe into the end cap. Push the other end of the 2-inch pipe through the 6cm hole in the black ABS sheet. The hole through the sheet should be just big enough to allow the 2-inch pipe to pass through, but not big enough to allow the 2-inch end cap to pass through. Attach a 2-inch connector to the 2-inch PVC pipe. Pushing these together should "lock" the connector and end cap on either side of the black plastic ABS sheet. Using screws, secure this ABS sheet, with the 2-inch connection port, onto the 45^o slope of the HUGO framework.

The cap that covers the HUGO connection port is comprised of a 3-inch PVC end cap with a U-bolt. The lift mechanism is a 1-3/8 inch by 3-7/8-inch long style U-bolt (ACE Hardware part #51612) that is attached to the top of the end cap. The U-bolt extends 6 cm above the top of the end cap. U-bolts of different lengths can be used if 3-7/8-inch bolts cannot be found. The end cap is attached to the HUGO junction box by a 40cm length of small black chain (#14 Jack chain twisted links, Home Depot part #533-880 or #100 black chain, ACE Hardware part # 5370457). Use small U-nails to attach one end of this chain to the bottom edge of the 3-inch end cap. Attach the other end of the chain to the 45^o elbow on the bottom, left-side of the working face of HUGO. The U-nail inserted into the end cap may need to be cut off or filed down so as not to interfere with the end cap fitting over the port.

The cap will weigh less than 1 Newton in water.

Design note: The HUGO cap, consisting of a 3-inch PVC end cap and U-bolt, is the top portion of an ELSS pod from the 2009 MATE competition mission.

Sound generator:

The three rocky outcroppings are simulated by milk crates. Each rocky outcropping has a PVC housing attached to it. Only one of the three PVC housings has a sound generator.

The three rocky outcroppings are labeled A, B, and C in 3-inch lettering (Home Depot part #436-361, ACE Hardware part #79325). These letters are glued to an appropriately sized piece of flat plastic. These letters will allow teams to identify which of the three outcroppings is generating sound.

Attached to one side of each rocky outcropping is 0.5m by 0.5m PVC square. These squares are constructed out of ½-inch PVC pipe with four 90^o elbows at the corners. All the squares will be painted black. Use cable ties or rope to secure the square to the milk crates that simulate the rocky outcropping. Use weights to hold the squares to the pool bottom.

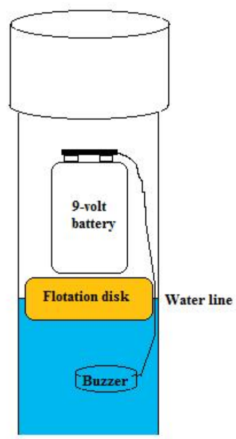
The sound is made from a Piezo Buzzer with a frequency between 1000Hz and 5000Hz. The voltage range of the buzzer is 1.5 to 28 volts DC.   Before being placed into its housing as shown in the figure below, the output sound level may vary between 50 to 75db depending upon the applied voltage.   The buzzer is powered by a 9-volt battery.

The buzzers used are one (or more) of the following:

Radio Shack part #s	DigiKey #s
273-074	102-1637-ND
273-059	102-1122-ND
273-060	458-1068-ND
	102-1630-ND
	102-1642-ND

To assemble, solder the buzzer to a small battery connector, using shrink wrap with sealant to waterproof the wire connections. Cut a small square of flat metal, approximately 1.5cm by 1.5cm. You may use a flat metal plate, angle aluminum, or even a coin. Use 5-minute epoxy to glue this metal over the front of the buzzer, covering the small hole that emits the noise. Use another drop of 5-minute epoxy to seal the hole where the wires run into the buzzer. This waterproofs the buzzer, but sound will still propagate through the metal plate.

To construct the housing, cut a 20cm length of 1 ½-inch PVC pipe. Use PVC cement to attach a 1 ½-inch end cap to one end of this pipe. This connection must be completely watertight. Cut a small disk of foam flotation approximately 1 ¼-inch to 1 ½-inch and approximately 2cm tall. This disk should just fit inside the 1 ½-inch PVC pipe. Use tape or Velcro to strap a 9-volt battery to one side of this flotation disk, and connect the 9-volt battery to the buzzer. Insert the disk of foam flotation into 1 ½-inch pipe, battery first, but make sure that the buzzer wires are to the side of the flotation so that the buzzer "hangs down" towards the open end of the pipe. Attach a 1 ½-inch 90^o elbow to the bottom of the pipe.



Attach the PVC housing securely to inside wall of a milk crate. The top of the housing, the 1 ½-inch end cap, should extend approximately 5cm above the rim of the milk crate. Fill the milk crate with sufficient weight so that it does not tip. As the milk crate and housing are immersed, make sure to keep the housing upright at all times. The housing acts as a diving bell, with the 9-volt battery dry above the flotation, while the waterproofed buzzer hangs below the flotation and into the water.

Design note: Teams practicing in deeper water conditions may need to use pipe longer than 20cm.

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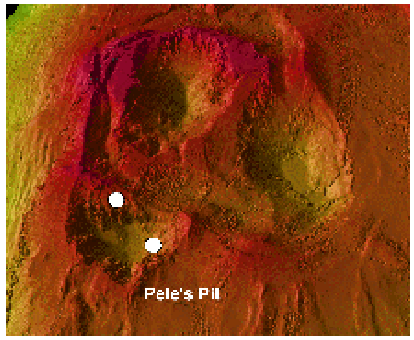
Task #2: Collect samples of a new species of crustacean

After anchoring HUGO's junction box to the seafloor, the crew on board the *Pisces V* conducted a survey of the surrounding area. It had been more than a month since the submersible last visited the site, so scientists were anxious to see if any new geologic features had formed. While the HUGO site was selected for its gentle topography and relative geologic stability, Loihi is otherwise a very active seamount. Always in motion, its eruptions and earthquakes result in a constantly changing terrain. This is especially true in the summit area, where new features such as pits, overhangs, and spires can be created – or destroyed – in one shake.



A bathymetric map of Pele's Pit with study sites marked
(courtesy of the Monterey Bay Aquarium Research Institute)

As the submersible descended into Pele's Pit, what appeared to be a hole in the wall of the pit came into view. The *Pisces V* pilot carefully maneuvered the vehicle to get a closer look. Through the portholes, the pilot and scientists on board the submersible could see that the hole was actually the opening to a cave, a plausible but not all-too-common feature on Loihi. This cave was likely the result of a lava tube that had flowed from Loihi's summit and became truncated when the pit collapsed.

The opening looked too precarious for the *Pisces V* to risk going inside. Instead, the pilot angled the main camera and zoomed in to get a closer look. The image of a tiny, white-bodied creature covered in what looked like threads of corn silk appeared on the video monitor. Moving slowly, it made its way along the floor of the cave. The pilot kept the camera focused and the video recording. After several minutes, the creature disappeared into the darkness.

Biologists reviewing the video footage believe the creature to be a new species belonging to the class *Remipedia*, whose crustacean members live only in underwater cave systems. Adapted to life in the dark, most remipedes are hermaphrodites and lack eyes. They have long antennae sprouting from their heads and plenty of sensory hairs along their bodies so that they can easily feel their way. Living in an environment where food sources can be scarce, these creatures are savvy hunters. They have powerful raptorial head limbs, which are used to hunt and seize other cave animals up to twice their body size. They can also filter-feed or scavenge dead carcasses.

Species of remipede
(courtesy of www.foxnews.com/story/0,2933,542800,00.html?test=latestnews)

Excited by the find, biologists are anxious to collect samples of the crustacean to verify that it is a new species and, if so, to document it for science.

Your task is to collect samples of this creature and return them to the surface.

This mission task involves:

- **Entering the cave.**
- **Maneuvering to the back wall of the cave.**
- **Collecting up to three samples of crustacean.**
- **Maneuvering out of the cave.**
- **Returning the samples to the surface.**

EXPLORER and RANGER class scoring – up to 60 points:

- Entering the cave so that your entire ROV, with the exception of the tether, is within the cave entrance – 5 points
- Maneuvering to the back wall of the cave so that the mission stations judges determine that a portion of the ROV is physically in contact with the wall – 10 points
- Collecting up to three samples of crustacean so that the samples are in control of your ROV and no longer in contact with cave wall or floor – 5 points for each sample (up to 15 points total)
- Maneuvering out of the cave so that your entire ROV, including the tether, is outside of the cave entrance – 15 points
- Returning up to three samples to the surface side of the pool under the control of your ROV so that one team member can retrieve the samples – 5 points for each sample returned (up to 15 points total)

Penalty points

- 10 points for damaging or otherwise modifying the cave structure, including the back wall where the crustaceans are located. The definitions of "damage" and "modifying" are up to the discretion of the competition officials. Teams are only penalized **ONCE**. That is, team cannot receive more than 10 penalty points for damaging or otherwise modifying the cave structure.
- 10 points for diver assistance. Diver assistance is provided **ONLY AFTER** a team requests it. The only exception to this is once the mission time has ended. At this time the divers will assist the ROV to the surface as part of the team's 5-minute demobilization period.

Mission notes

Teams must navigate their vehicle into the cave, maneuver to the back wall of the cave, and collect samples of this newly discovered species of crustacean. Teams must do this without damaging or otherwise modifying the cave in any way, or they will receive penalty points. After collecting the samples, teams must then maneuver out of the cave and return the samples to the surface. Teams are permitted to make one or multiple trips into and out of the cave to collect up to three samples and return them to the surface. Teams are also permitted to collect more than three samples and return them to the surface, but will not receive additional points. Crustaceans that are knocked from the wall to the cave floor may be collected. However, teams that damage the back wall in doing so receive penalty points.

The entire vehicle, except for the tether, must travel through the opening of the cave. **NO PORTION** of the ROV structure, including cameras and payload, may remain outside of the entrance to the cave. Competition support divers, underwater cameras, and/or mission station judges will verify this.

The crustaceans are positioned on either the back wall of the cave, on the floor of the cave, or both. A sample is considered "collected" once the crustacean is completely removed from the back wall or the floor so that no part of it remains in contact with these areas **AND** is in control of your ROV. Teams may not shake, bump, or otherwise intentionally manipulate the wall in order to cause crustaceans to fall to the floor. However, teams will receive points for collecting a sample if they completely remove a crustacean from the wall or floor then subsequently proceed to drop or otherwise lose control of it with their ROV. In addition, teams must remove three different crustaceans in order to receive the full 30 points for sample collection. Teams will **NOT** receive the full 30 points if they remove then drop or otherwise lose control of the same crustacean sample three different times.

The entire vehicle, including the tether, must exit the opening of the cave in order to receive points for maneuvering out of the cave. Points for maneuvering out of the cave are awarded **ONLY** if teams have previously maneuvered their ROV to the back wall of the cave so that the mission stations judges determine that a portion of the ROV is physically in contact with the wall.

A team member may reach into the water to retrieve the samples **ONLY AFTER** the ROV has reached the surface and physically touched the side of the pool.

Mission prop specifications

See the **Mission Prop Photos** and **SolidWorks Assemblies and Drawings** documents for visuals.

The cave is 80cm by 80cm square. The RANGER class cave is up to 2.5 meters long. The cave is straight, with no intentional angles or bends. The EXPLORER class cave is up to 3.5 meters long. The cave includes a 90^{o} angle. EXPLORER class teams must navigate this angle in order to reach the back wall of the cave.

Design note: Regional competitions may use caves less than 2.5 meters long. Contact your regional coordinator for additional information.

The crustaceans are located within the final 0.5 meters of the cave.

The cave is a PVC framework covered with black plastics or tarps. The minimum (inside) diameter of the framework is 80cm by 80cm. The bottom of the cave may be covered with black plastic or tarps, or may be left open. To some degree, light levels are reduced within the cave. The back wall of the cave is constructed out of an 85cm x 85cm black plastic 1/8-inch ABS sheet. (Check sign-making/printing stores for black plastic ABS sheeting. Alternatively, Plexiglass or Lexan sheeting may be substituted.) Samples of the crustacean are located on this sheet. A small hatch or flap is incorporated into the back end of the cave to allow divers to reset the crustaceans without having to navigate the entire extent of the cave. The ABS sheet may act as a door that opens up to allow divers access as well.

The crustaceans are simulated by Kalin's 6-inch Mogambo grub fishing lures. (Check local fishing tackle stores for availability. Mogambo grub fishing lures are also available online from a variety of sources.) Ten crustaceans are located within each cave. Teams can retrieve up to three of these crustaceans for points.

EXPLORER class crustaceans are found on the back wall of the cave. Ten crustaceans are located on the back wall.

RANGER class crustaceans are found on both the back wall and the floor of the cave. Five crustaceans are located on the back wall; five crustaceans are located on the floor of the cave within 0.5 meters of the back wall. RANGER teams may collect any three crustacean samples that they choose.

The crustaceans on the back wall of the cave are arranged in no particular pattern.

The 6-inch Mogambo lures will be modified for ease of collection.

The ten EXPLORER class crustaceans and five RANGER class crustaceans located on the back wall are hanging from posts drilled into the black ABS plastic sheet. To construct these wall-climbing crustaceans, take an 8cm length of solid core 14-gauge copper wire. Insert this wire from the top, down through the center of the body of the crustacean (the tail should be up) so that 1cm of wire is protruding through the body. Use needle nose pliers to bend this 1cm length of wire 90^o or more into the soft body of the crustacean. This will "lock" the crustacean lure onto the end of the wire and keep it from sliding off. Approximately 6cm of wire should protrude from the top of the crustacean lure. Bend the top 2cm of the wire 135^o down towards the lure to form a hook. This hook will fit around a screw.

Insert five long screws (1-inch to 1 ½-inch) partway through the hard black ABS plastic sheeting. EXPLORER class teams insert ten screws into the back wall; RANGER class teams insert five. Screws should be centered to some degree; no screw should be within 10cm of an edge of the back wall. Insert the screws so that a portion of them remains on the inner side of the black plastic sheet. This will allow the crustacean hook to easily attach. One crustacean hangs from each screw.

The five RANGER crustaceans that are located on the floor are outfitted with small legs. To construct these legs, take an 8cm length of solid core 14-gauge copper wire. Bend this length of wire to a 90^o angle at the middle. Push these "legs" through the center of the soft plastic body of the lure. There are 9 segments on the crustacean lure; the legs should be pushed through the middle, fifth, body segment. The legs should be positioned so that the tail of the crustacean extends upwards and the plastic body rests off the bottom.

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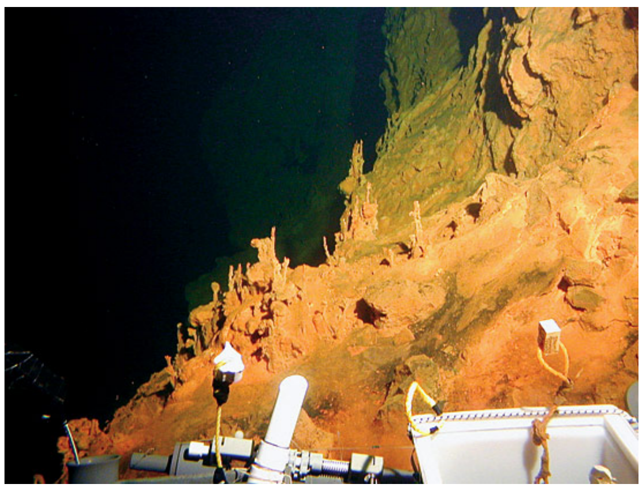
Task #3: Sample a new vent site

Energized by the exciting discovery of a species potentially new to science, the crew on board the *Pisces V* continued their descent into Pele's Pit. Since the pit collapsed during the 1996 earthquake swarm, hydrothermal vent activity on the crater floor and north slope have intensified. New chimneys with "trunks" the size of small redwood trees and spires reminiscent of the long, spindly fingers of a Halloween ghoul have built up at the places where the vent fluids issue onto the seafloor.

Before the collapse the vents in this area were defined as "low temperature" because their temperatures were only about 30 °C. The volcanic eruption of 1996 and the creation of Pele's Pit changed this and initiated high temperature venting. Temperatures of more than 200 °C have been recorded.



The Loihi landscape
(courtesy of Woods Hole Oceanographic Institution)

Upon reaching bottom, the pilot turned the vehicle starboard and began making way toward the "Forbidden Vents," an area of high temperature venting. Soon, with the help of the *Pisces V*'s powerful external lights, the chimneys and spires of the Forbidden Vents came into view.

The scientist peering out of the submersible's starboard porthole noticed it first. This vent field had, within the course of a year, spawned new hydrothermal chimneys and spires that rose straight up, like sentries called to attention, from the seafloor. One chimney in particular stood out from the rest. It was by far the tallest, with the largest diameter, and surrounded by spires of varying heights. It was quite a spectacular scene, but also very treacherous terrain, with an overhang extending from the wall of the pit and covering the spires located on the north side of the chimney. With the video rolling and the lights from the still cameras flashing, the pilot carefully maneuvered the *Pisces V* as close to the chimney as possible to attempt to measure the temperature of the venting fluid. There were several spots along the chimney where the pilot could insert the temperature probe without damaging the structure.

Unfortunately, even with the manipulator arm fully extended, the temperature probe would not reach inside the chimney for an accurate measurement. With the submersible's conning tower already resting on the edge of the overhand, the situation was too precarious to maneuver the vehicle any closer.

Your task is to return to the site, measure the temperature of the venting fluid in three different locations along the chimney height, and collect a sample of a vent spire and return it to the surface.

This mission task involves:

- **Measuring the temperature of the venting fluid at three different locations along height the chimney.**
- **Creating a graph of the temperature data versus chimney height.**
- **Collecting a sample of a vent spire.**
- **Returning the sample of the vent spire to the surface.**

EXPLORER class scoring – up to 80 points:

- Measuring the temperature of venting fluid at three different locations along the height of the chimney – 10 points for each sample (30 points total)
    - Accurately measuring the temperature of venting fluid at the base of the chimney within ±5.0^{o}C of the benchmark – 20 points
- Creating a graph of the temperature data versus chimney height – 10 points
- Collecting a sample of a vent spire so that it is completely removed from the chimney structure – 10 points
- Returning the sample of the vent spire to the surface side of the pool under the control of your ROV so that one team member can retrieve the sample – 10 points

RANGER class scoring – up to 80 points:

- Measuring the temperature of venting fluid at three different locations along the height of the chimney – 10 points for each sample (30 points total)
- Creating a graph of the temperature data versus chimney height – 20 points
- Collecting a sample of a vent spire so that it is completely removed from the chimney structure – 20 points
- Returning the sample of the vent spire to the surface side of the pool under the control of your ROV so that one team member can retrieve the sample – 10 points

Mission notes

Teams must measure the temperature of the fluid at three different locations along the chimney and create a graph of the temperature versus chimney height. The locations are designated as base, mid, and top with corresponding heights of approximately 40cm, 70cm, and 100cm, respectfully. Teams must measure the temperature with a sensor either mounted on or carried by their ROV.

EXPLORER class teams must present their data as temperature readings in degrees Celsius. The readings should be visible to the mission station judges on the ROV's video monitor or integrated into the ROV's control system or other device. EXPLORER class teams have the additional challenge of measuring the temperature at the base of the chimney for accuracy. "Accuracy" is defined as within ±5.0°C of the benchmark temperature reading. No partial points will be given. Mission station judges will compare the teams' measurement to the benchmark temperature reading and score it accordingly.

RANGER class teams must present their data as temperature readings in degrees Celsius. The reading should be visible to the mission station judges on the ROV's video monitor or integrated into the ROV's control system or other device. If the team relies on a conversion chart to convert from volts to temperature or some other conversion method, that chart must be present at the station, be a minimum of 16 point font and clearly noted what conversions are taking place. RANGER class teams' readings are NOT scored against a benchmark for accuracy. However, teams must demonstrate that their readings are different than the ambient pool temperature. "Different" is defined as at least a 2.0°C difference in temperature readings between one and the others.

All teams must inform the judges when they are preparing to take a reading and when they are ready to have their measurement scored. To ensure the quality of their temperature readings, teams should take measurements from within the vent. This means inserting the sensor into a ¾-inch PVC tee opening.

The water emerging from the vent chimney is either higher or lower than the ambient pool water temperature. It is recommended that teams design their sensors to measure a range of 0°C to 60°C.

Teams must create a graph of temperature versus height during the mission time or during the 5-minute demobilization period and present it to the mission station judges for review. The graph can be created neatly by hand or computer-generated. Teams that cannot create their graph in this time will not receive points for graphing their temperature data versus chimney height. The mission station judges will score the graph prior to teams exiting the control shack area.

Six spires extend from the cement base of the vent chimney. (The spires do **NOT** interfere with the task of measuring the temperature of the opening nearest the vent base.) Two of these spires are constructed out of ½-inch PVC; two are ¾-inch PVC; and two are 1-inch PVC. Teams must retrieve **ONE** of these spires, and may choose to retrieve a ½-inch, ¾-inch or 1-inch spire. Teams are NOT required to retrieve one of each size category of spire; only **ONE** spire of **ANY** size can be sampled. Teams are permitted to collect multiple spires and return them to the surface, but will not receive extra points. Spires that are dropped or knocked off the cement base may be retrieved and returned to the surface.

Mission prop specifications

See the **Mission Prop Photos** and **SolidWorks Assemblies and Drawings** documents for visuals.

Vent chimney:

The vent chimney is constructed out of ¾-inch PVC pipe secured to a 2-inch PVC pipe for support. A garden hose travels from the surface to the bottom of the pool where it connects to the vent. The water from the hose simulates the venting fluid.

The base of the vent sits on the bottom of the pool and the top extends approximately 90cm from the bottom. The vent is comprised of a heavy cement base, a 2-inch PVC central support column, and a ¾-inch PVC pipe that carries the water that teams must measure. The vent has three openings, one approximately 40cm from pool bottom, one approximately 70cm from pool bottom, and one approximately 100cm from pool bottom.

To construct the vent chimney, use a ¾-inch MHP hose to pipe adapter fitting to connect the male end of a garden hose to the base of the vent chimney. Insert a 12cm length of ¾-inch PVC pipe into the slip end of the fitting. Insert the other end of this pipe into a ¾-inch male adapter. Attach a hose splitter to the male adapter. Attach a ¾-inch MHP hose to pipe adapter fitting to each outlet of the hose splitter. Insert one end of a 3cm length of ¾-inch pipe into the left junction split. Insert the other end of this pipe into a ¾-inch 45^{o} elbow. Insert a 12cm length of ¾-inch PVC pipe into this elbow, running parallel to the 12cm PVC pipe below it. Insert the other end of this pipe into a ¾-inch male adapter. Attach another hose splitter to the male adapter. Attach another ¾-inch MHP hose to pipe adapter fitting to each outlet of the hose splitter. Insert a 3cm length of ¾-inch pipe to the left junction split. Insert the other end of this pipe into a ¾-inch 45^{o} elbow. Insert a 12cm length of ¾-inch PVC pipe into this elbow, running parallel to both of the 12cm PVC pipes below. Top off the vent with a 3.4-inch PVC tee.

The five ¾-inch MHP hose to pipe adapter fitting is Home Depot part# 685-707; the two hose splitter or hose Y is Home Depot part # 708-607, ACE Hardware part #73352, OSH part# 661-1834.

Design note: Some hose splitters are not set at a 90^{o} angle. Make sure the hose splitter you purchase has the outlets set at a 90o angle. All part numbers correspond to hose with the correct angles.

The base section is designed to stabilize and secure the ¾-inch PVC pipe. It is constructed out of a round plastic oil pan, approximately 40cm in diameter and 10cm high. Fill the oil pan with cement. Insert a 2-inch PVC connector into the semi-wet cement as an attachment point. This connector should be oriented vertically, so that when a 2-inch pipe is inserted, the pipe extends directly upwards. Once the cement has dried, insert a 72cm length of 2-inch PVC pipe into this connector. Use cable ties or hose clamps to secure the ¾-inch PVC pipe vent system to the 2-inch PVC pipe.

Design note: The cement base with 2-inch connector is the cement base used in the 2008 MATE competition missions.

Spires:
There are six small spires around the base of the vent chimney. These spires are constructed out of varying diameters of PVC pipe and range in height from 8cm to 18cm; once placed within their "holders" they rise 10cm to 20cm above the cement base of the vent chimney.

The spire “holders” are constructed out of PVC pipe that has been cemented into the base. Two ½-inch spires are placed within 1-inch PVC pipe. Two ¾-inch spires are placed within in 1 ¼-inch pipe. Two 1-inch spires are placed within 1 ½-inch PVC pipe. The spires sit loosely inside their holders so they can be easily retrieved.

If teams are constructing a new cement base for this year, it is suggested they insert two 1-inch PVC end caps, two 1 ¼-inch PVC end caps, and two 1 ½-inch PVC end caps into the wet cement. Insert a long wood screw or bolt from the inside of the end cap out the top. These screws or bolts go into the wet cement to help hold the end caps firmly in place once the cement has dried. Teams using pre-constructed cement bases from the 2008 MATE missions can use glue, Velcro, screws, or other means to secure the end caps into the cement. Insert a short 4cm length of 1-inch, 1 ¼-inch or 1 ½-inch PVC pipe into the end caps. These serve as the holding ports for the smaller diameter PVC spires. Insert an 8cm to 18cm length of ½-inch PVC pipe into the 1-inch end cap and pipe, an 8cm to 18cm length of ¾-inch PVC pipe into the 1 ¼-inch end cap and pipe, and an 8cm to 18cm length of 1-inch PVC pipe into the 1 ½-inch end cap and pipe.

No spire should be placed directly in front of the vent opening nearest the base or these spires may interfere measuring the venting fluid at that location. Measure an angle of 75^{o} to either side of the lowest vent opening (150^{o} total arc). No spires should be placed within that 150^{o} arc.

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Task #4: Sample a bacterial mat

Coming up short in their efforts to measure the temperature of the chimney fluid, the pilot and scientists on board the *Pisces V* set their sights on another area of hydrothermal activity that might yield similar features. The submersible turned to its portside and headed in the direction of the Lohiau vent field located on the northwest wall of Pele’s Pit.

As the submersible traveled along the bottom of the crater, an orange glow filled the video monitors and illuminated the faces of the scientists peering through the portholes. On Loihi, a diverse community of microbes thrive in the mineral-rich venting fluid. These microbes form thick mats that virtually carpet the summit, including Pele's Pit. Loihi’s vent fluids are especially rich in iron, creating the ideal environment for iron-oxidizing bacteria, the predominant microbe found on the seamount. It is the presence of these bacteria and the product of their metabolism – rust – that give the terrain its orange hue.

As the bacteria oxide the iron, they both accelerate the deterioration of rocks and affect water chemistry. The rust they form in turn impacts other microorganisms and affects chemical cycling on the planet. The microbiologists on the scientific team are particularly interested in studying these iron-oxidizing bacteria, including how fast they form iron oxide deposits, how they do it biochemically, and how this process affects ocean chemistry and ecosystem function. To do this, it was important for the crew of the *Pisces V* to collect samples of the microbial mats and return them, undisturbed, to the surface.

Microbial mats on the flanks of Pele's Pit

(courtesy of www.oar.noaa.gov/spotlite/archive/spot_loihi.html and www.soest.hawaii.edu/HURL/gallery/Geology/images/mats001.jpg)

The pilot took the controls of the manipulator arm and prepared to grasp a core sampler. The orange glow outside of the porthole reminded her of the setting sun – and the fact that the low-voltage warning light on the submersible's control panel was beaming. With the Pisces V battery power waning, the pilot of the *Pisces V* was obliged to announce the end the dive and begin the process of returning to the surface. Unfortunately, both the temperature of the venting fluid and a sample of the bacterial mat would have to wait for another day.

This mission task involves:

- **Collecting a sample of a bacterial mat.**
- **Returning the sample to the surface.**

EXPLORER class scoring – up to 60 points:

- Collecting a sample of a bacterial mat so that the sample is completely removed from and no longer in contact with the "seafloor" – 20 points
- Returning the sample to the surface side of the pool so that one team member can retrieve the sample – 20 points
  - Returning the following volume of sample to the surface – up to 20 points
    - < 25mL – 0 points
    - 25mL to 100mL – 10 points
    - 101mL to 175mL – 20 points
    - 176 to 225 – 10 points
    - >225mL – 0 points

RANGER class scoring – up to 60 points:

- Collecting a sample of a bacterial mat so that the sample is completely removed from and no longer in contact with the "seafloor" – 20 points
- Returning the sample to the surface side of the pool so that one team member can retrieve the sample – 20 points

- Returning the following volume of sample to the surface – up to 20 points
    - < 25mL – 5 points
    - 25mL to 100mL – 10 points
    - 101mL to 175mL – 20 points
    - 176mL to 225mL – 10 points
    - >225mL – 5 points

Penalty points

- 40 points for returning the entire bacterial mat to the surface

Mission notes

The bacterial mats are simulated by a plastic container full of agar. The containers of "used" agar are replaced between each and every mission attempt so that each team samples from one full container of fresh, undisturbed agar.

Any team that disrupts or disturbs their agar container (i.e., the tether drags over it or the vehicle lands on top of it) does **NOT** receive a new container during that mission attempt. Instead, the team must sample from the container they disturbed. Teams that lose or destroy their agar sample after collection do **NOT** receive another container.

Teams are not permitted to lift the entire container of agar to the surface. The vehicle must remove a portion of the agar and return it to the surface. Any team that does return the entire container to the surface receives penalty points.

Teams must remove the sample from their ROV and deliver the entire sample to the mission station judges. Teams are neither permitted to measure their own sample of agar nor to remove a portion of the sample in order to bring the sample closer to the ideal volume range for full points once it is on the surface.

Mission Prop Specifications:

See the **Mission Prop Photos** and **SolidWorks Assemblies and Drawings** documents for visuals.

The bacterial mat is simulated by agar. (Agar is available online, but you should consider checking with your school's biology or chemistry departments before ordering.) The "recipe" used to create the bacterial mat is 2 teaspoons of agar per 550mL of salt water plus 2-3 drops of food coloring. The salt water used should be the same salinity as ocean water; Tropical Fish Stores can provide you with this.

Agar should be soaked in the liquid first for 10-15 minutes, then gently brought to a boil and simmered while stirring until it dissolves completely, this will take about 5 minutes for powder and 10-15 minutes for flakes. Unlike gelatin, agar can be boiled and can even be re-melted if necessary. Agar melts at 85 °C and solidifies from 31 °C to 40 °C .

Once heated, let it cool for about 5 minutes, then pour the agar mixture into a 16 oz (540 ml) plastic container. The plastic container is round with an 11cm diameter at the top. The container is 7cm deep. Each container holds approximately 550mL of agar. (You can find these plastic containers at Smart & Final. You may also find them at Sam's Club or other bulk discount store.)

The plastic container of agar is nested within a second plastic container that has been secured to a sheet of plastic. This sheet of plastic, in turn, is secured to the bottom of the pool.

Use four small screws (6-20 ½-inch sheet metal screws are recommended) to attach a plastic container to the center of a 30cm x 30cm sheet of black 1/8-inch ABS sheet. (Check sign-making/printing stores for black plastic ABS sheeting. Alternatively, Plexiglass or Lexan sheeting may be substituted.) Attach a large (5cm x 5 cm) square of industrial strength Velcro loops to the inside bottom of the plastic container. Attach a 5cm x 5cm square of Velcro hooks to the outside bottom of the plastic container of agar. (It is recommended that you do this step **BEFORE** pouring the agar.)

Fit the plastic container of agar inside the container secured to the plastic sheet so that the Velcro pieces "match." This secures the agar to the sheet of plastic. The container of agar can be removed by applying gentle force to loosen the Velcro connection. As needed, replacement containers, with fresh agar and Velcro on the outside bottom, are inserted into the base container.

Use lead dive weights, pool bricks, or rocks (e.g. the Mexican beach pebbles from the 2008 MATE competition) to anchor the black plastic ABS sheet to the bottom of the pool. Weights should not be piled above the height of the plastic container (7cm) otherwise they may impede access to the sample.
